NETWORK ANALYSIS

CS 448B | Fall 2024

MANEESH AGRAWALA

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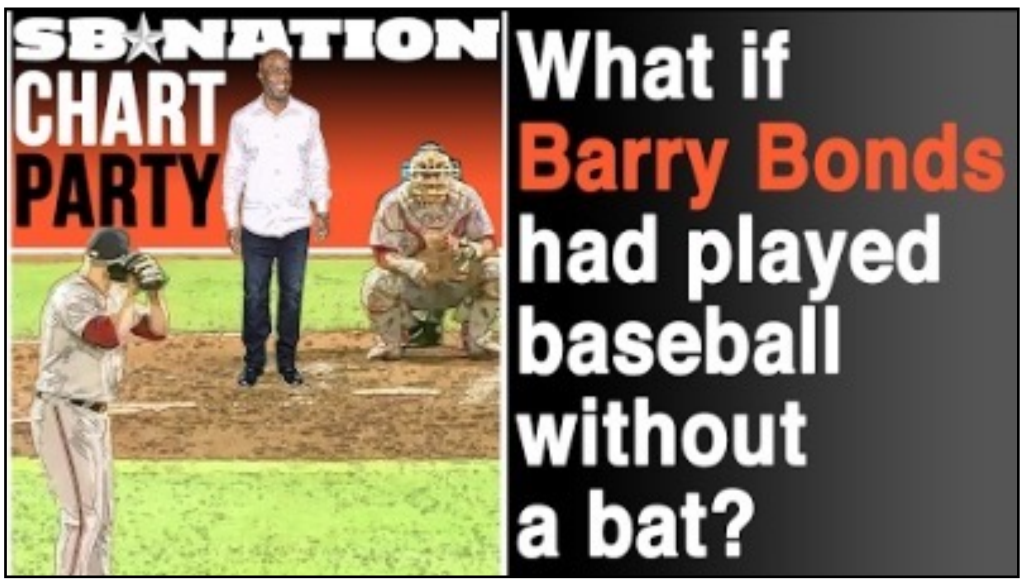

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ANNOUNCEMENTS

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FINAL PROJECT

Design Reviews Dec 2 and Dec 4

Data analysis/explainer
- Analyze dataset in depth & make a visual explainer

Deliverables
- An article with multiple different interactive visualizations
- Short video (2 min) demoing and explaining the project

Schedule
- Project proposal: Today!
- Design Review and Feedback: 10th week of quarter, 12/2 and 12/4
- Final code and video: Sun 12/8 8pm

Grading
- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

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FINAL PROJECT GUIDELINES

Consider the audience
Your visual explainer should be of interest to a group of people beyond your immediate circle (an explainer about your own Spotify data unlikely be of interest to others you don't know)

Pick relatively less explored topics/datasets
Do some research on what has already been done for the topic/dataset(s)

Certain data like songs (e.g. Spotify) or movies (e.g. IMDB) are already well analyzed and should be avoided, unless you want to try to take a very different angle or use innovative analysis methods

Develop a narrative
In the early stages of the analysis process, try to uncover patterns to help you form and shape a narrative through-line for the explainer

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FINAL PROJECT GUIDELINES

Design visualization interactions
Choose base visualizations that can support a high level of interactivity
- Bubble charts, tree maps, and word clouds typically aren't the most effective choices

Design interactive features that would enable viewers to interact with the data in a way that strengthens your narrative
- Tooltip is typically not enough interaction

Draw inspiration from sites like the New York Times and the Pudding

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NETWORK ANALYSIS

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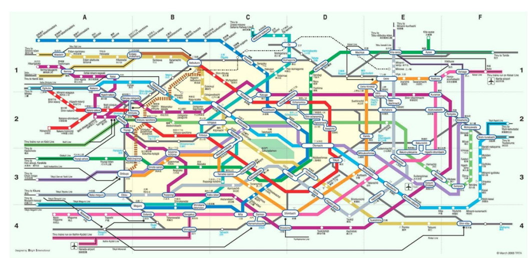
TRANSPORTATION



http://www.lx97.com/maps/

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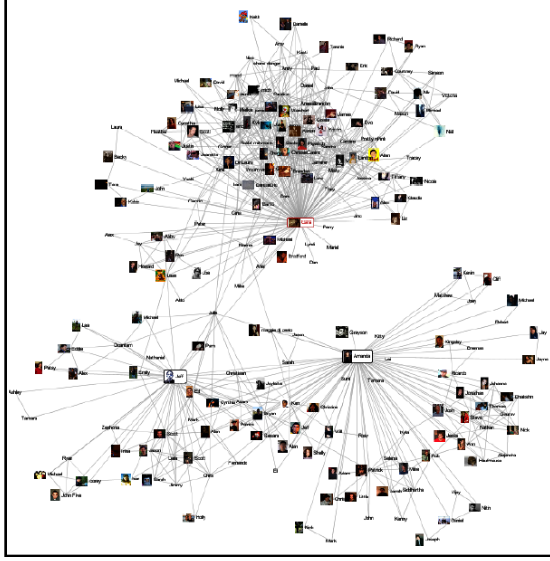
SOCIAL NETWORKS



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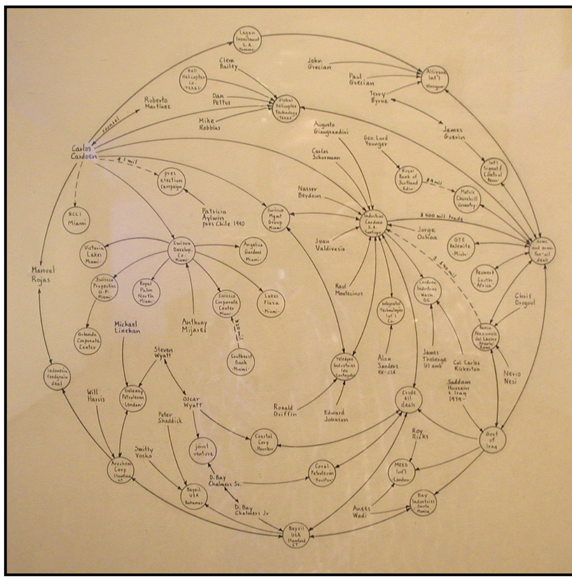

"Mark Lombardi (1951-2000) draws on the major political and financial scandals of the day to create large-scale linear diagrams that at first glance look like celestial maps; a closer reading reveals the intricate web of connections that lurk beneath current headlines.

Lombardi, M. 'George W. Bush, Harken Energy and Jackson Stephens, ca 1979–90'

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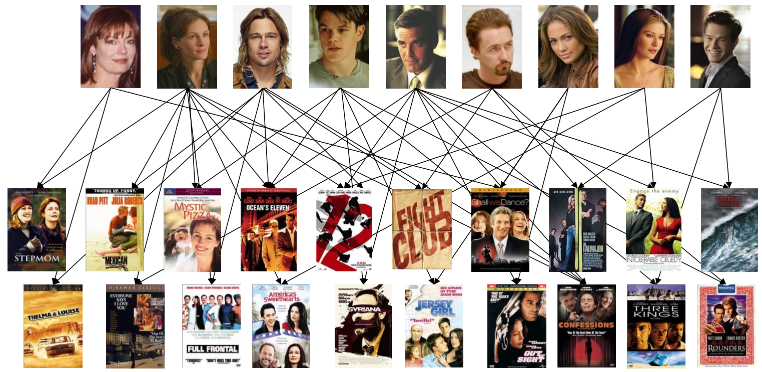
ACTORS & MOVIES (BIPARTITE)



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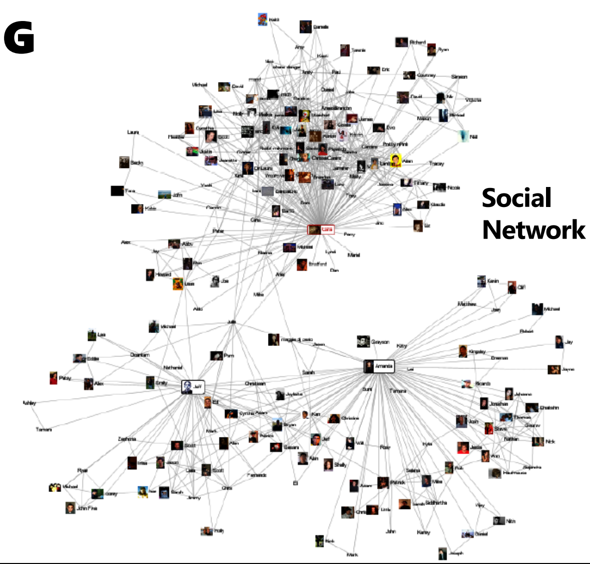
CHARACTERIZING NETWORKS

What does it look like?



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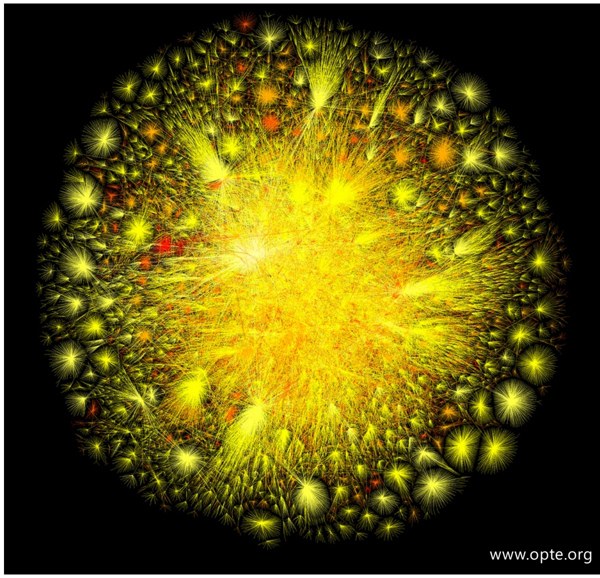

Size?
Density?
Centrality?
Clustering?
Components?
Cliques?
Motifs?
Avg. path length?
...

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TODAY

Learning Objectives

1. Measures of importance/centrality
2. Extracting community structure
3. Simulating network models

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CENTRALITY

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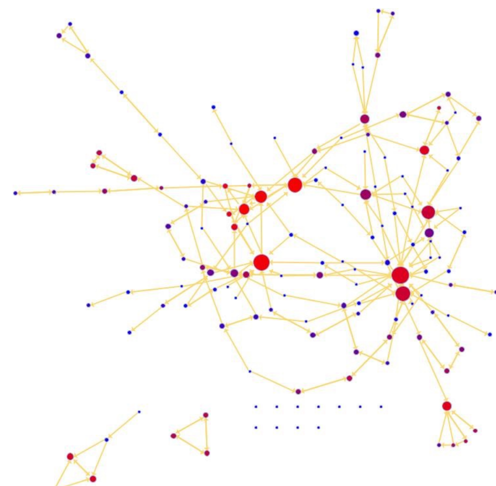
HOW FAR APART ARE THINGS?



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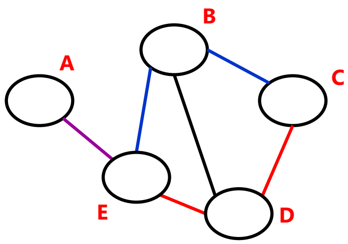
DISTANCE: SHORTEST PATHS

Shortest path (geodesic path)

The shortest sequence of links connecting two nodes
Not always unique

A and C are connected by 2 shortest paths
A – E – B - C
A – E – D - C



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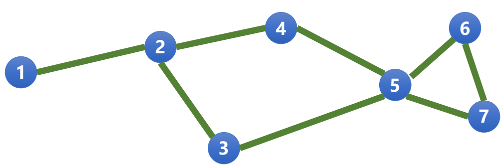
DISTANCE: SHORTEST PATHS

Shortest path from 2 to 3: 1



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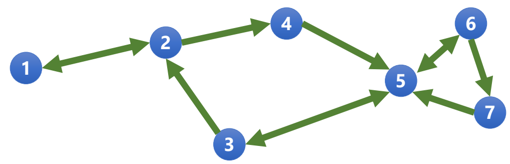
DISTANCE: SHORTEST PATHS

Shortest path from 2 to 3?



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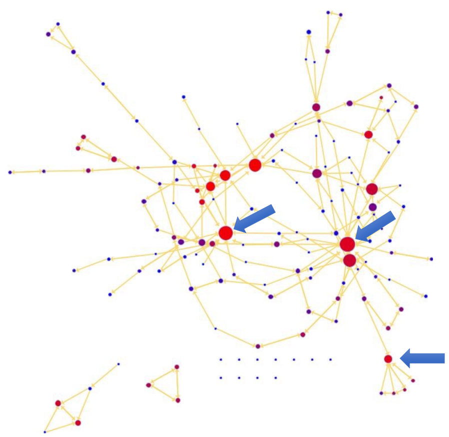
MOST IMPORTANT NODE



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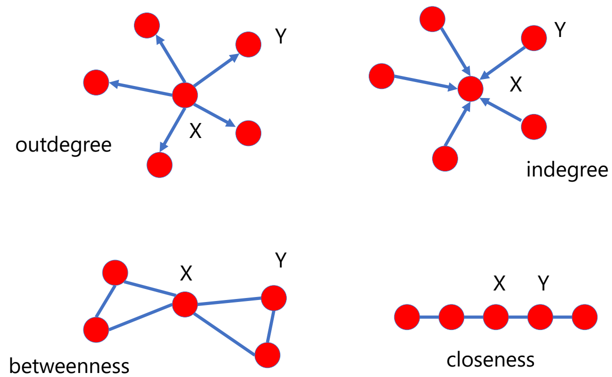
CENTRALITY



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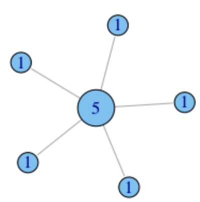
DEGREE CENTRALITY (UNDIRECTED)



$$C_D = d(i)$$

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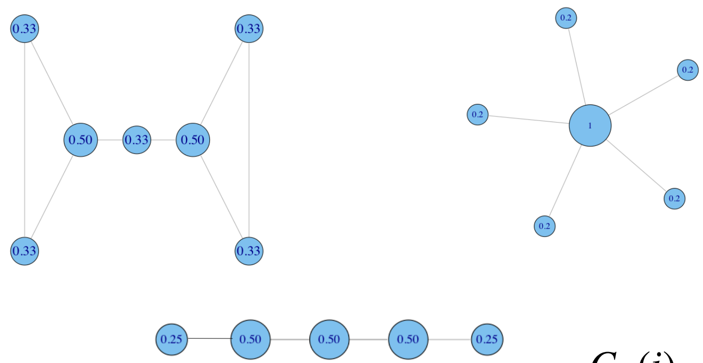
NORMALIZED DEGREE CENTRALITY



$$C_D(i) = \frac{d(i)}{N-1}$$

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WHEN IS DEGREE NOT SUFFICIENT?

Does not capture

- Ability to broker between groups
- Likelihood that information originating anywhere in the network reaches you

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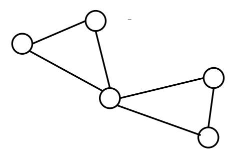
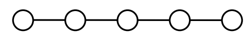
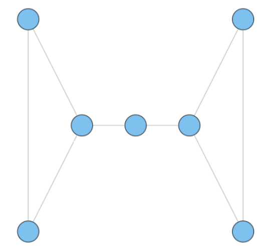
BETWEENESS

Assuming nodes communicate using the most direct (shortest) route, how many pairs of nodes have to pass information through target node?







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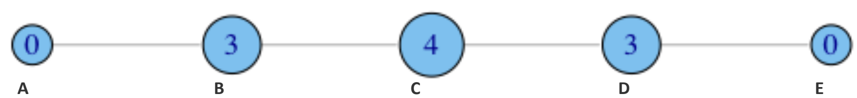
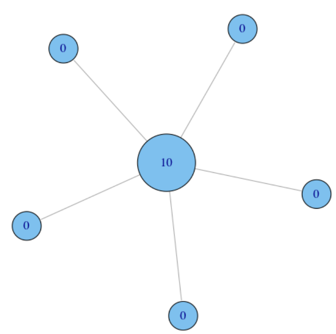
BETWEENESS - EXAMPLES





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BETWEENESS - DEFINITION

$$C_B(i) = \sum_{j,k \neq i, j<k} g_{jk}(i) / g_{jk}$$

g_{jk} = the number of shortest paths connecting *jk*
$g_{jk}(i)$ = the number of shortest paths containing *i*.

Normalization:

$$C_B^{'}(i) = C_B(i\ ) / [(n-1)(n-2)/2]$$

number of pairs of vertices
excluding the vertex itself

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WHEN ARE C_d, AND C_b NOT SUFFICIENT?

Does not capture
Likelihood that information originating anywhere in the network reaches you

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CLOSENESS - DEFINITION

e.g., which node is closest to the *center* of the graph

Closeness Centrality:

$$C_c(i) = \left[\sum_{j=1, j\neq i}^{N} d(i,j) \right]^{-1}$$

Normalized Closeness Centrality

$$C_C^{'}(i) = (C_C(i)) / (N-1) = \frac{N-1}{\sum_{j=1, j\neq i}^{N} d(i,j)}$$

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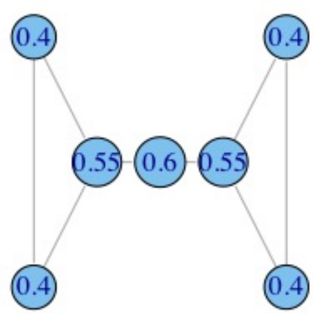
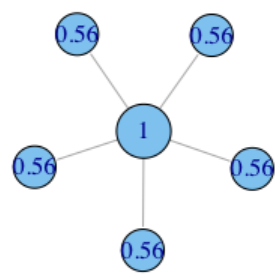
CLOSENESS - EXAMPLES





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COMMUNITY STRUCTURE

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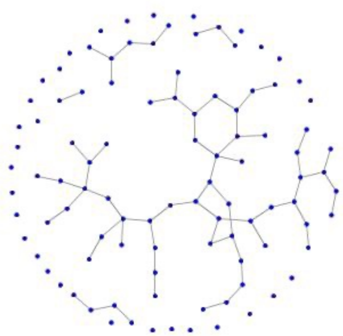
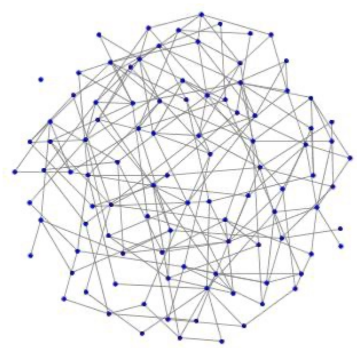
HOW DENSE IS IT?





density = e / e_{max}

Max. possible edges:

Directed: $e_{max} = n*(n-1)$

Undirected: $e_{max} = n*(n-1)/2$

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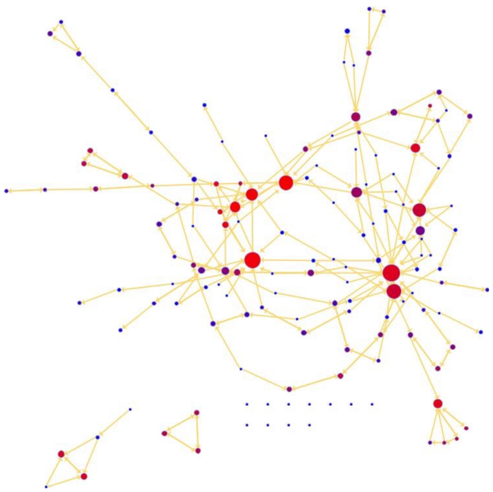
IS EVERYTHING CONNECTED?



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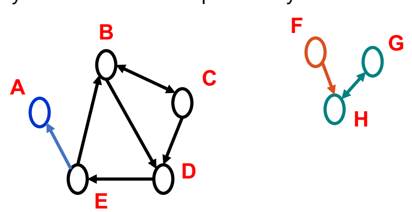
CONNECTED COMPONENTS - DIRECTED

Strongly connected components

Each node in component can be reached from every other node in component by following directed links

B C D E
A
G H
F



Weakly connected components

Each node can be reached from every other node by following links in either direction

A B C D E
G H F

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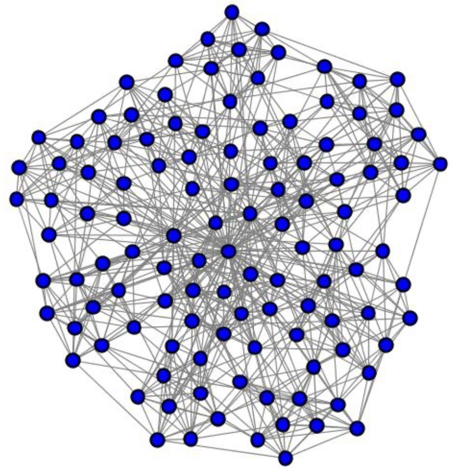
COMMUNITY FINDING - CLUSTERING



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HIERARCHICAL CLUSTERING

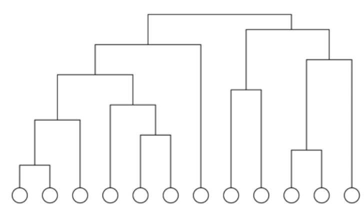
Process

Calculate affinity weights *W* for all pairs of vertices

Start: *N* disconnected vertices

Add edges (one by one) between pairs of vertices/clusters in order of decreasing weight (use closest distance to compare clusters)

Result: nested components



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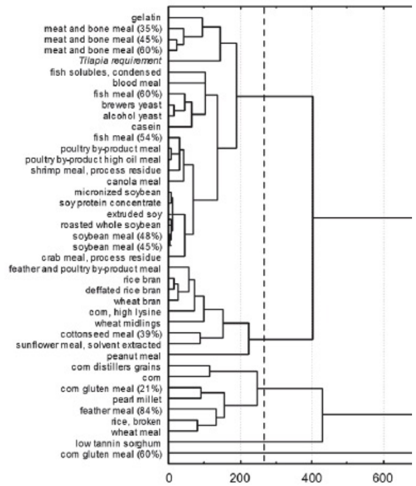
CLUSTER DENDROGRAMS



Depicts cluster trees produced by hierarchical clustering algorithms

Leaf nodes arranged in line, internal node depth indicates order/value at which clusters merge

Basic recursive layout with orthogonal two-segment edges

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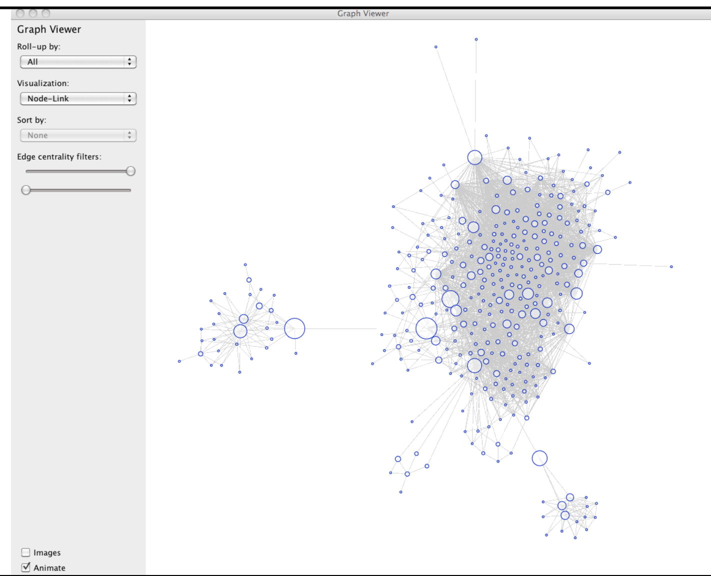

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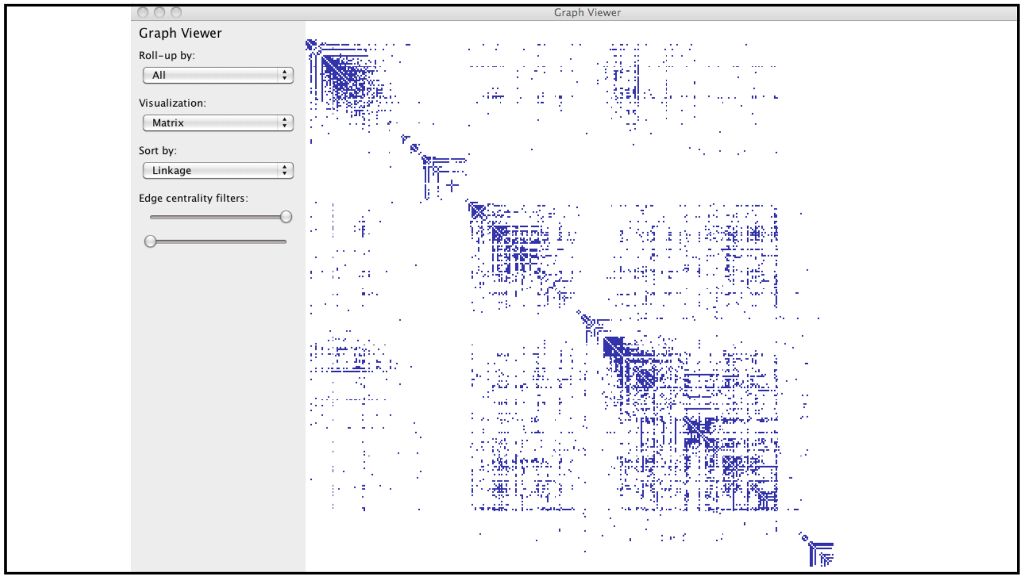

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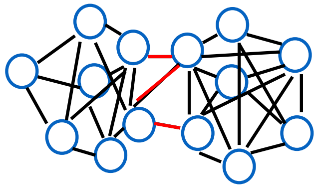
BETWEENESS CLUSTERING

Girvan and Newman 2002 iterative algorithm:

Compute C_b of all *edges*

Remove edge i where $C_b(i) == max(C_b)$

Recalculate betweenness



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SIMULATING NETWORK MODELS

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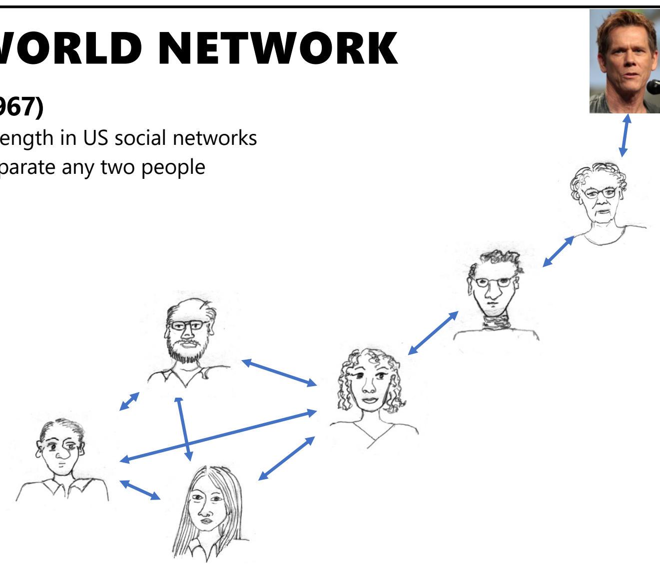
SMALL WORLD NETWORK

Milgram (1967)

Mean path length in US social networks

~ 6 hops separate any two people



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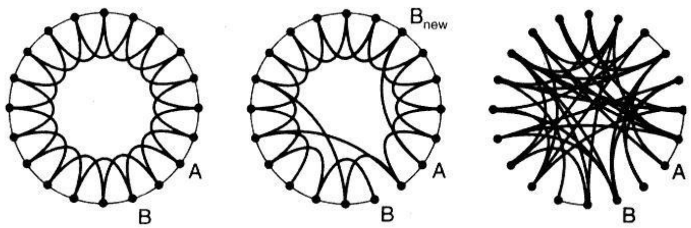
SMALL WORLD NETWORK

Watts and Strogatz 1998

a few random links in otherwise structured graph make network a small world



regular lattice: my friend's friend is always my friend

small world: mostly structured with a few random connections

random graph: all connections random

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DEFINING SMALL WORLD PHENOMENA

Properties

high clustering

low mean shortest path

$$C_{\text{network}} >> C_{\text{random graph}}$$

$$l_{\text{network}} \approx \ln(N)$$

Examples

neural network of C. elegans

semantic networks of languages

actor collaboration graph

food webs

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SUMMARY

Structural analysis
- Centrality
- Community structure

Simulation models enable further analysis

Network analysis applicable in many domains

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