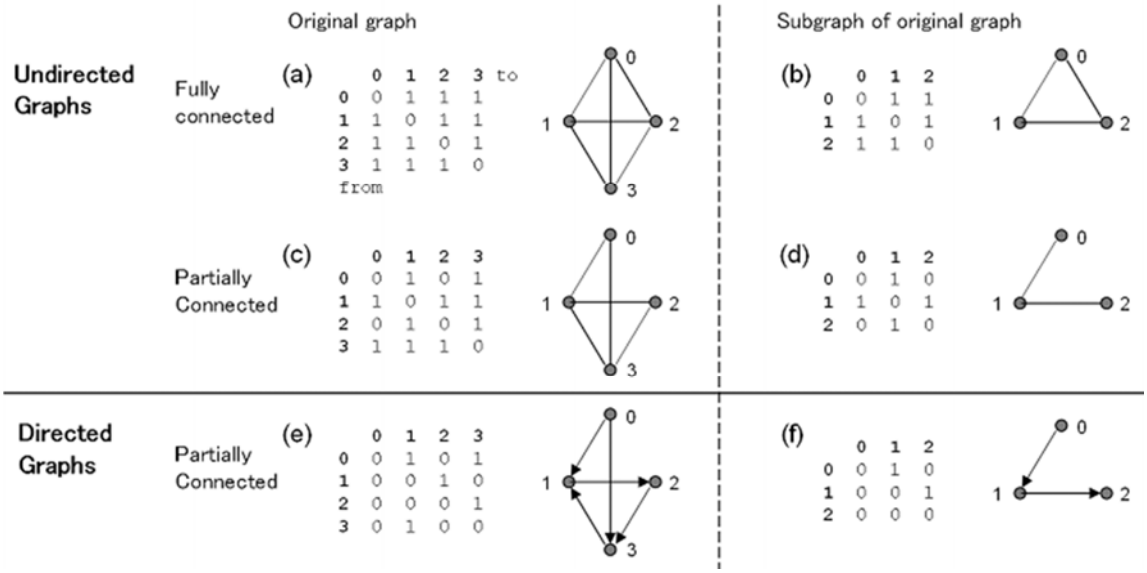
Representations of Network Data cont.

Matrix representation and visual layout



Information Visualization MOOC

Unit 6 – "With Whom": Networks

Overview and Terminology

Reference:

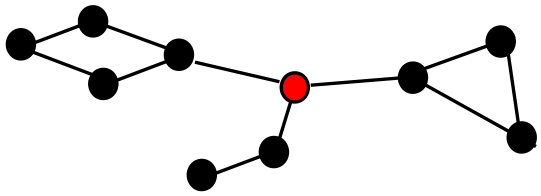
Börner, Katy, Soma Sanyal, and Alessandro Vespignani. 2007. "Network Science." Chap. 12 in *Annual Review of Information Science & Technology*, edited by Blaise Cronin, 537-607. Medford, NJ: Information Today, Inc./American Society for Information Science and Technology.

Network Analysis Examples and Goals

- Natural Networks: Neuronal, cell signaling, food webs
- Social Networks: Friendship, business, communication, collaboration networks
- Technological: Water networks, power grid, Internet, WWW

Importance of network thinking:

- Food webs might completely disassemble if just one species goes extinct.
- Weak ties and brokers are extremely important in professional networks.



Relevant Research Disciplines

The study of networks has a long tradition in

- graph theory and discrete mathematics
- sociology
- communication research
- bibliometrics/scientometrics
- webometrics/cybermetrics
- biology
- physics

Today, it is conducted in mathematics, statistics, physics, social network analysis, economics, information science, and computer science, etc.

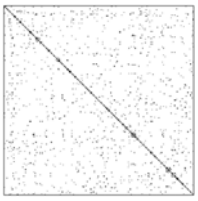
Discipline	Mathematics / Physics	Statistics/Social Network Analysis
Terminology Used	Adjacency matrix	Sociomatrix
	Average shortest path length or Diameter	Characteristic path length
	Clustering coefficient	Fraction of transitive triples

Representations of Network Data

Matrices

1	0	0	6	0
0	10.5	0	0	0
0	0	.015	0	0
0	250.5	0	-280	33.32
0	0	0	0	12

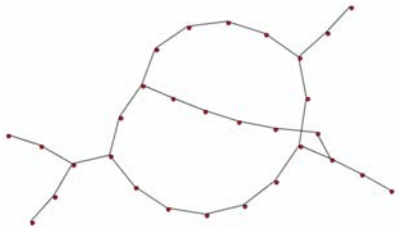
Adjacency Matrix



Lists of nodes & links

```
*Vertices 3
1 "Doc1" 0.0 0.0 0.0 ic Green bc Brown
2 "Doc2" 0.0 0.0 0.0 ic Green bc Brown
3 "Doc3" 0.0 0.0 0.0 ic Green bc Brown
*Arcs
1 2 3 c Green
2 3 5 c Black
*Edges
1 3 4 c Green
```

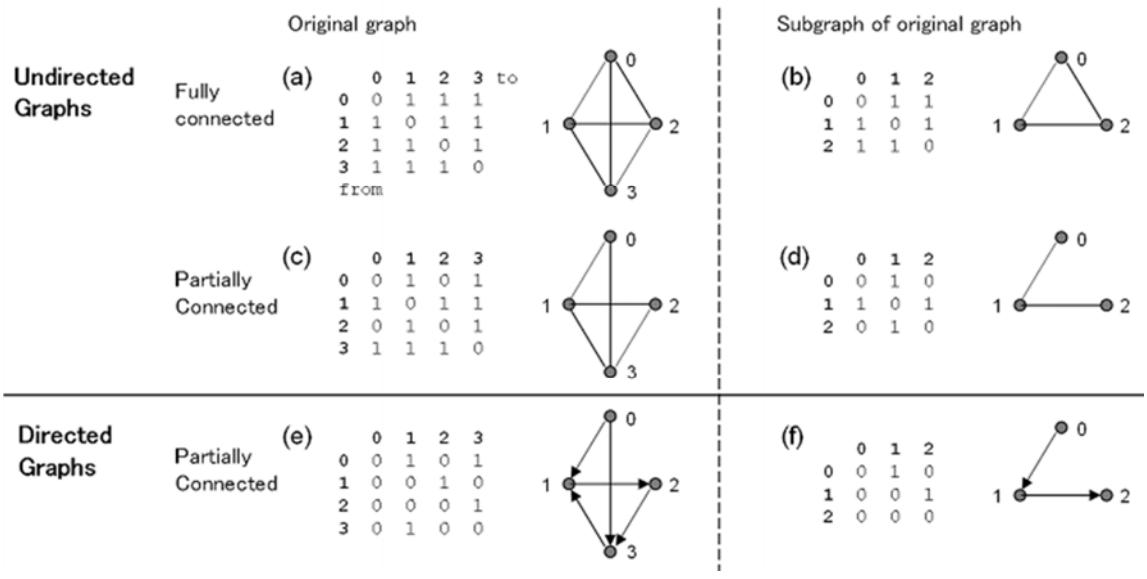
Network layout



When to use what kind of representation?

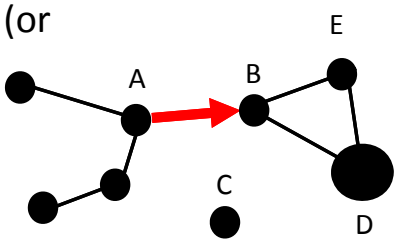
Representations of Network Data cont.

Matrix representation and visual layout



Terminology

Network (or graph) is composed of nodes (or vertices) and links (or edges).



Nodes can be

- **Isolated**: Unconnected to other nodes.
- **Labeled**: Have labels attributes—e.g., weights.

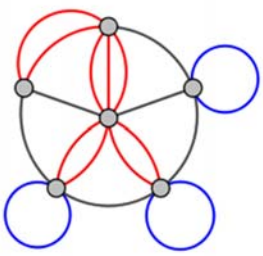
Edges can be

- **Undirected** (symmetric) or **directed** (non-symmetric).
- **Labeled**: Have labels attributes—e.g., weights.
- **Signed**: Be positive and negative (friend/foe, trust/distrust).

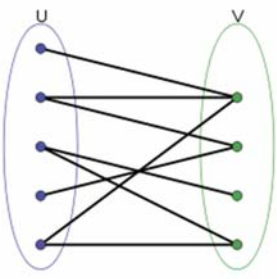
Terminology

Networks can be

- **Labeled**: Network contains labels (weights, attributes) on nodes and/or edges.
- **Temporal**: For each node/edge we know the time when it appeared in the network.
- **Undirected**: Relations between pairs of nodes are symmetric or **directed** (also called *digraph*) with directed links.
- **Multigraph**: Network has multiple edges between a pair of nodes.
- **Bipartite**: Nodes can be divided into two disjoint sets U, V such that every link connects a node in U to one in V.
- **Signed:** Edges can be positive and negative (friend/foe, trust/distrust).



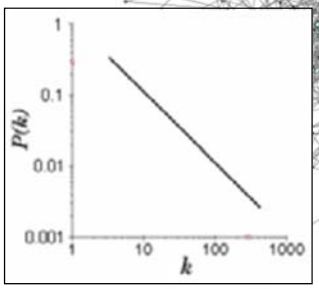
Multigraph



Bipartite Network

Network Measurements

- Node and Link Properties
- Network Properties
- Statistical Properties
- Network Types

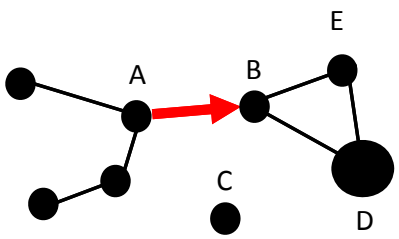


Reference:

Börner, Katy, Soma Sanyal, and Alessandro Vespignani. 2007. "Network Science." Chap. 12 in *Annual Review of Information Science & Technology*, edited by Blaise Cronin, 537-607. Medford, NJ: Information Today, Inc./American Society for Information Science and Technology.

Node and Link Properties

- ***Isolated node***: Not connected to any other node.
- ***Degree of a node***: Number of links connected to it.
- ***Betweenness centrality of a node***: Number of shortest paths between pairs of nodes that pass through a given node.
- ***Betweenness centrality of a link***: Number of shortest paths among all possible node pairs that pass through a given link.
- ***Shortest path length***: Lowest number of links to be traversed to get from nodes *i* to *j.*



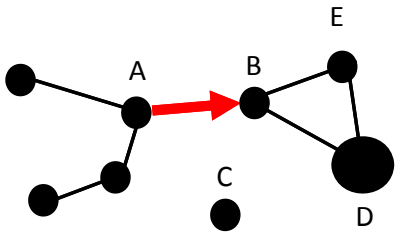
Network Properties

Number of

- Nodes
- Isolated nodes
- Edges
- Self-loops

Diameter: Longest of all shortest paths among all possible node pairs in a network—i.e., #links to be traversed to interconnect the most distant node pairs.

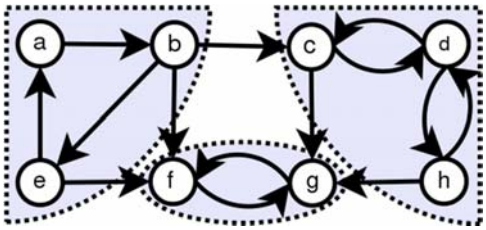
Density: Ratio of the number of edges in the network to the square of the total number of nodes.



Network Properties cont.

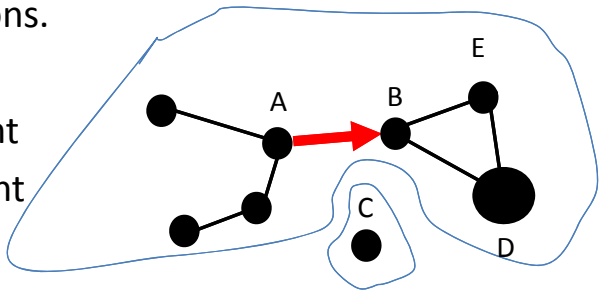
Number of

- ***Strongly connected components***: There is a directed path from each node in the network to every other node.



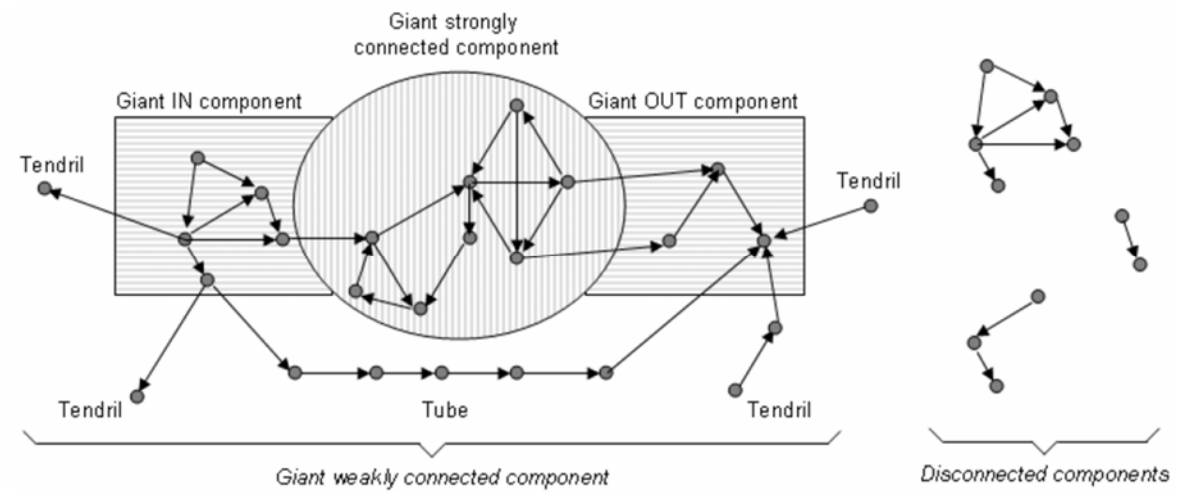
- ***Weakly connected components:*** Maximal subgraph in which all pairs of vertices are reachable from one another—disregards link directions.

Giant component



Network Properties cont.

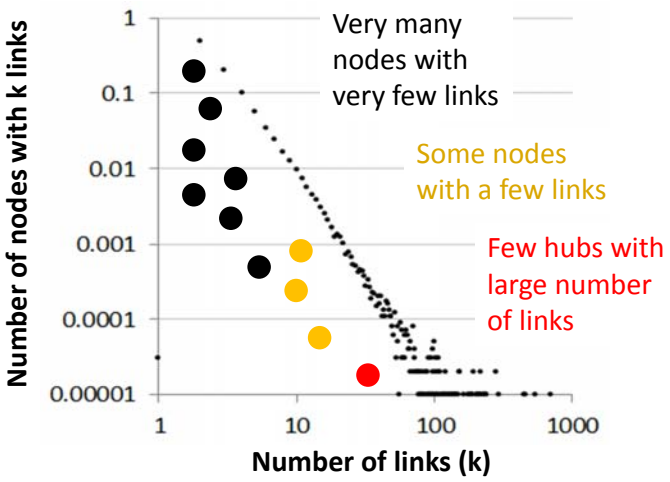
- ***Clustering coefficient:*** Measures the average probability that two neighbors of the node *i* are also connected.

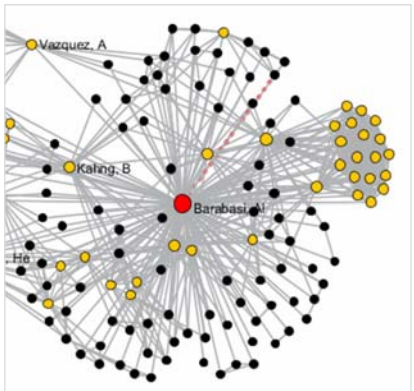


Statistical Properties

- ***Node degree distribution*** *P(k)* of an undirected graph is defined as the probability that any randomly chosen node has degree *k*.

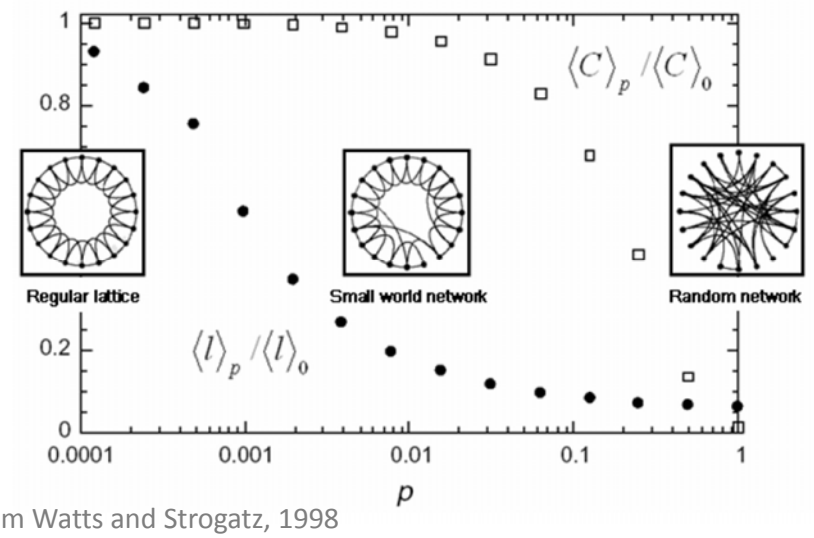
Power law distribution P(k) for a scale free network





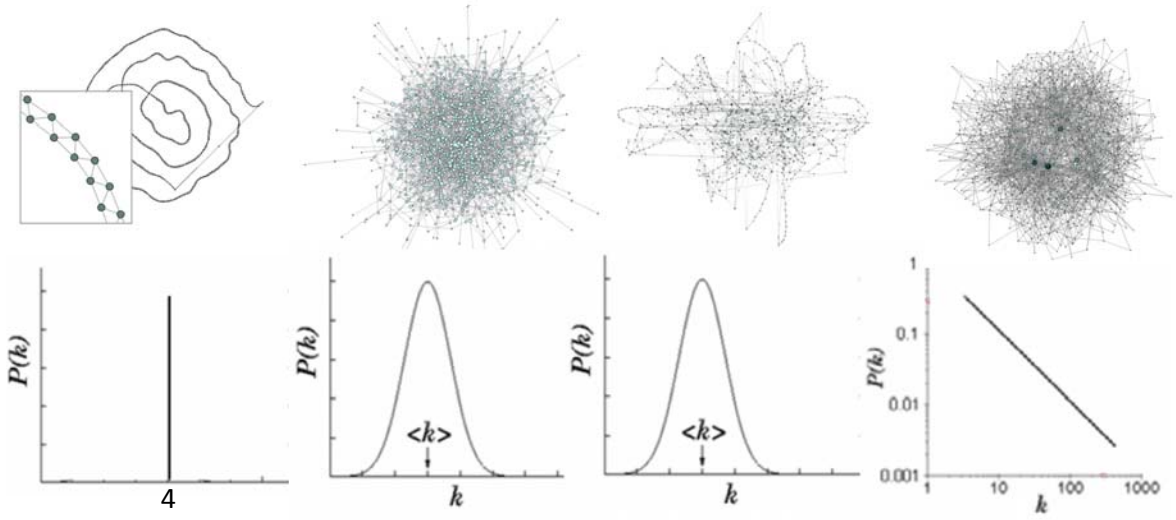
Network Properties and Network Types

- ***Average clustering coefficient*** measures the average probability that two neighbors of the node *i* are also connected.
- ***Average path length***: Average number of steps along the shortest paths for all possible pairs of network nodes.



Adopted from Watts and Strogatz, 1998

Network Types



Lattice Random Small World Scale-Free

Small World: Road maps, food chains, electric power grids, networks of brain neurons, telephone call graphs, and social influence networks.

Scale-free: World-Wide Web, the Internet, social networks, airline.