CS 103: Networks

with emphasis on social and information networks

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Fall 2015

Plan for Today

- Course Intro
- Logistics
- Graph Theory

What is This Course About?

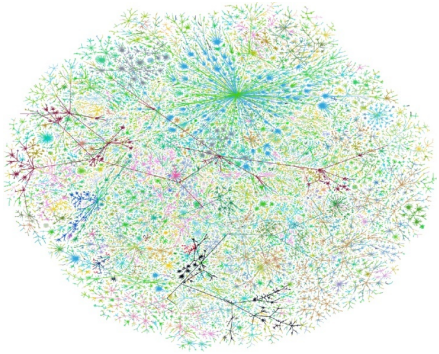
Networks

"the study of how things are connected to each other, and how those patterns of connectivity have impacts on society, on the economy, on technology, and on life in general."

Networks

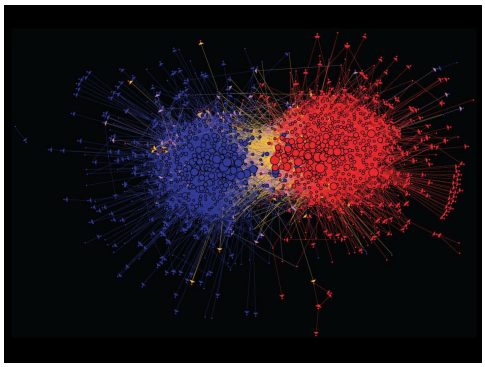
- Networks are everyone
- Defined by **interactions** between components

Networks: Communication



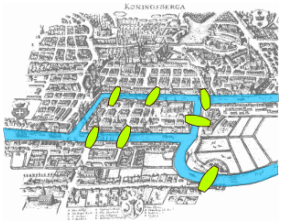
Graph of the Internet (Autonomous Systems)

Networks: Information



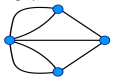
Connections between political blogs

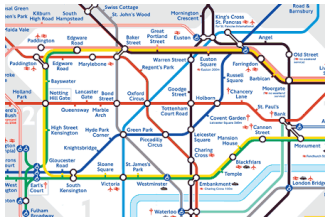
Networks: Technology



Seven Bridges of Königsberg (Euler 1735)

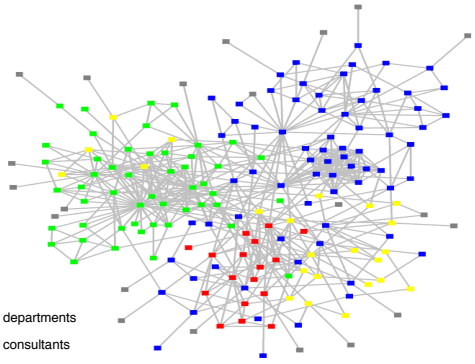
Return to the starting point by traveling each link of the graph once and only once.





London Underground

Networks: Organizations

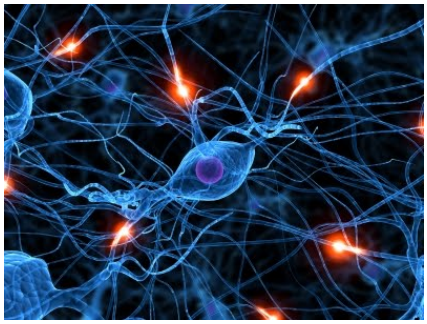


: departments

: consultants

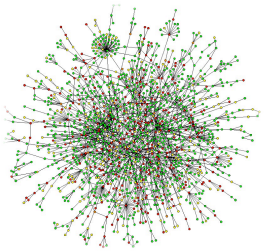
: external experts

Networks: Brain

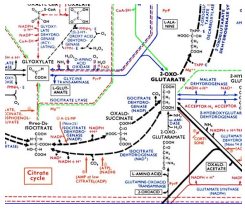


Human brain has between 10-100 billion neurons

Networks: Cells

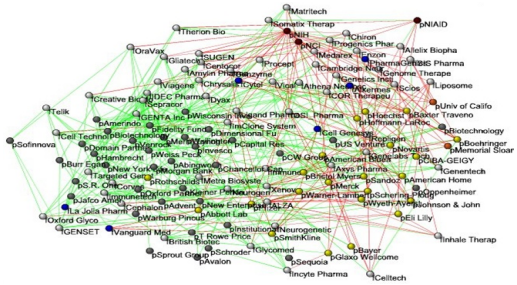


Protein-Protein Interaction Networks:
Nodes: Proteins
Edges: 'physical' interactions



Metabolic networks:
Nodes: Metabolites and enzymes
Edges: Chemical reactions

Networks: Economy

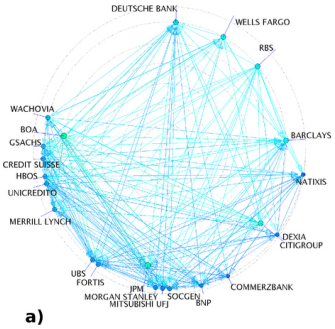


Nodes:
- Companies
- Investment
- Pharma
- Research Labs
- Public
- Biotechnology

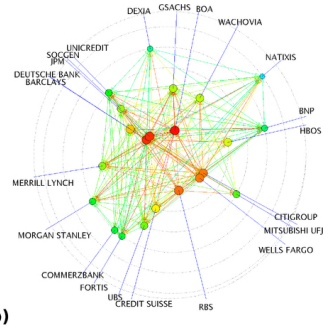
Links:
- Collaborations
- Financial
- R&D

Bio-tech companies, 1991

Networks: Finance



a)

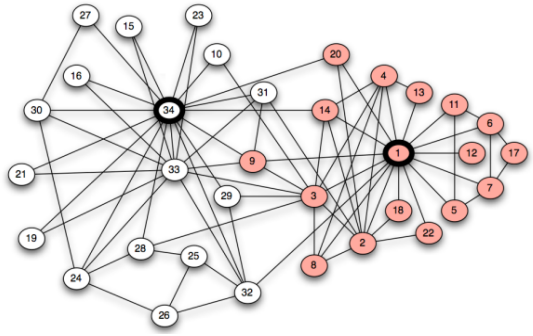


b)

- Loans among financial institutions
  - Which institutions are powerful?

Slide credit: Jure Leskovec

Networks: What is this?



- 34 person Karate club

Networks: What about this?

- **E-mail communication patterns within HP**
  - Superimposed on the company hierarchy
  - 436 employees

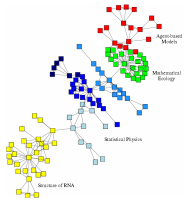
Networks are everywhere

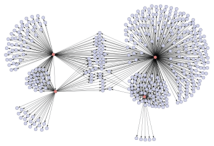
- **Modern society is "connected" in different ways**
  - Global communication
  - The Internet
  - Social networks
  - Financial systems
  - News and media
- **This course:** learn about networks and the processes that occur in them

Networks: Structure & Process

What do we study in networks?

- **Structure and evolution**
  - What is the structure of a network?
  - Why and how did it became to have such structure?
- **Processes and dynamics**
  - Networks provide a "skeleton" for spreading of information, behavior, diseases
  - How do information and diseases spread?





Specific questions

- **What are the structural features of networks?**
  - Hard to eyeball features of large networks
- **Can we reason about behavior and interaction in networks?**
  - Strategic incentives, cause-and-effect relationships
- **What are the dynamics of aggregate behavior?**
  - Why are YouTube and Facebook so popular?
  - How do things go viral? How do diseases spread?

CS 103 at a Glance

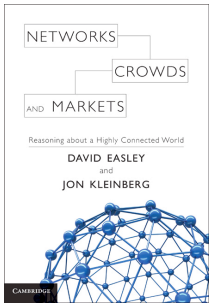
We will follow a really great book with perspectives from:

- Computer science
- Economics
- Sociology

Learning goals:

- Understand the basics of graph theory
- Understand the basics of game theory
- Apply them to model real-world networks and information systems

Note: our main mode of inquiry will be to build (simple) **mathematical** models



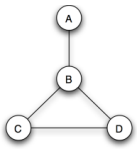
Logistics

Review course webpage / syllabus:

http://people.cs.umass.edu/~sheldon/teaching/cs103/

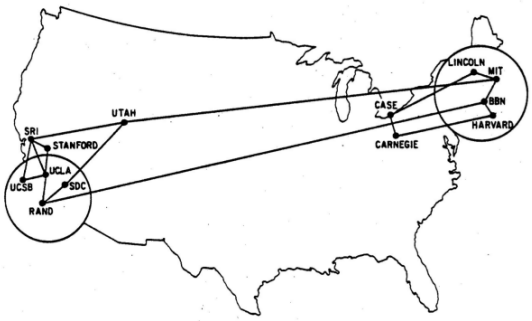
Let's dive in: Graph theory

- A *graph* is a mathematical representation of a network
  - Set of objects: *nodes (vertices)*
  - Pairs of objects: *edges*



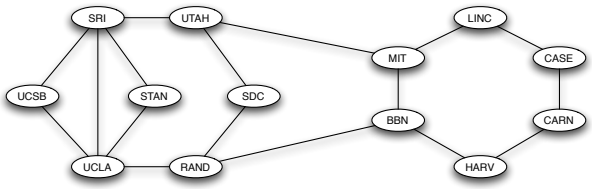
- Two nodes are *neighbors* if they are connected by an edge

Example: ARPANET



Internet in 1970: 13 nodes

Example: ARPANET



(Only connectivity matters)

More Definitions

- Board work
  - Path
  - Connected graph
  - Length of path
  - Distance between nodes
  - Connected component

Exercise

- Consider the following graph
  - Nodes = the numbers 1 through 12
  - Edges between two numbers that differ by exactly three
- Answer these questions
  - What are the neighbors of 4?
  - Is the graph connected?
  - If not, how many connected components does it have?
  - What is the distance between 1 and 10?

Exercise

- Now consider the following graph
  - Nodes: numbers 1 to 12
  - Edges between two nodes that differ by **at most** 3
- Is the graph connected?

Activity

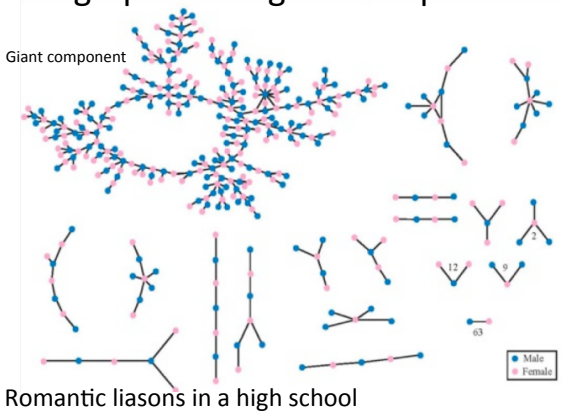
- Thought experiment / world friendship graph
  - What is the world friendship graph?
  - Is it connected?
  - How big is the component that you are in?

Giant Component

Giant component = component that contains a "significant fraction of" all of the nodes

Can there be two giant components?

Real graphs have giant components



- Romantic liasons in a high school
  - Existence of giant component means higher risk of STDs

For Next Time

- Get the course text (pdf)
- Read Chapters 1 and 2
- Post to Piazza
  - Introduce yourself and say something about yourself or this class