Graphs and Networks

CS 4460 - Information Visualization

Spring, 2019

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today

- Graphs and Networks
  - Specific type of data / data structure that requires specific type of visualization approach
  - we'll talk about characteristics of graphs
  - basic terminology
- Show some examples of graph visualizations

Graph Visualization **Overview**

It's about connections

- Connections throughout our lives and the world
  - Circle of friends
  - Delta's flight plans
  - …
- We can model many different connected sets of data items as a Graph
- lots of phenomena in the real world have graphs
  - therefore, lots of the datasets that we have are graphs

What is a Graph?

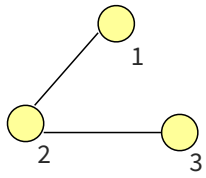
- **Vertices** (nodes) connected by
- **Edges** (links)

Adjacency list

1: 2
2: 1, 3
3: 2

	1	2	3
1	0	1	0
2	1	0	1
3	0	1	0

Adjacency matrix



Drawing

Graph Terminology

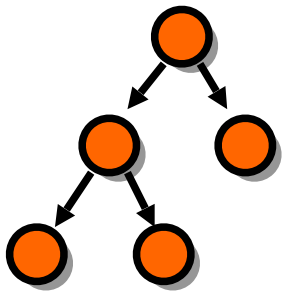
- Graphs can have **cycles**
- Graph **edges** can be **directed** or **undirected**
- The **degree of a vertex** is the number of edges connected to it
  - **In-degree** and **out-degree** for directed graphs
- Graph edges can have values (**weights**) on them (nominal, ordinal or quantitative)

Trees are Different

- Subcase of general graph
- No cycles
- Typically directed edges
- Special designated root vertex

- Also different are hierarchies

- We will talk about these next time



Graph Uses

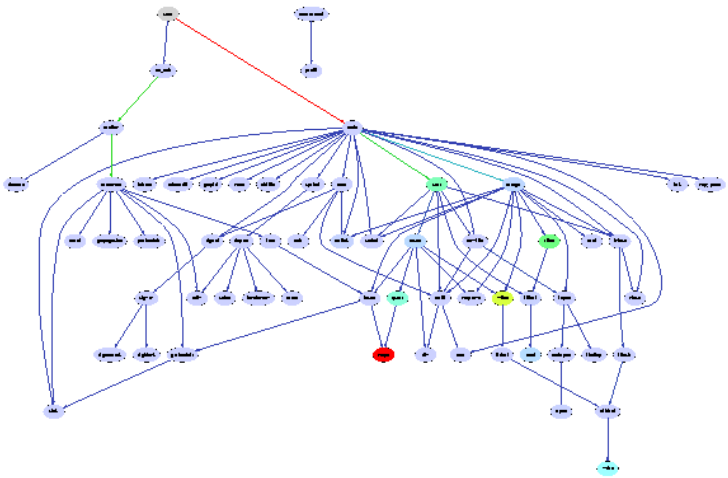
- In information visualization, any number of data sets can be modeled as a graph
  - US telephone system
  - World Wide Web
  - Distribution network for on-line retailer
  - Call graph of a large software system
  - Semantic map in an AI algorithm
  - Set of connected friends
- Graph/network visualization is one of the oldest and most studied areas of InfoVis

Graph Visualization Challenges

- Graph layout and positioning
  - Make a concrete rendering of abstract graph
- Navigation/Interaction
  - How to support user changing focus and moving around the graph
- Scale
  - Above two issues not too bad for small graphs, but large ones are much tougher

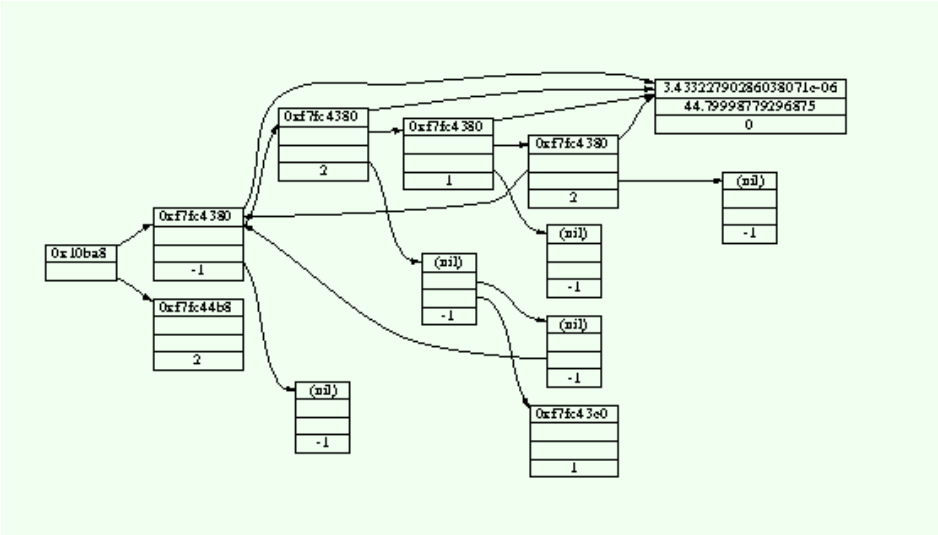
Showing Vertex - Issues

- We can use encodings, such as:
  - Shape
  - Color
  - Size
  - Location
  - Label



Showing Edges - Issues

- edges don't have to be straight



Aesthetic Considerations; Edges

- **Crossings** -- minimize (edge crossings)
- Total **Edge Length** -- minimize towards proper scale
- **Area** -- minimize towards efficiency
- **Maximum Edge Length** -- minimize longest edge
- **Uniform Edge Lengths** -- minimize variances
- **Total Bends** -- minimize orthogonal towards straight-line

- While aesthetic, these considerations also impact the fundamental usability and effectiveness of graphs!

Shneiderman's NetViz Nirvana

1) Every node is visible

2) For every node you can count its degree

3) For every link you can follow it from source to destination

4) Clusters and outliers are identifiable

User Tasks for Graph Vis

User Tasks for Graphs

- So what do people want to do with or learn from network visualizations?
  - User tasks is a recurring theme of this class
  - Too often this is neglected.

Graph Vis Task Taxonomy

- Start with Amar et al ‘05 low-level tasks (they still apply)
- Then add four types of graph-specific tasks (next few slides)

Lee et al
BELIV ‘06

Graph Vis Task Taxonomy

- 1. **Topology-based** tasks

- **Adjacency**
  Find the set of nodes adjacent to a node
- **Accessibility**
  Find the set of nodes accessible to a node
- **Common connection**
  Given nodes, find the set of nodes connected to all
- **Connectivity**
  Find shortest path
  Identify clusters
  Identify connected components

Graph Vis Task Taxonomy

- 2. **Attribute-based** tasks

- **On the nodes**
  Find the nodes having a specific attribute value
- **On the edges**
  Given a node, find the nodes connected only by certain kinds of edges

Graph Vis Task Taxonomy

- 3. **Browsing** tasks
  - **Follow path**
    Follow a given path
  - **Revisit**
    Return to a previously visited node

- 4. **Overview** task
  - Compound exploratory task
    Estimate size of a network
    Find patterns

Graph **Layout Approaches**

Layout Heuristics

- Layout algorithms can be
  - polyline edges
  - planar
  - orthogonal
  - grid-based
  - curved lines
  - hierarchies
  - circular
  - ...

Scale Challenge

- May run out of space for vertices and edges (turns into “ball of string”/ hairball)
- Can really slow down algorithms
- Sometimes use clustering to help
  - Extract highly connected sets of vertices
  - Collapse some vertices together

Navigation/Interaction Challenge

- How do we allow a user to query, visit, or move around a graph?
- Changing focus may entail a different rendering
- Think back to the basic tasks for general visualization. These become challenging for graphs.

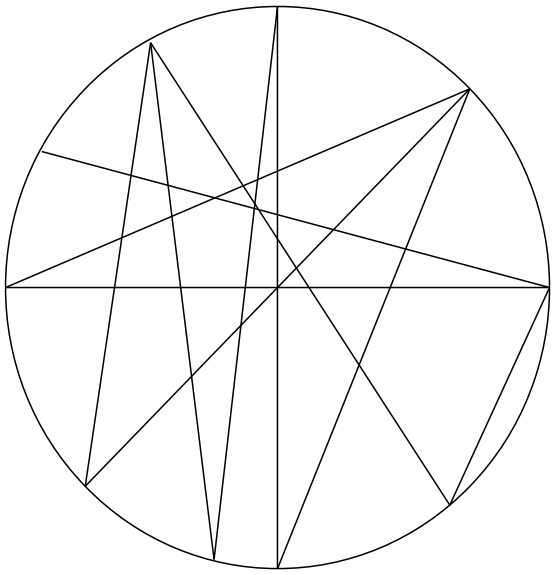
Graph **Layout Techniques**

Circular Layout

Ultra-simple
May not look so great

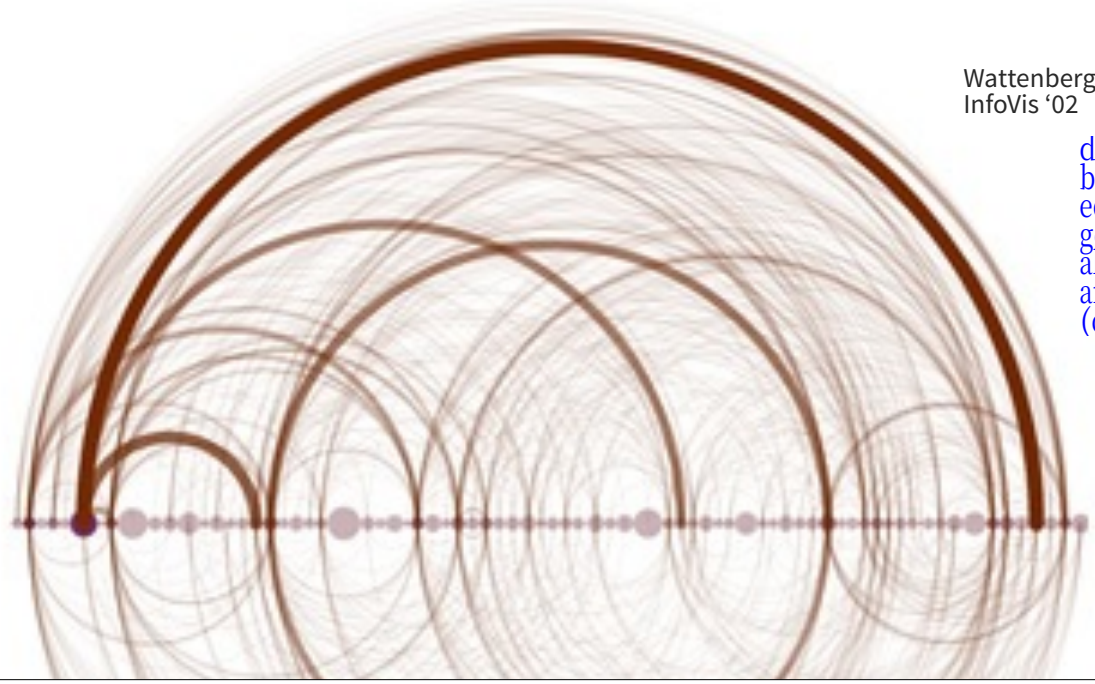
Space vertices out around circle
Draw lines (edges) to connect vertices

place nodes with equal distance along the verge of the circle, draw edges between them.



http://www.visualcomplexity.com/vc/index.cfm?method=Arc%20Diagrams

Arc Diagram Layout



Wattenberg
InfoVis '02

draw edges across the top or bottom. Show direction: all edges across the top are going from left to right, and all edges across the bottom are from right to left (clockwise overall).

Tree Layout

- Run a breadth-first search from a vertex
  - This imposes a spanning tree on the graph
- Draw the spanning tree
- Simple and fast, but obviously doesn't represent the whole graph

Hierarchical Layout

Try to impose hierarchy on graph
  Reverse edges if needed to remove cycles
  Introduce *dummy* nodes
Put nodes into layers or levels
Order l->r to minimize crossings

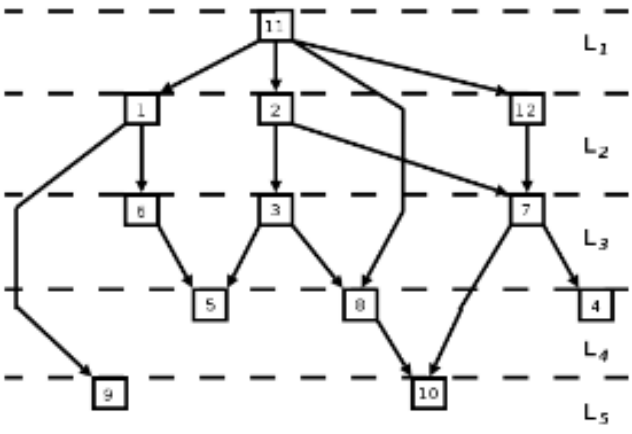


Figure: A graph showing a layered layout, created with the Sugiyama heuristic, with the layers shown. The bends in the edges correspond to dummy nodes.

http://www.csse.monash.edu.au/hons/se-projects/2006/Kieran.Simpson/output/html/node7.html#sugiyamaexample

Force-directed Layout

- Example of constraint-based layout technique
- Impose constraints (objectives) on layout
  - Shorten edges
  - Minimize crossings
  - …
- Define through equations
- Create optimization algorithm that attempts to best satisfy those equations

Force-directed Layout

- Spring model (common)
  - Edges – Springs (gravity attraction)
  - Vertices – Charged particles (repulsion)
- Equations for forces
- Iteratively recalculate to update positions of vertices
- Seeking local minimum of energy
  - Sum of forces on each node is zero

Force-directed Example

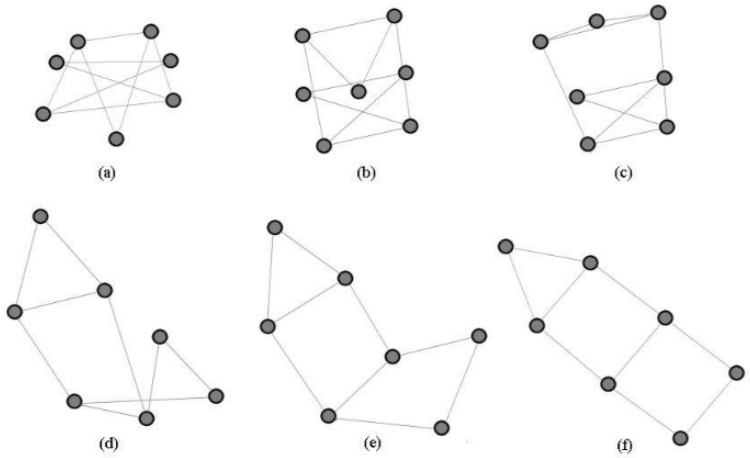
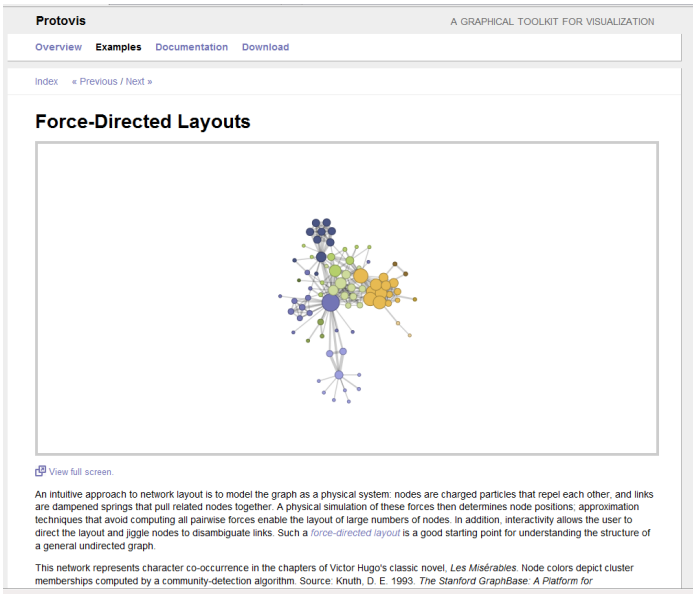


Figure 2: A graph drawing through a number of iterations of a force directed algorithm.

http://www.cs.usyd.edu.au/~aquigley/3dfade/

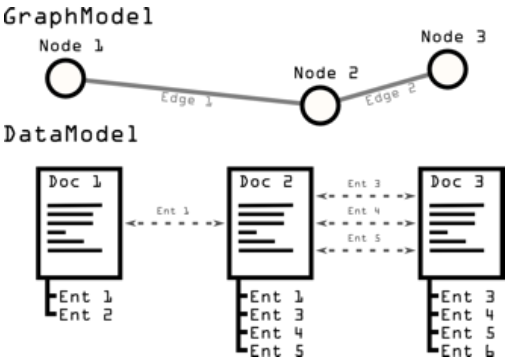
In Action

http://vis.stanford.edu/protovis/ex/force.html



Later in semester, we'll look at

- ForceSPIRE: Text Analysis via Force Directed Layout



Graph Layouts

- Lots of variants exist
  - and for each, lots of parameters can be adjusted to fine-tune the layout
- Important to understand high-level tradeoff

Graph Drawing Support

- Libraries
  - JUNG (Java Universal Network/Graph Framework)
  - Graphviz (formerly dot?)
- Systems
  - Gephi
  - TouchGraph
- Also, NodeXL

But Is It InfoVis? my take on this…

- I generally don't consider a pure graph layout (drawing) algorithm to be InfoVis
  - Nothing wrong with that, just an issue of focus
- For InfoVis, I like to see some kind of interaction or a system or an application…
  - Still, understanding the layout algorithms is very important for infovis

Graph Visualization **Examples**

Human Diseases

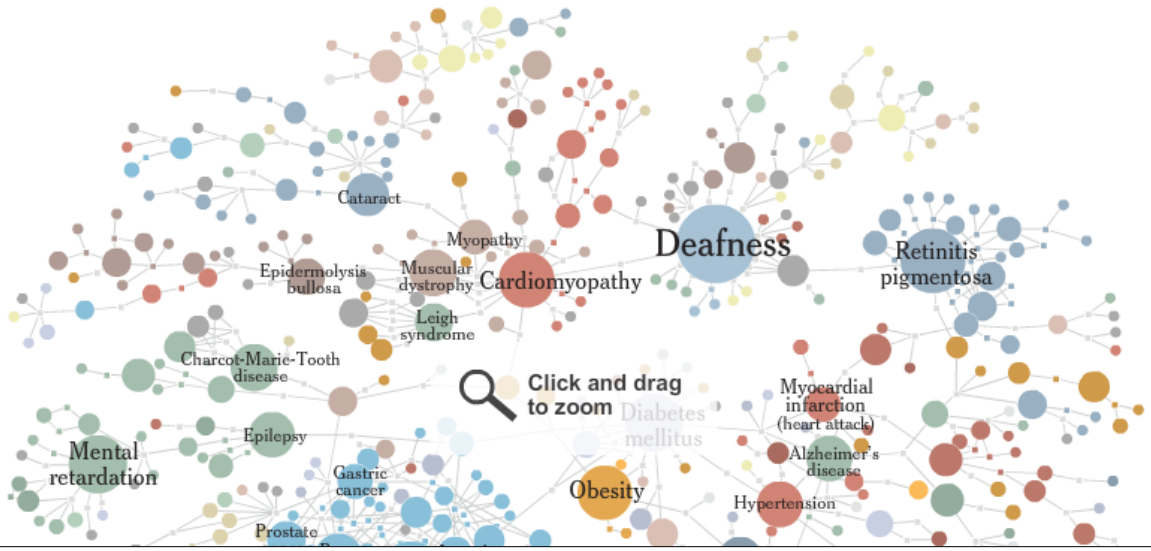
http://www.nytimes.com/interactive/2008/05/05/science/20080506_DISEASE.html

May 5, 2008

SIGN IN TO E-MAIL | FEEDBACK

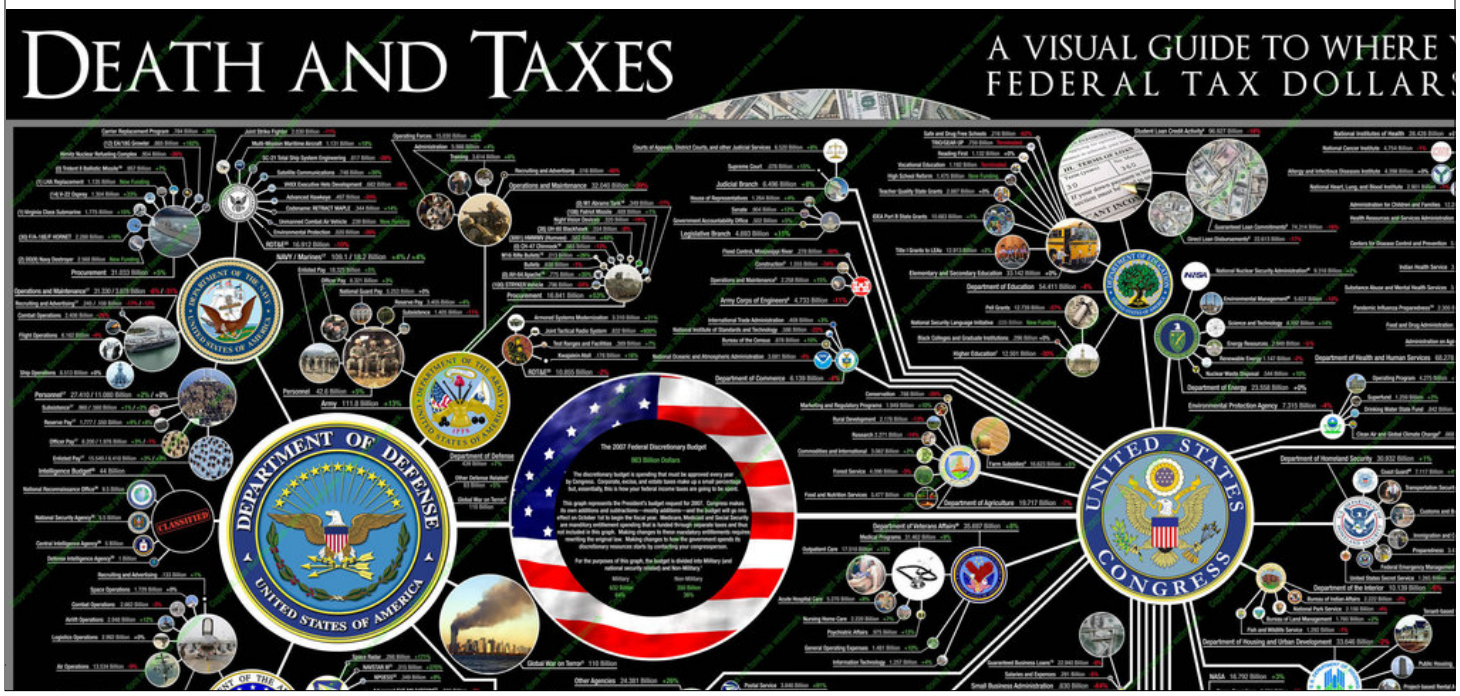
Mapping the Human 'Diseasome'

Researchers created a map linking different diseases, represented by circles, to the genes they have in common, represented by squares. Related Article: Redefining Disease, Genes and All



US Budget

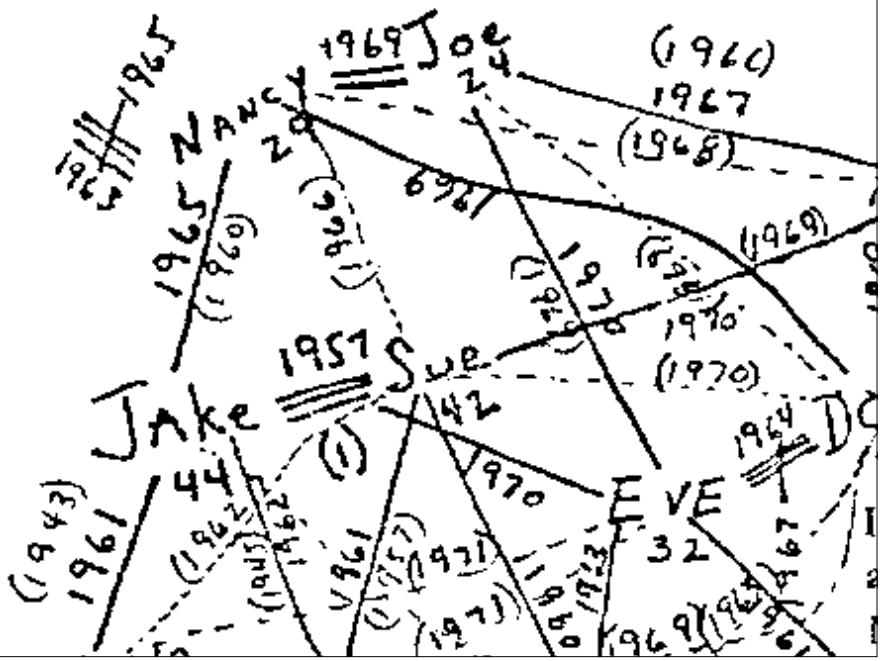
http://mibi.deviantart.com/art/Death-and-Taxes-2007-39894058



Social Network Visualization

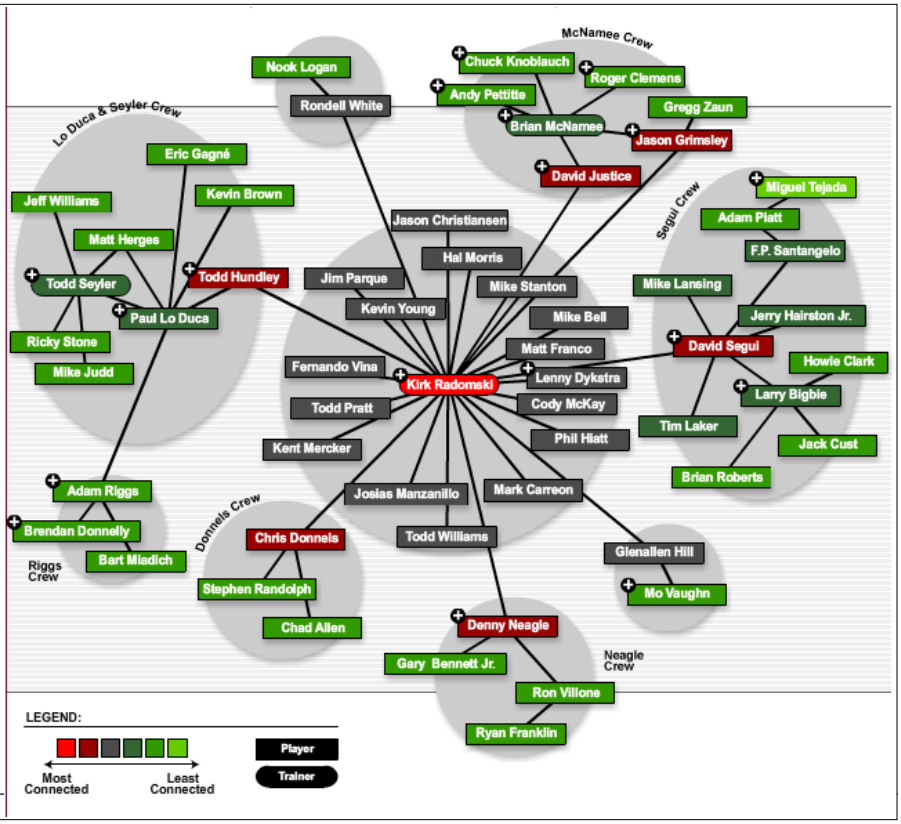
- Social Network Analysis
  - http://www.insna.org

Hot topic again
Why?
Facebook, …



Steroids in MLB

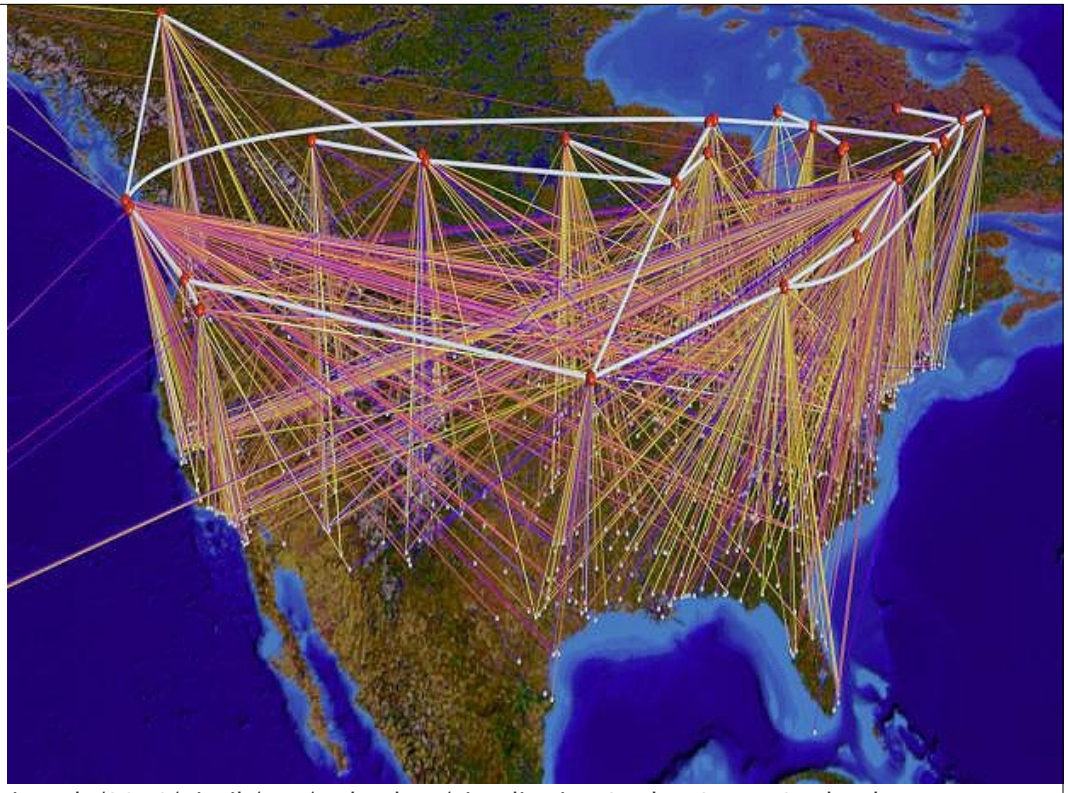
http://www.slate.com/id/2180392/



Geo Applications

- Many problems and data sets have some geographic correspondence

Byte traffic into the ANS/ NSFnet T3 backbone for the month of November, 1993



http://www.ncsa.uiuc.edu/SCMS/DigLib/text/technology/Visualization-Study-NSFNET-Cox.html

Follow the Money

Where does a dollar bill go?

http://www.nsf.gov/news/special_reports/scivis/follow_money.jsp

London Tube

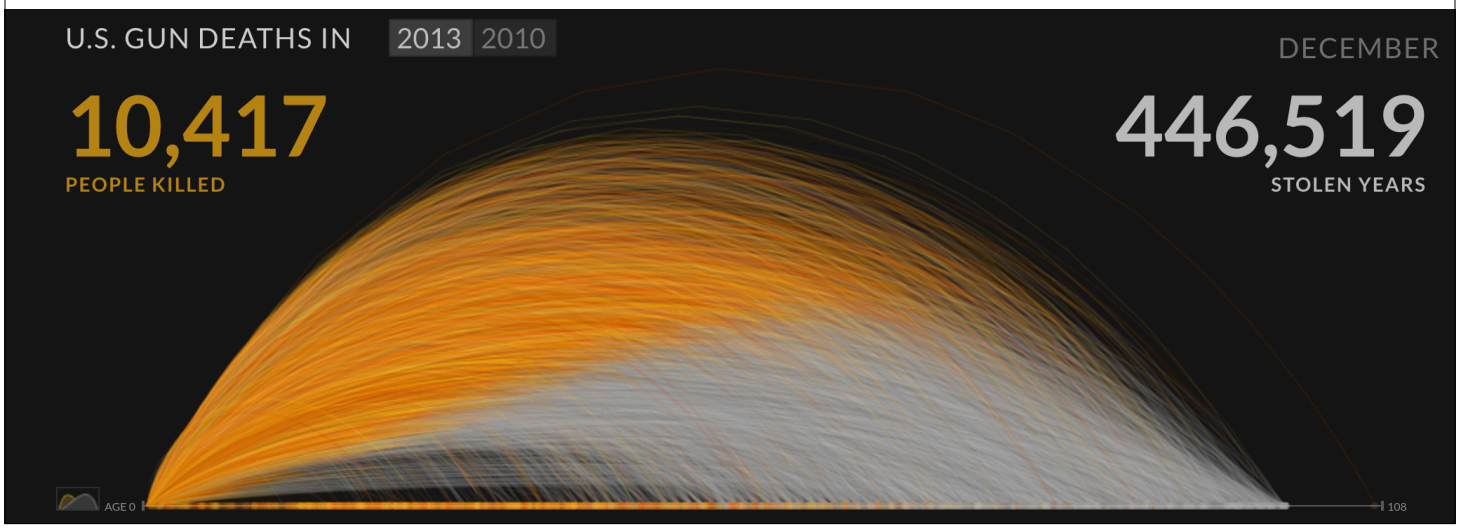
Harry Beck

Alex Endert endert@gatech.edu

Atlanta
MARTA

endert@gatech.edu

https://guns.periscopic.com/?year=2013



one particular challenge with graphs

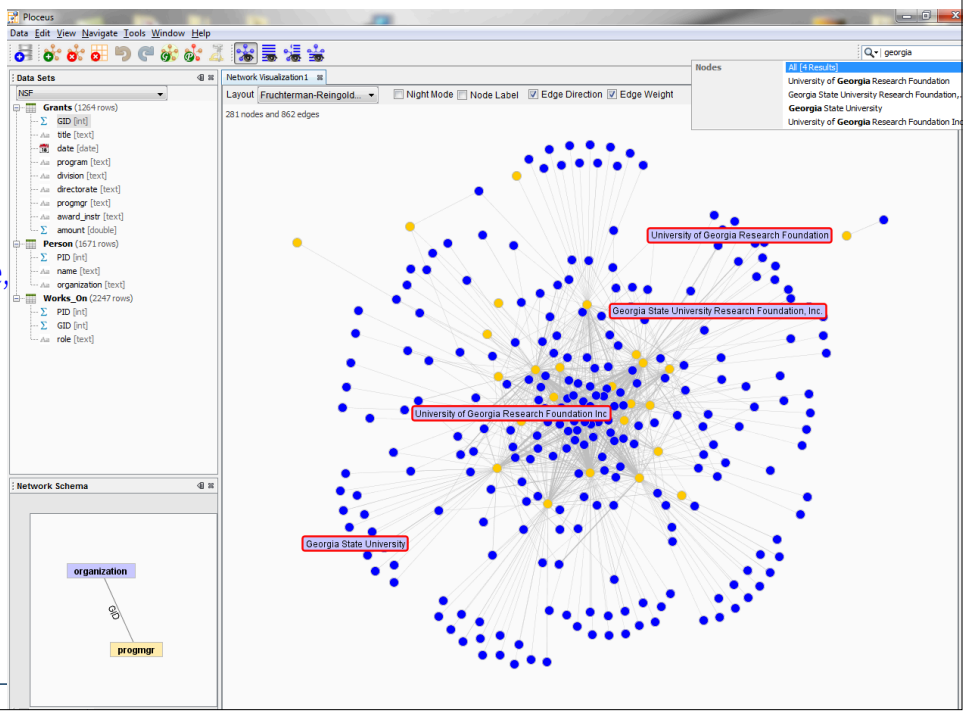
- Data often does not come in “graph model”
  - nodes and edges may not be pre-defined
  - users have to “define” what they want to be nodes, then what defines the relation between them (edges)
- A couple of tools that help you do this

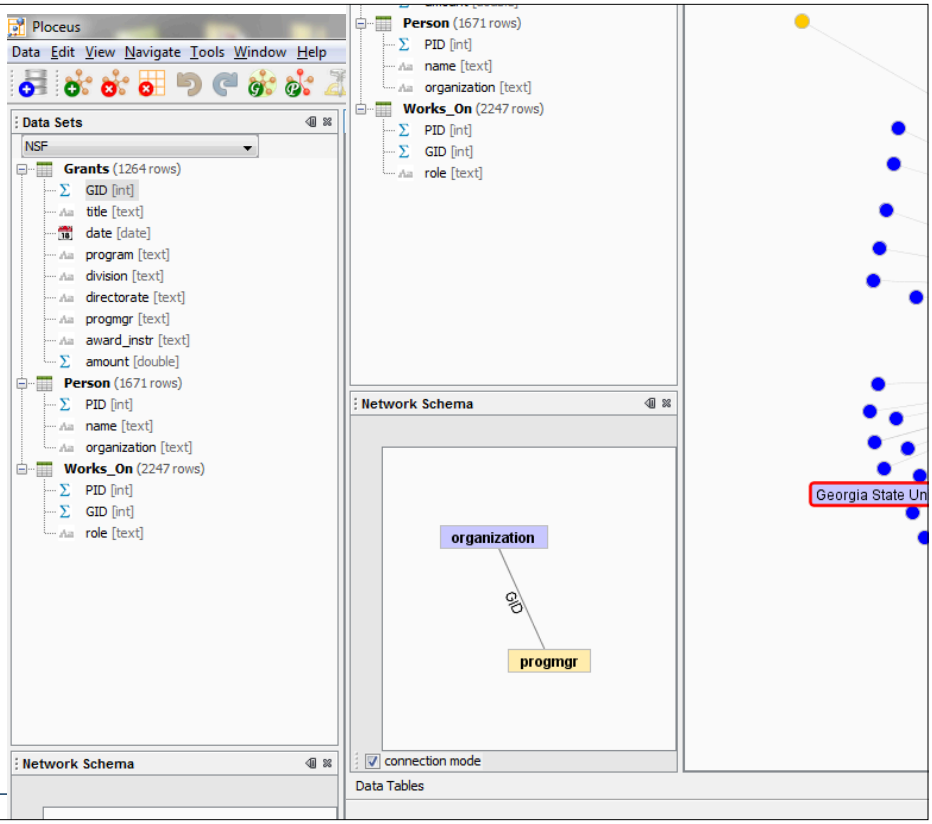
Liu, Zhicheng, Shamkant B. Navathe, and John T. Stasko. "Ploceus: Modeling, visualizing, and analyzing tabular data as networks." *Information Visualization* 13.1 (2014): 59-89.

Ploceus

- Users select attributes to define edges between nodes

if two nodes share the same attribute, use an edge to connect them.





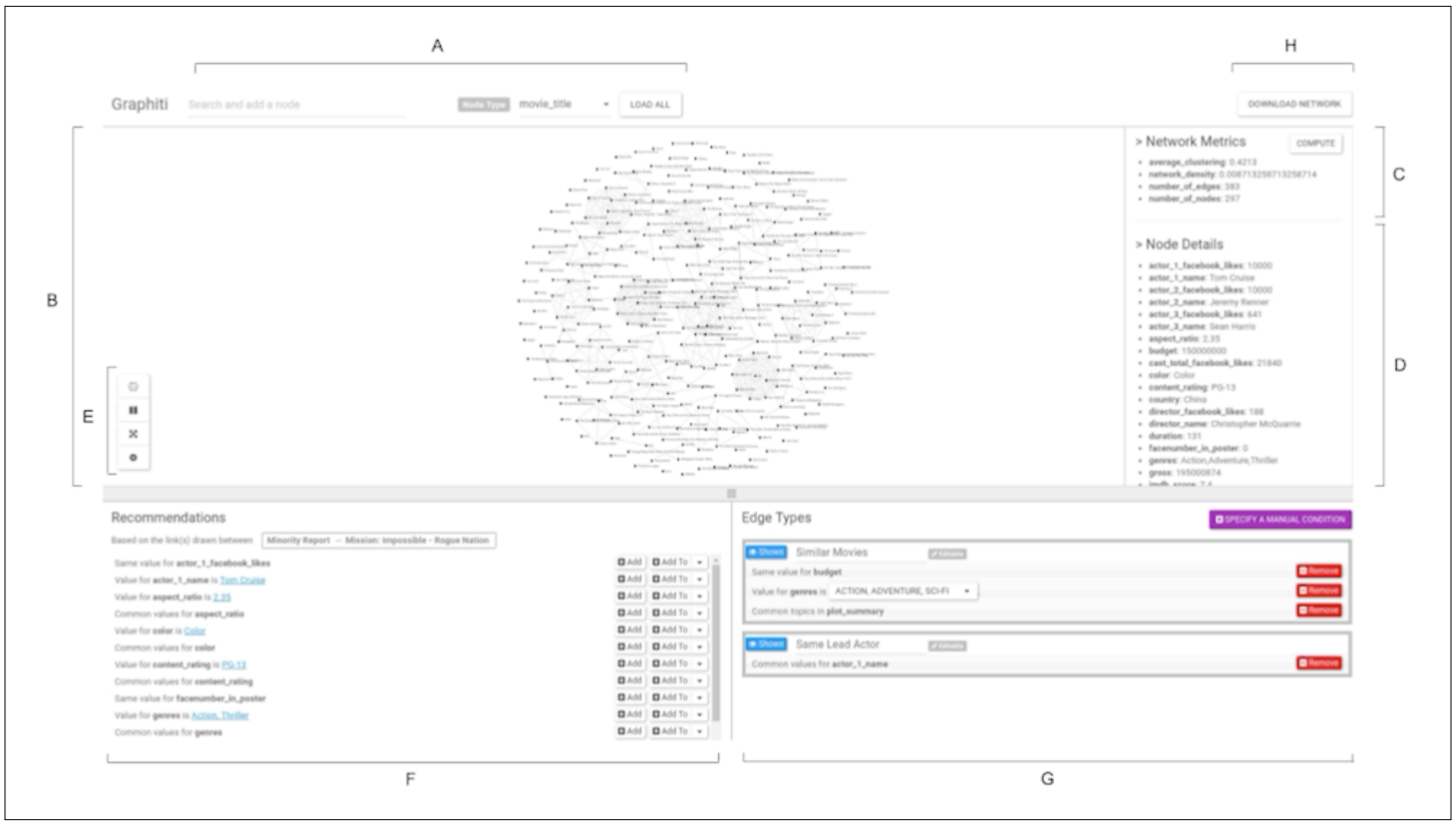
another take on this

- What if you don't know the attributes that correspond to the relationship you want to define?
  - "If these two nodes are connected, what (in the data) defines that connection?"

Srinivasan, Arjun, et al. "**Graphiti**: Interactive Specification of Attribute-based Edges for Network Modeling and Visualization." *IEEE Transactions on Visualization and Computer Graphics*(2017).

Graphiti

- helps users create graph models.
  - E.g., I want a graph that has these two nodes connected. The system searches and creates edge rules that help form this graph
-

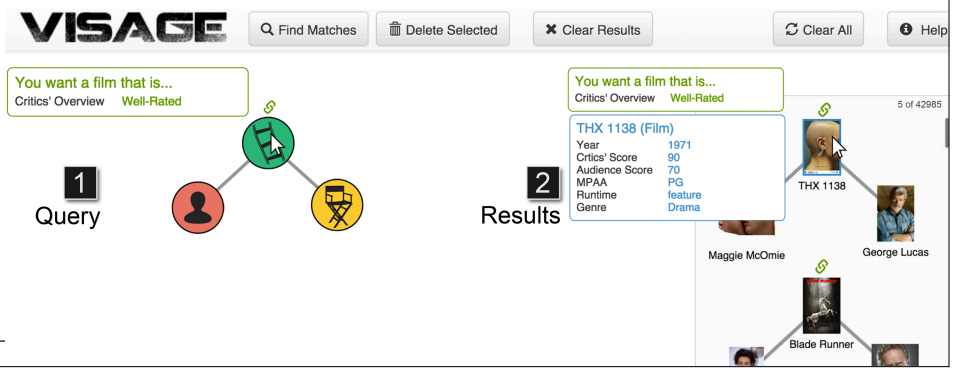


Another online graph vis example

- http://visualscm.herokuapp.com/

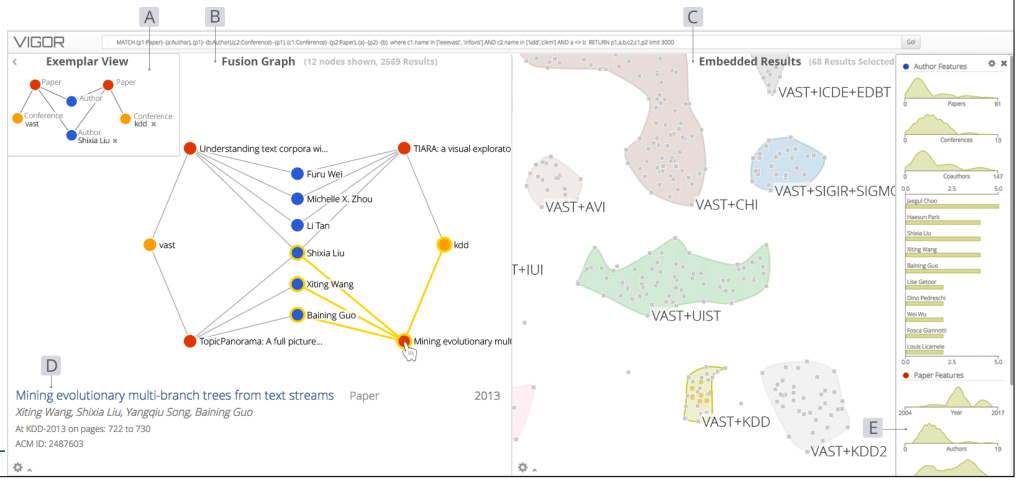
Graph Querying

- Specifying what you're looking for in graphs is complex
  - must specify structure of graph and content
- VISAGE http://spicy.bike/pr_visage/



How to show query results

- A long list … not great
- Instead, show results visually: http://spicy.bike/pr_vigor/



today, we covered

- Graph Characteristics and Terms
- Examples of Graphs
- Example of tools that help you build graph network models