

FUNDAMENTALS OF NETWORK SCIENCE

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Complex Social Systems (2025)

26/03/2025

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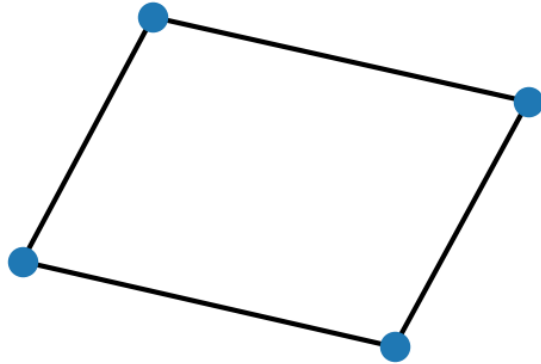
INTRO: WHAT IS NETWORK SCIENCE?

- An interdisciplinary field focused on studying **complex networks**.
 - LinkedIn, neural networks, internet, market transactions...
 - Considers social, biological, technological, and information networks, and many others.
 - Core concepts:
 - **Nodes**: Entities in a system.
 - **Edges**: Links between entities, representing a sort of **interaction** between them.
 - In this framework, **we analyze connectivity patterns, identify influential nodes, and model dynamic processes** in systems.
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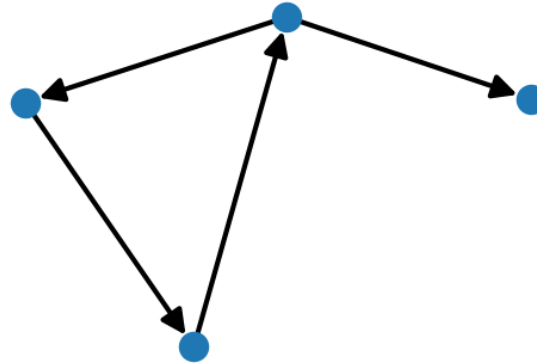
GRAPHS

We study complex networks as graphs.

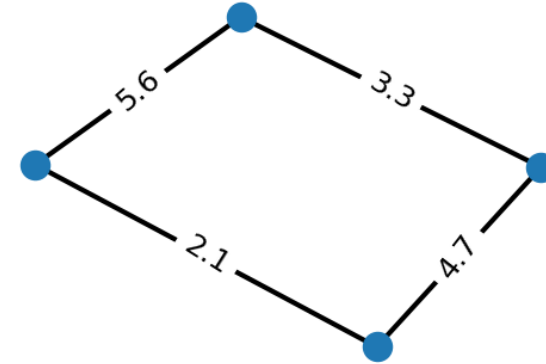
Undirected graph
edges have no direction



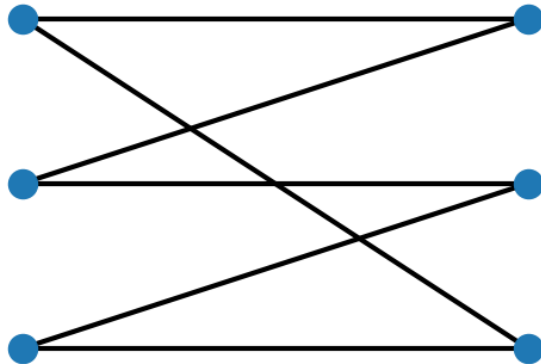
Directed graph
arrows indicating edge orientation



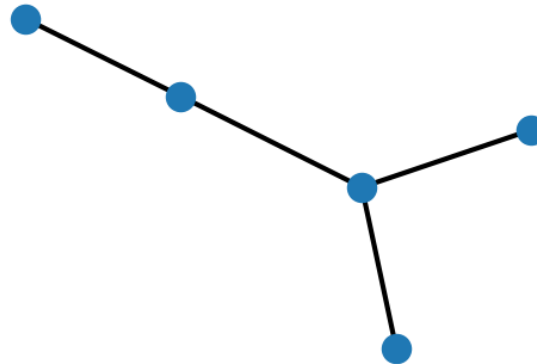
Weighted graph
each edge has a numerical weight



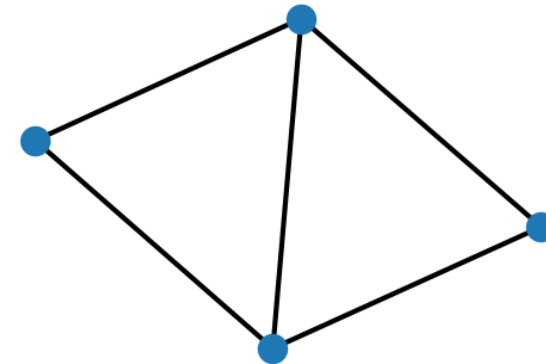
Bipartite graph
two disjoint sets of vertices connected by edges



Acyclic graph
with no cycles

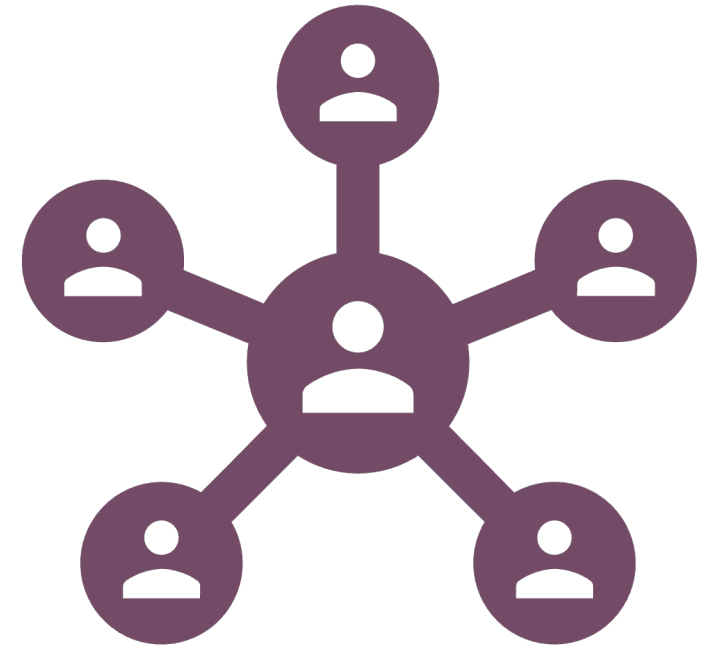


Cyclic graph
contains at least one cycle



SOCIAL NETWORKS

- We use social networks to model how we **communicate**, **share information**, and **build communities** in social systems.
- Using social networks, we analyze:
 - **Connectivity**: How individuals are linked by relationships.
 - **Communities**: Groups of users with dense connections, indicating shared interests or common networks.
 - **Centrality**: How some users act as hubs or influencers.

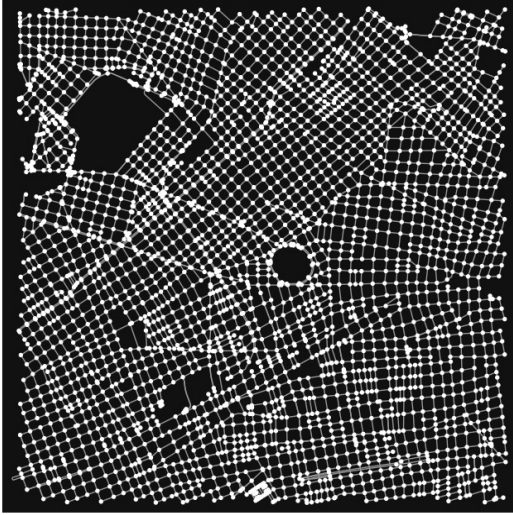


METRICS

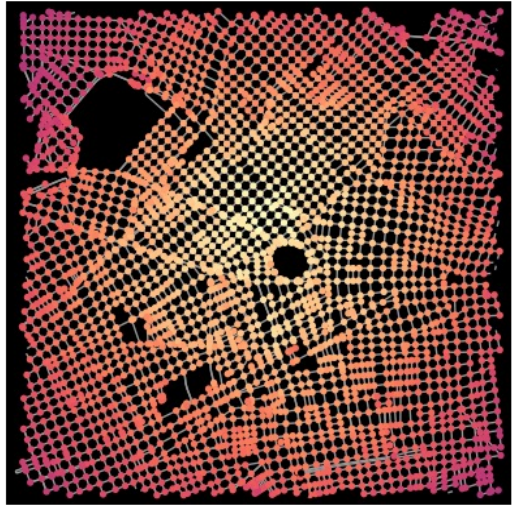
Degree	The number of connections a node has. Indicates a node's popularity and influence.
Modularity	It is a measure of the density of connections within individual clusters (communities) in a graph relative to connections between clusters.
Shortest Path Length	The minimum number of steps (or cost) required to reach one node from another.
Centrality Measures	Betweenness: How nodes act as bridges Closeness: How costly do nodes reach others Eigenvector: How connected are nodes to other influential nodes

METRICS – EXAMPLE

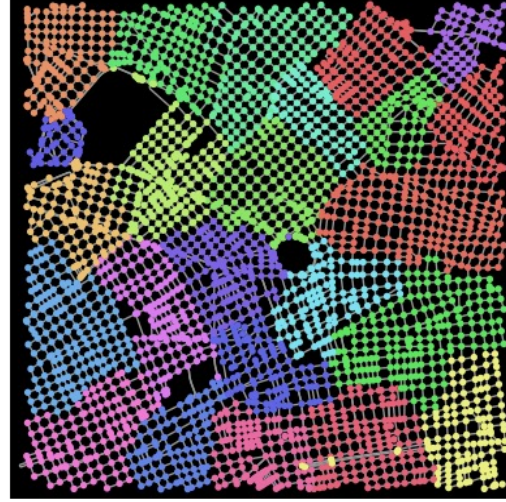
B. Aires traffic network



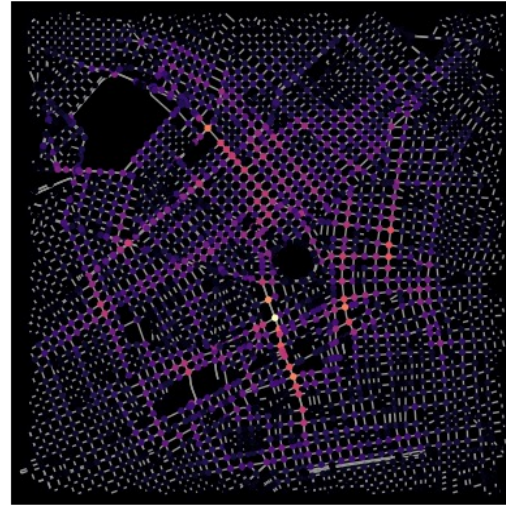
Closeness centrality



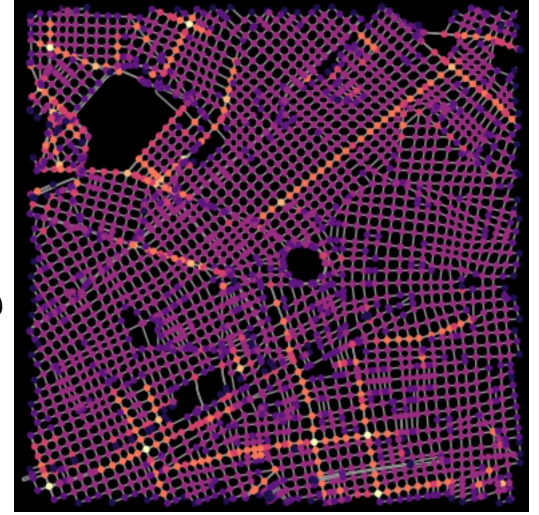
Communities



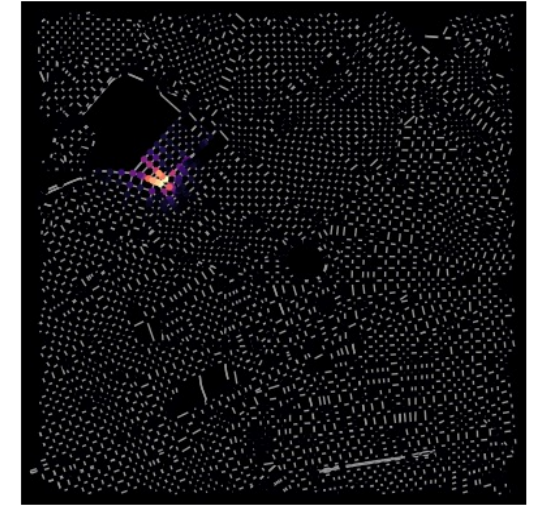
Betweenness centrality



Nodes degrees



Eigenvector centrality





NETWORKX

- **NetworkX** is a Python package for the **creation, manipulation, and study** of the structure, dynamics, and functions of networks.
 - Data structures for graphs, digraphs, and multigraphs
 - Many standard graph algorithms
 - Network structure and analysis measures
 - Generators for classic graphs, random graphs, and synthetic networks
 - Well-tested with over 90% code coverage
 - Additional benefits from Python include fast prototyping, easy-to-teach, and multi-platform

TUTORIALS

- Colab:

https://colab.research.google.com/drive/1MZzsrD5TsyRgb9toT-qhwTb0N0Ib_jt0?usp=sharing

- Shortened URL:

<https://tinyurl.com/45r75k58>

- To run locally:

ComplexSocialSystemsCourse > labs > lab3
