

A History and Applications of Network Analysis



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Data Institute Conference 2017



- Origins in Graph Theory
- Origins in Social Dynamic Analysis
- The Internet and Modern-day Network Science
- Some Current Applications of Network Analysis

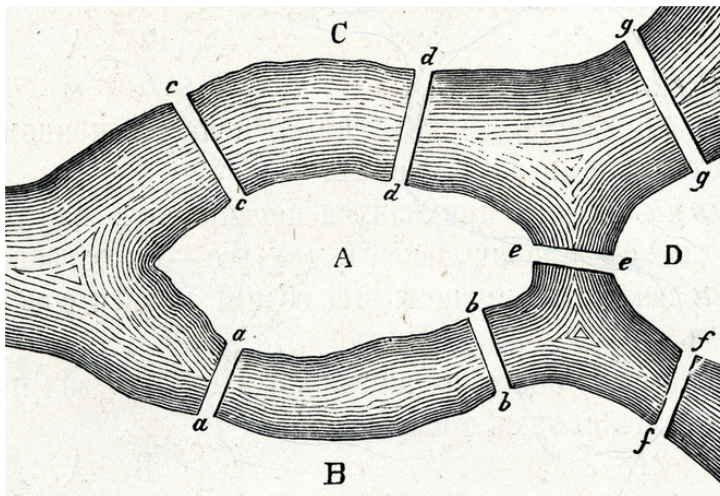


- Network Analysis is rooted in **graph theory**: “the mathematical theory of the properties and applications of graphs”
 - A **graph** is a mathematical object $G = (V, E)$, where
 - V = vertex set
 - E = edge set describing relationships among vertices $u, v \in V$
 - Subtlety here: *network* and *graph* are often used interchangeably
 - A **network** is the relational representation of a complex system
 - A **graph** is the mathematical object that we inevitably analyze



- Swiss mathematician and logician (1707 - 1783)
- Network analysis begins with solution to the “Bridges of Königsberg” question in 1735

The Seven Bridges of Königsberg





- **Big Question:** Can one walk across all seven bridges and never cross the same one twice?
- Euler represented each of the four land areas separated by the river with letters A, B, C, and D
- Edges represented bridges between them
- **Simple observation:** if there is a path crossing all bridges, but never the same bridge twice, then nodes with odd number of links must be either the starting or the end point of this path

Ch. 2 of <http://barabasi.com/networksciencebook/>



- Austrian - American psychiatrist (1889 - 1974)
- Key interest in the dynamics of social interactions within groups of people



- Moreno immigrated to New York in 1930
- March, 1933 - gave a talk at a medical conference in New York City, discussing the first social network studies
- In 1934, he published a book on his studies - *Who Shall Survive*, which contains the seeds of *sociometry*, now known as **social network analysis**
- Book depicted **sociograms** - a new model for human interactions

The First Social Network: Sociograms

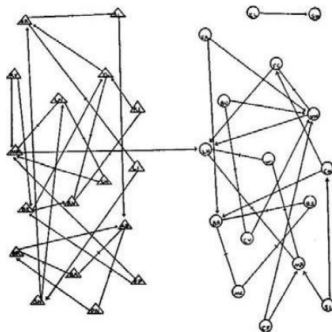


Figure: An early hand-drawn image of a social network, taken from *Who Shall Survive*, depicting friendship patterns between the boys (triangles) and girls (circles) in a class of schoolchildren in the 1930s.

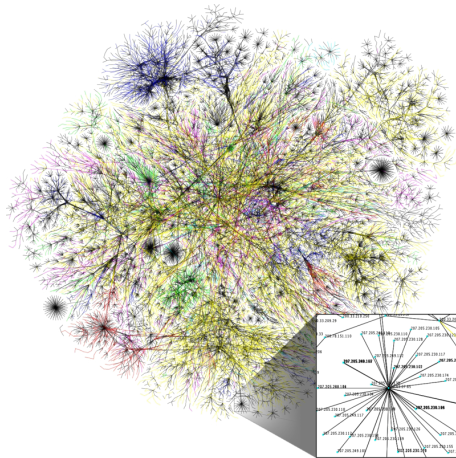
In Contrast: Social Networks Today





- Many possible definitions of an edge!
 - professional relationships
 - exchange of goods or money
 - communication
 - romantic or sexual relationships
- Can be used to understand a wide array of social dynamics
- Modern day look at online communities such as LinkedIn, Twitter, or Facebook, dynamics of animals, voting behavior of Senators, etc.

The Internet: Kickstarting modern-day Network Analysis





- Vertices - computers
- Edges - physical connections between them, e.g., optical fiber cables or telephone lines
- **Questions of Interest:**
 - understanding centralized control
 - transferral of data
 - avoid bottlenecks and improve efficiency

Interestingly, we do not completely understand the structure of the internet and must rely on experiments for approximation



- Vertices - web pages
- Edges - hyperlinks between them
- **Questions of Interest:**
 - The “importance” of a webpage (HITS / PageRank)
 - Spread of ideas (cascades, information dissemination)
 - Spread of news

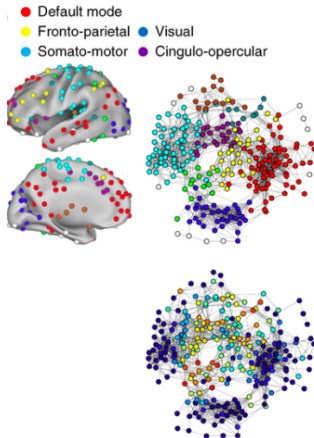


Figure: Networks in cognitive neuroscience.



- Vertices - regions of the brain
- Edges - structural or functional interactions
- **Questions of Interest:**
 - Segmentation of functional and physical regions
 - Blood flow and effects on cognition
 - Differences between networks and disease

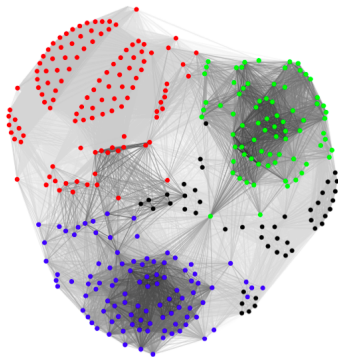


Figure: Network representation of relationships between *E-coli* strains among patients with urinary tract infection.



- Vertices - genes, chromosomes, SNPs
- Edges - structural or functional interactions
- **Questions of Interest:**
 - Segmentation and relationship with clinical outcomes (cancer, antibiotic resistance, etc.)
 - Driver genes collections?
 - Causal relationship between vertices?
 - Differences among individuals



- Power grid networks
- Transportation (air, subway, road systems)
- Migration networks
- Textual networks
- Citation networks
- Recommendation networks



- Network science has a long history (1735!)
- Inherently interdisciplinary! (biology, physics, mathematics, sociologists, statisticians)
- Networks are “a way of thinking” and can provide a unique way to extract information from a system...
- ... now on to the good stuff