Arrange Networks and Trees

Cmpt 767 - Visualization

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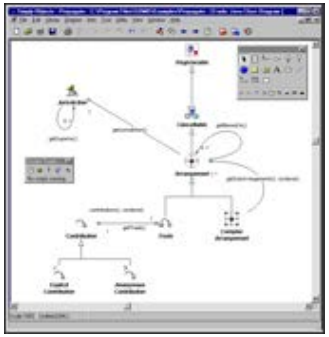
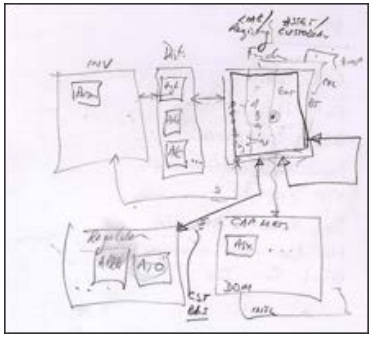
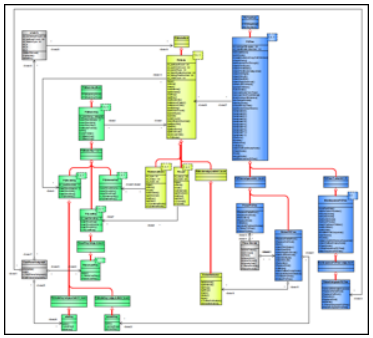
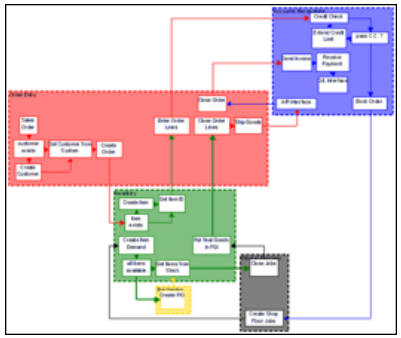
[incl. sides from Moeller/Munzner/Eades/Sedlmair]

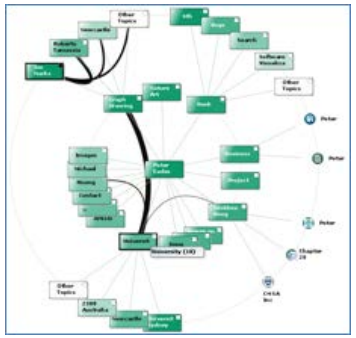
Networks & Graphs







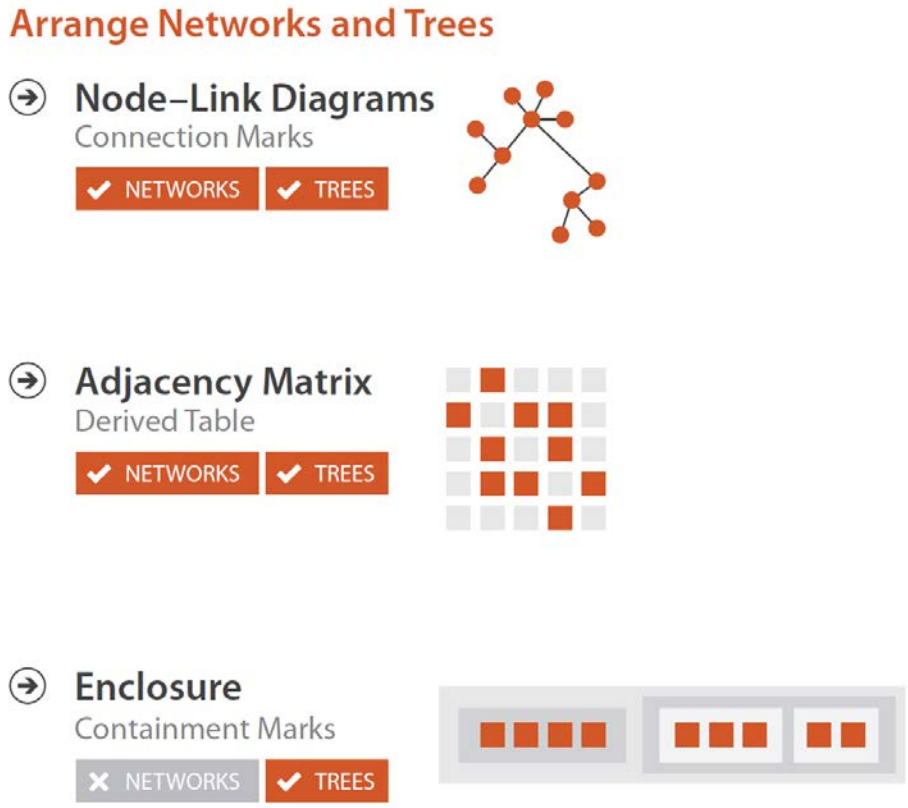




etc.

Overview

- Connection and Containment Channels



Readings

- Munzner, “Visualization Analysis and Design”:
  - Chapter 9 (Arrange Networks and Trees)
- Heer 2018, CSE512 - *Data Visualization*

Applications

- Tournaments
- Organization
- Charts
- Genealogy
- Diagramming (e.g., Visio)
- Biological Interactions (Genes, Proteins)
- Computer Networks
- Social Networks
- Simulation and Modeling
- Integrated Circuit Design

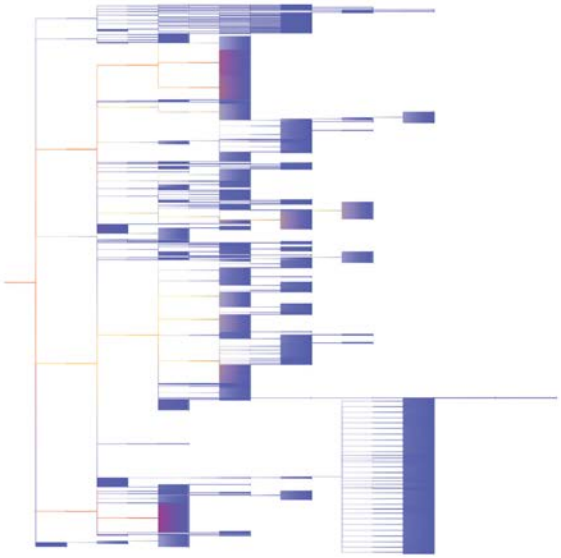
Goal of Spatial Layout

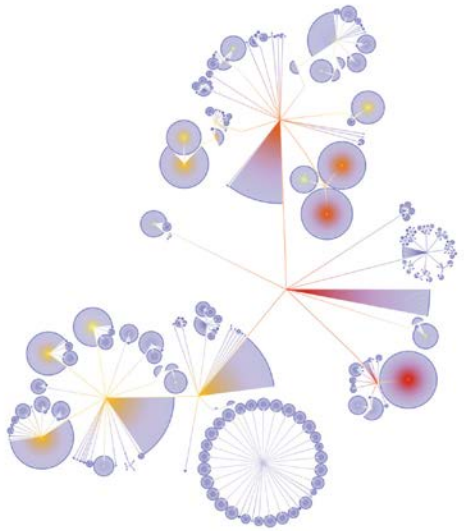
Place nodes and edges to optimize

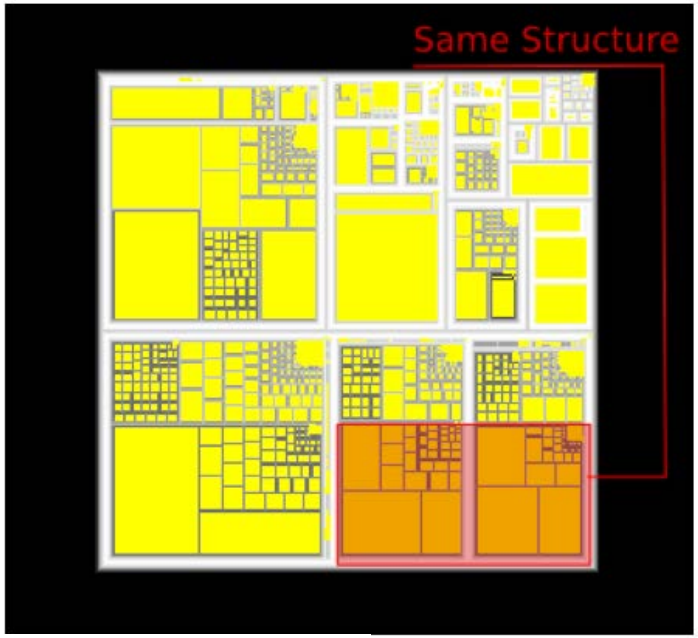
- Connectivity
- Path-following
- Topological distance
- Clustering/grouping
- Ordering (i.e. hierarchy level)

Connection vs. Containment

- relevant for drawing graphs + trees
- containment -- essentially treemaps
- connection -- traditional view of graphs
- Different information - equal vs hierarchical

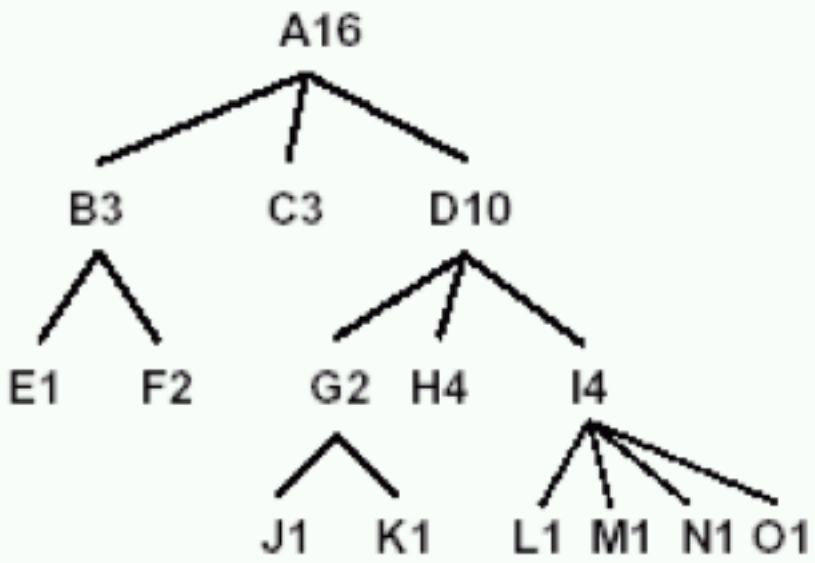




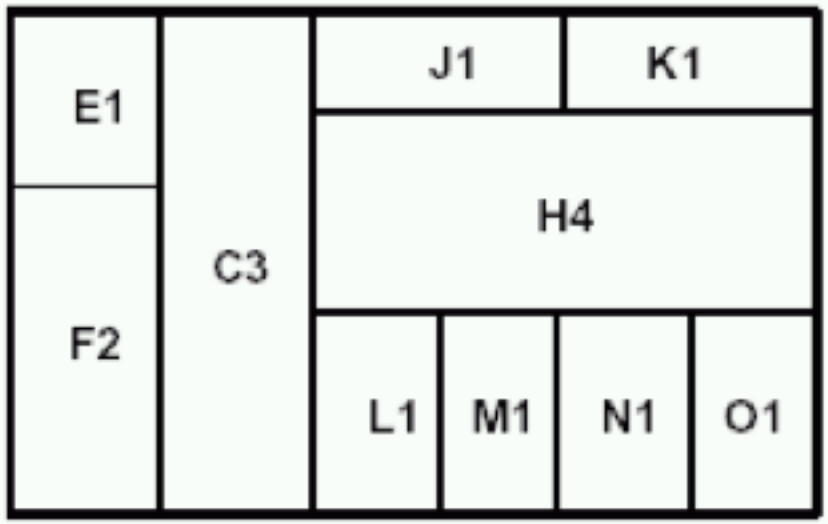


Auber: http://tulip.labri.fr/Documentation/3_7/userHandbook/html/ch06.html

Tree-map



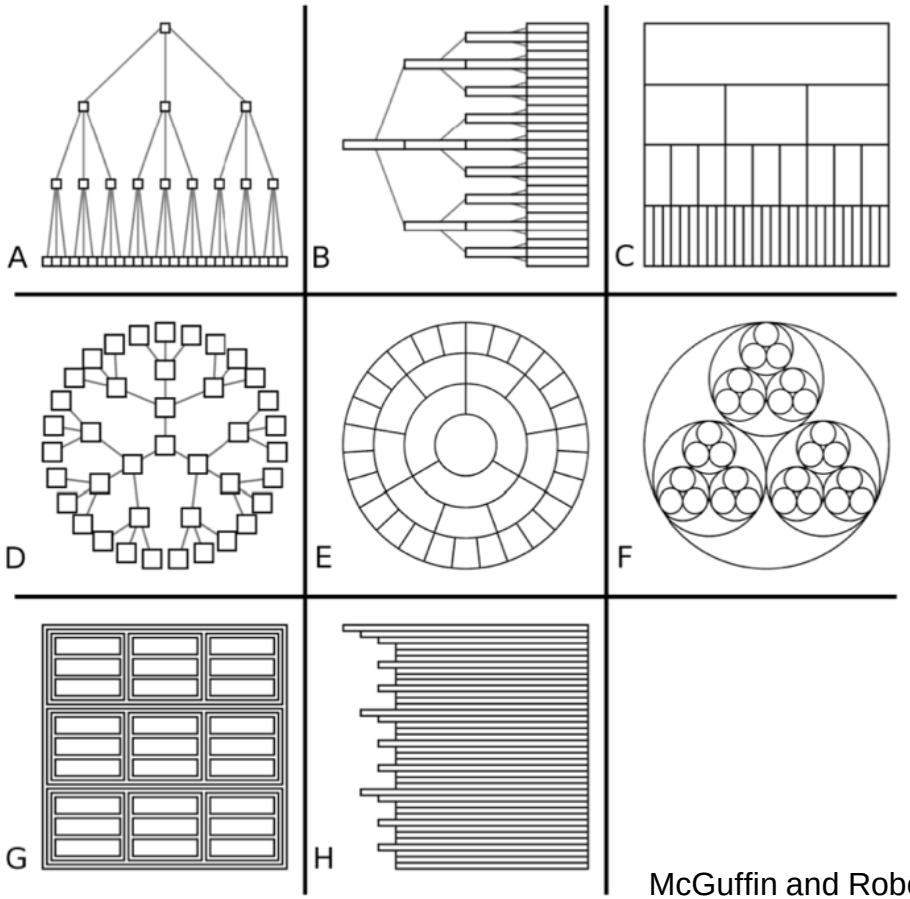
Node and link diagram



Treemap

Connection vs. Containment

- Eight visual encodings of the same tree dataset



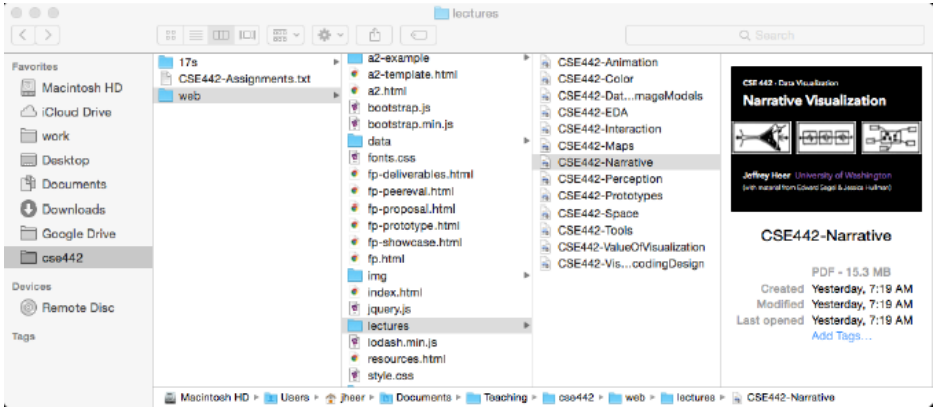
McGuffin and Robert 2010

Tree layouts

- **Indentation**: File directory style

```
Folder
    Subfolder
        File1
        File2
```

- **Single focus**: accordion style
  - Separate breadth and depth along 2D and focus on a single path at a time
  - Example:
    Mac File Explorer



Enclosure Diagrams

Set theory style

- Pros
  - Provides single view of an entire tree
  - Easier to spot large/small nodes
- Cons
  - Difficult to accurately read structure/depth
- Examples
  - Circle Packing Layout
  - Tree Maps

Node-Link Diagrams

Traditional data structure style

- Naive Recursive Layout Algorithm
- Reingold and Tilford's "Tidy" Layout Algorithm (linear time algo)
- Cluster Dendograms
- Radial Tree Layout
- Hyperbolic Layout
- Sugiyama-Style Layout
- Force-Directed Layout: Uses Barnes-Hut algorithm
- Degree-of-Interest Trees (expansion-by-interest)

Treemaps

- Squarified Treemaps
  - Greedy optimization for objective of square rectangles
- Cushion Treemaps
  - Shading to emphasize hierarchical structure
- Cascaded Treemaps
- Voronoi Treemaps
  - Iterative, weighted Voronoi tessellations to achieve cells with value-proportional areas

More Tree Vis Methods

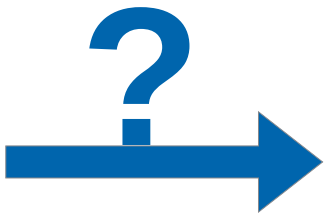
- Layering
  - Sunburst Trees: Use polar partition
- Matrix Diagrams
- Use Attributes to drive layouts
- Pivot Graph
  - Roll-Up and Selection Operators
- Hive Plots

Graph Drawing

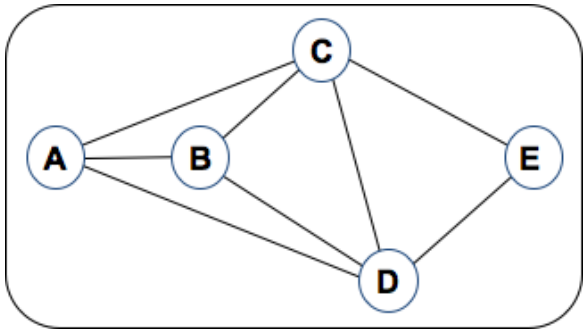
- The classical graph drawing problem is to develop **algorithms to draw graphs nicely.**

graph

A - B, C, D
B - A, C, D
C - A, B, D, E
D - A, B, C, E
E - C, D



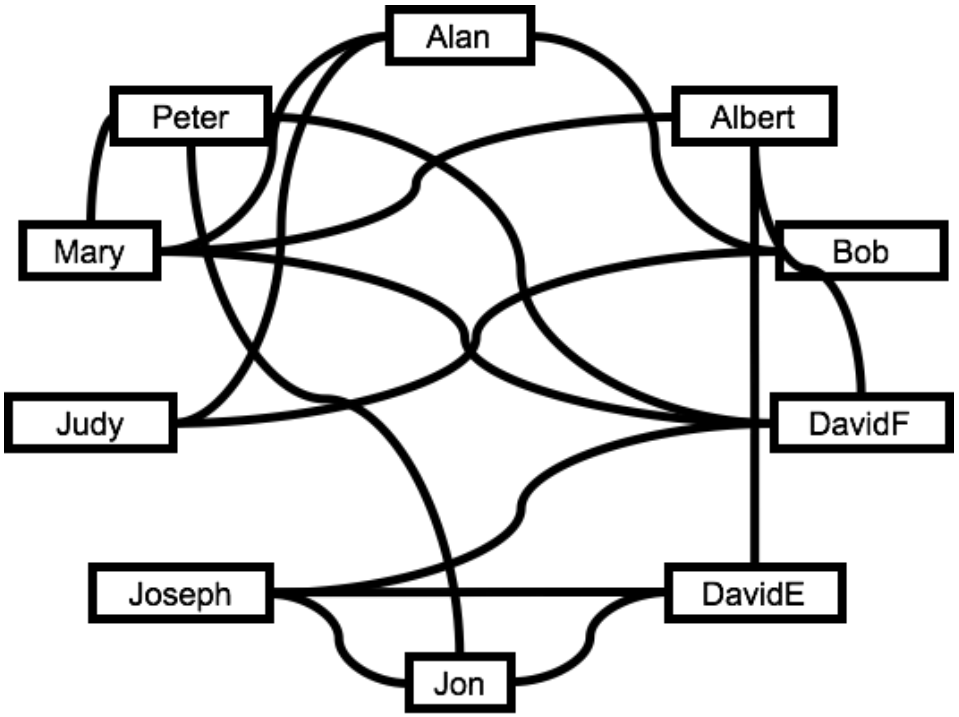
nice graph drawing



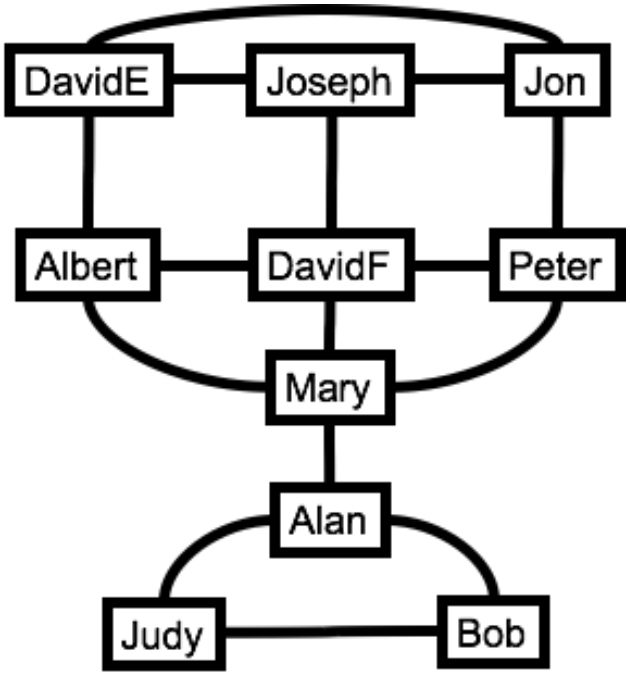
Example

X	***Adjacent to X***
Mary	Peter, Albert, DavidF, Peter
Judy	Bob, Alan
Peter	Mary, DavidF, Jon
DavidF	Albert, Joseph, Peter, Mary
Jon	Peter, Joseph, DavidE
DavidE	Jon, Joseph, Albert
Joseph	DavidE, Jon, DavidF
Bob	Judy, Alan
Alan	Bob, Mary, Judy
Albert	DavidF, Mary, DavidE

Example

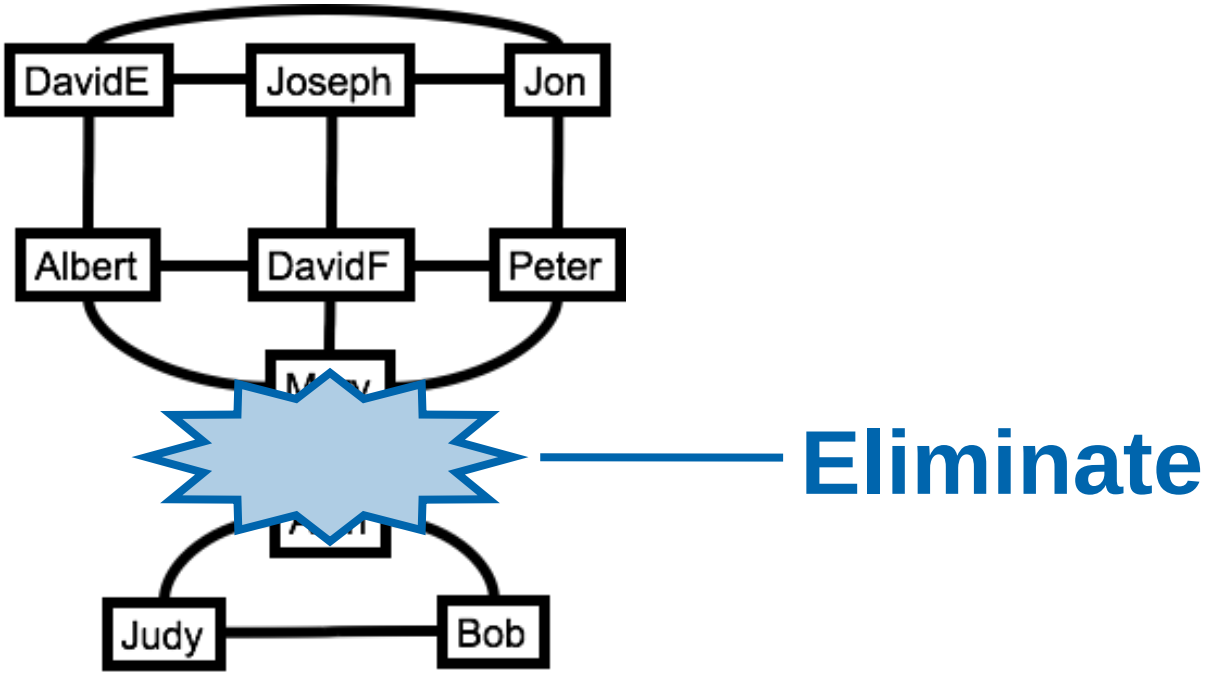


Example

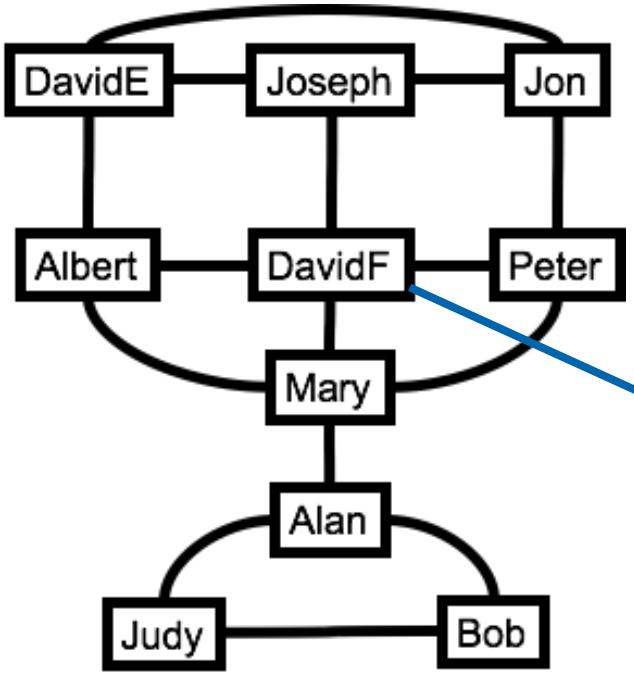


Example

- Terrorist network



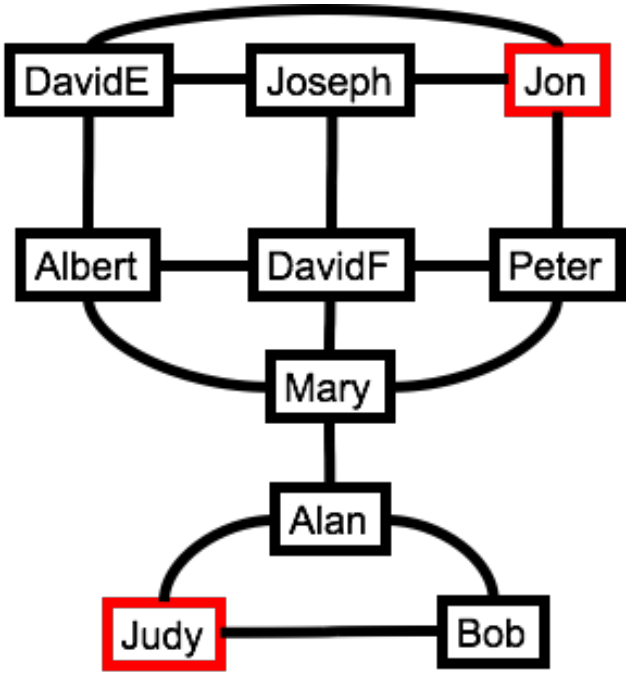
Example



- Mobile phone network:
  - nodes: people
  - edges: phone calls

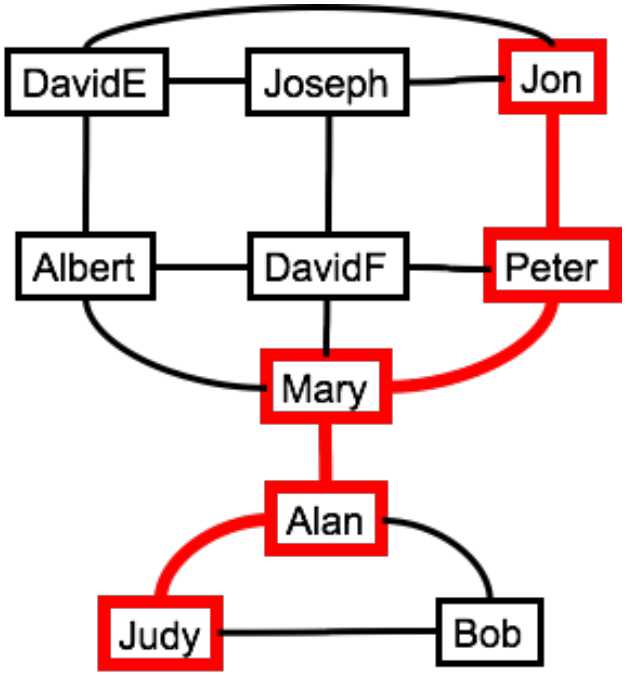
Good deal $$$$

Example



- Transport network:
  - nodes: places
  - edges: train lines

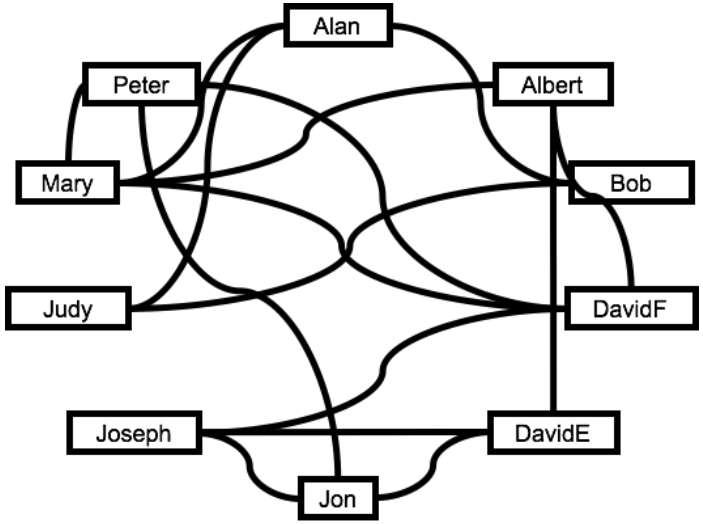
Example



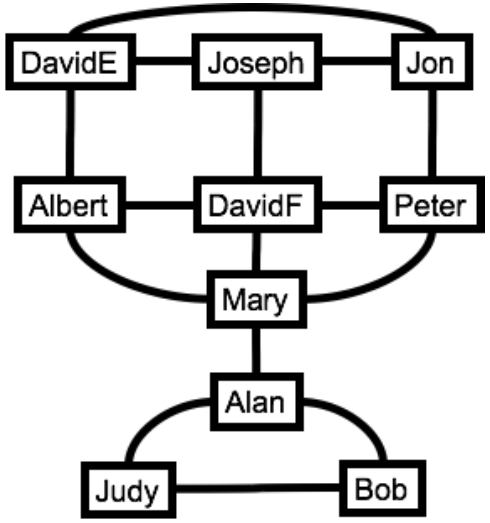
- Transport network:
  - nodes: places
  - edges: train lines

Shortest path?

What algorithm gives good drawings of graphs?

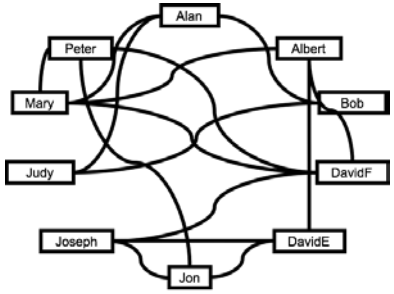


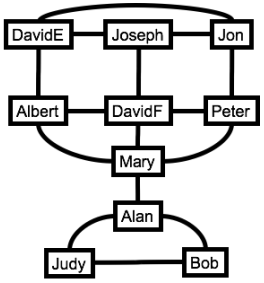
Bad



Good

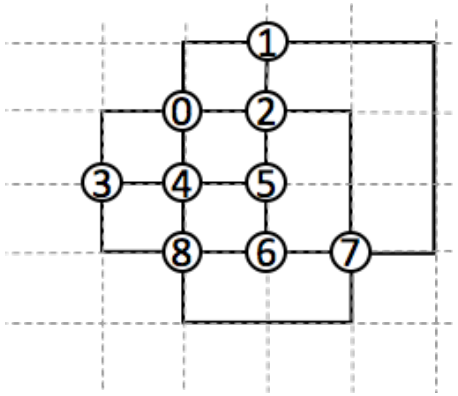
Quality measures for networks



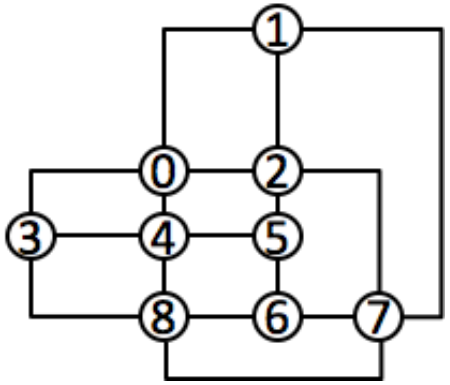


- Classical quality measures
  - minimize edge crossings
  - minimize bends
  - …
- Human subject experiments found crossings & bends to be most important ***wrt*** readability
  - Purchase et al.,1997
  - Ware et al 2002
  - Huang et al 2004

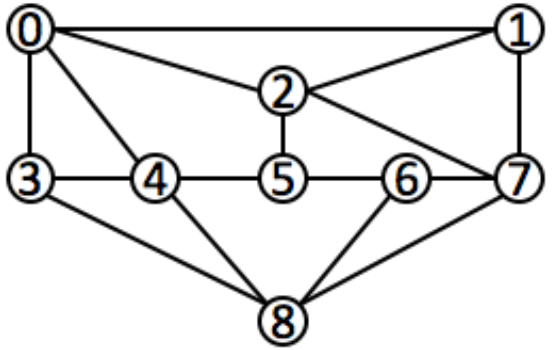
Different kinds of layouts



grid-based



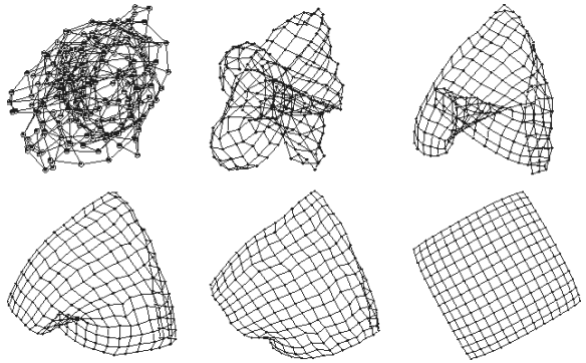
orthogonal



straight-line

Force-directed layouts

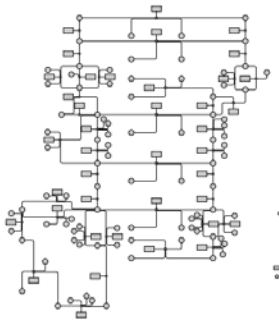
https://bl.ocks.org/mbostock/4062045



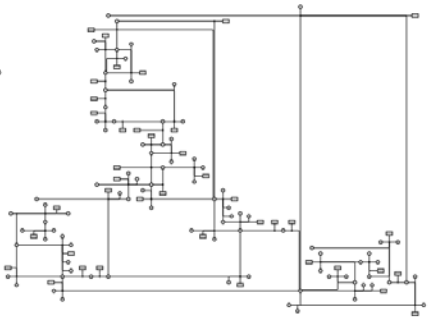
© Sander

Human-centered layout

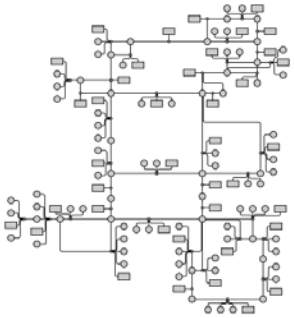
- User study
- Develop algorithm
- Evaluate algo-created layouts against human-created layouts



Human



algo-yFiles



algo-HOLA (new)

Kiefer et al. (InfoVis 2015).
HOLA: Human-like Orthogonal Network Layout

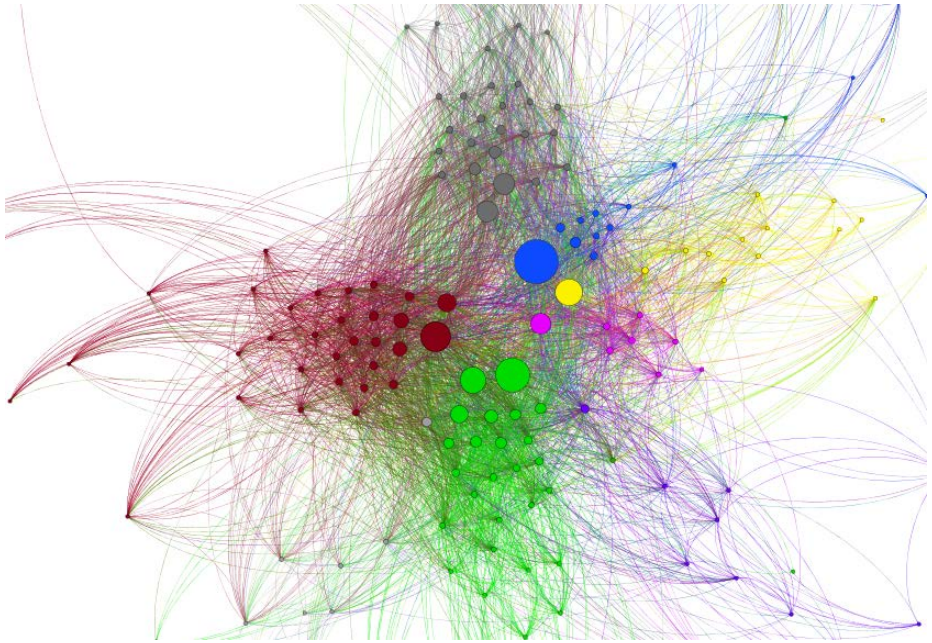
Scalability

Too many
nodes and/or edges

More Nodes, More Problems

- Tree breadth often grows exponentially
  - Quickly runs out of space, even with tidy layout
- Possible solutions
  - Filtering
  - Focus + Context
  - Scrolling/Panning
  - Zooming
  - Aggregation

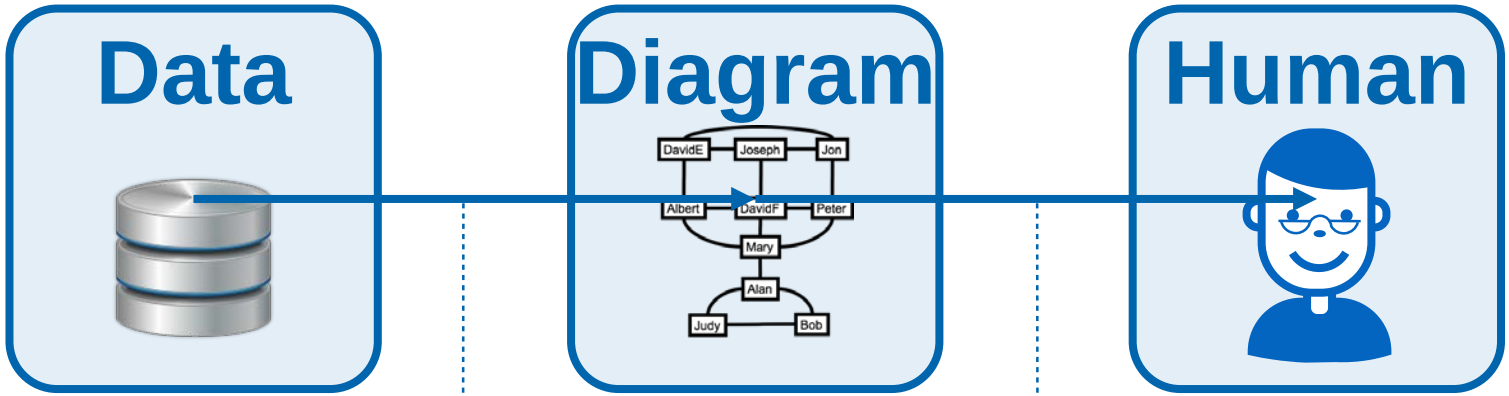
Showing all the data?



https://twitter.com/axelmaireder/media

Hairball

Measures: Faithfulness VS. Readability



Faithfulness measures how well the diagram represents the data.

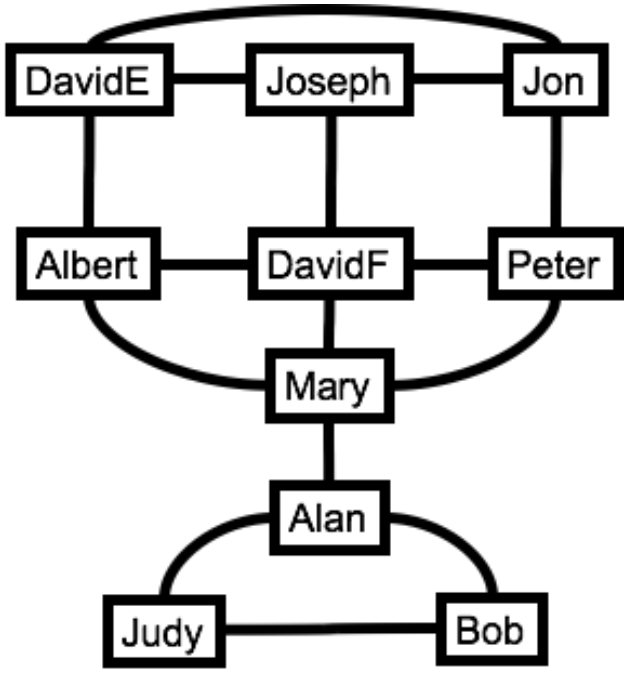
(a mathematical concept)

Readability measures how well the human understands the diagram.

(a psychological concept)

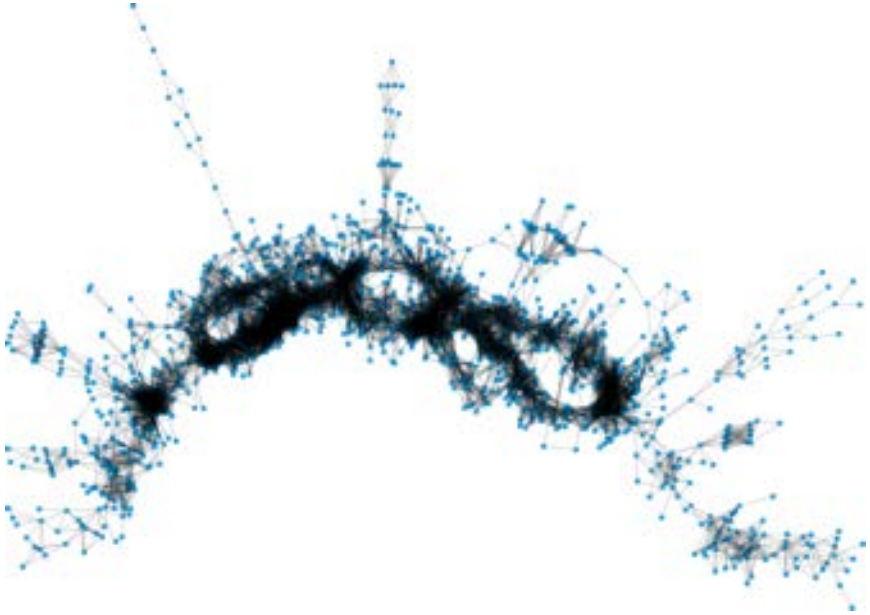
Quan Nguyen et al. (PacificVis 2013). On the faithfulness of graph visualizations

In small graphs: faithfulness usually given



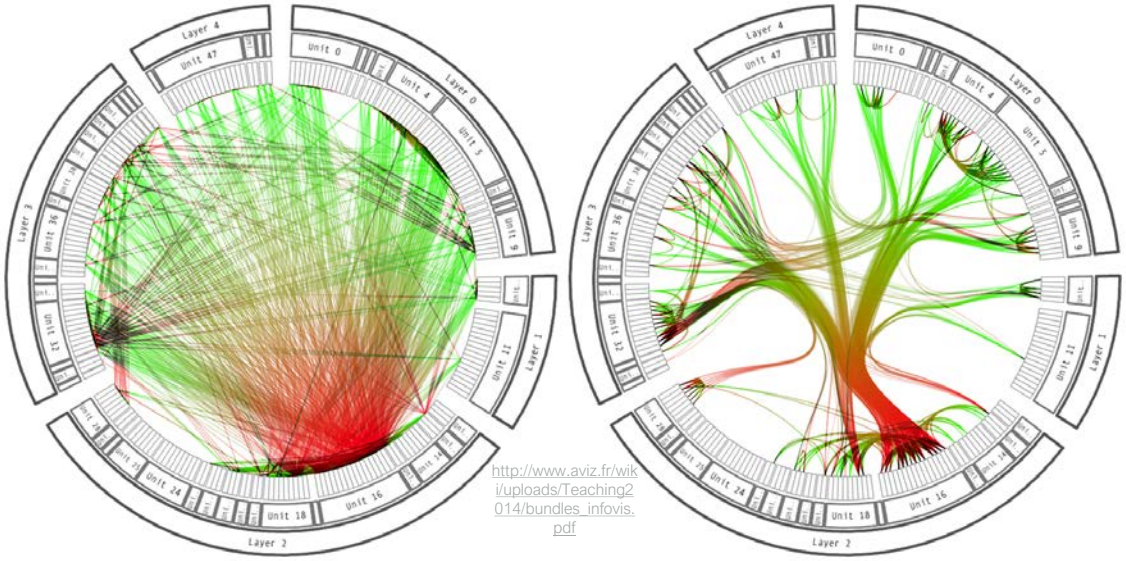
—> optimize readability

In large graphs: faithfulness usually not given



—> tradeoff between faithfulness & readability

Edge bundling

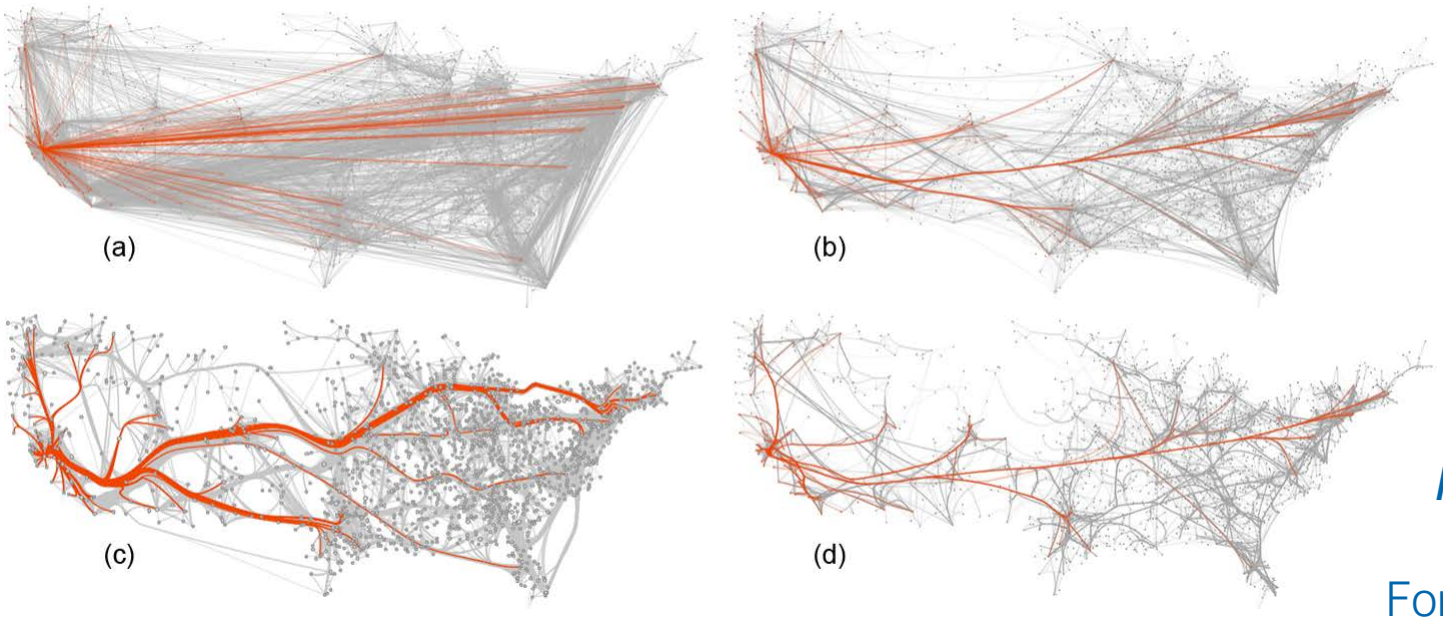


http://www.aviz.fr/wiki/uploads/Teaching2014/bundles_infovis.pdf

Sacrifice faithfulness, gain readability

Holten (InfoVis 2006).
Hierarchical Edge Bundles:
Visualization of Adjacency Relations in Hierarchical Data

Edge bundling

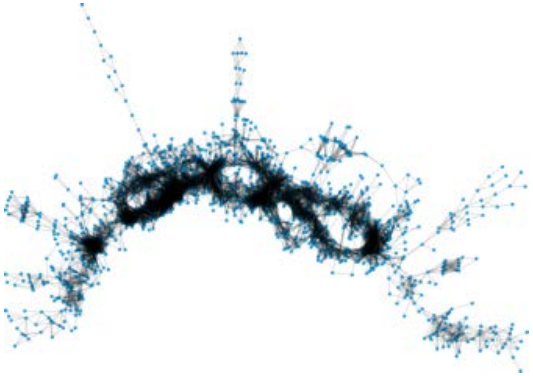


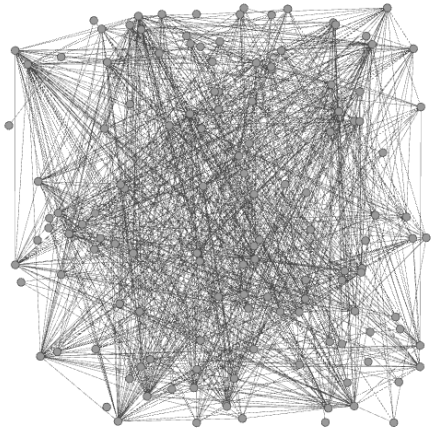
US migration graph

Holten & van Wijk (EuroVis 2009). Force-Directed Edge Bundling for Graph Visualization.

What about edge crossing?

- Some quality measures that work well for small graphs (such as edge crossing) seem to loose their importance the larger a graph gets

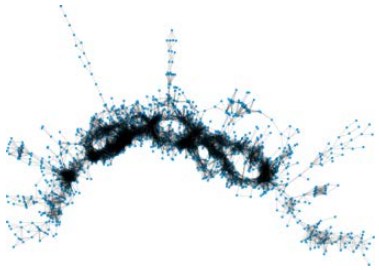




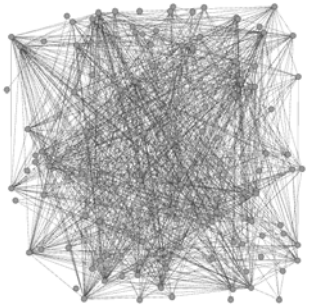
http://eppsnet.com/images/facebook-hairball.png

How many edge crossing do you see?

Instead: “Show me the structure”



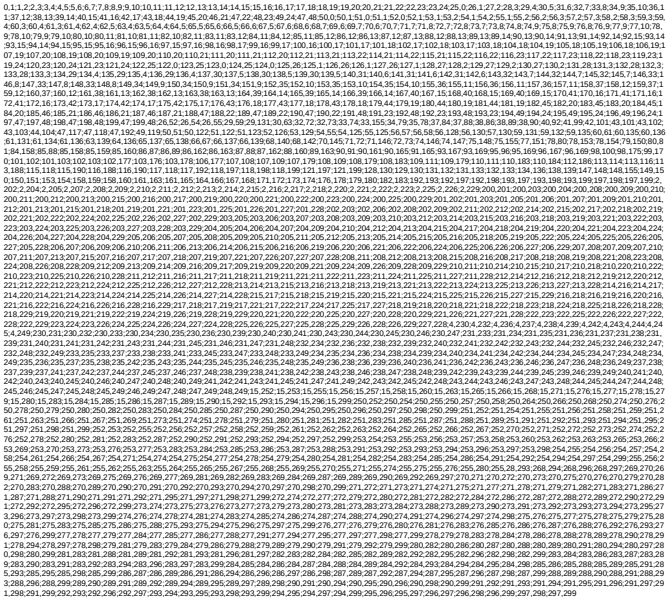
A



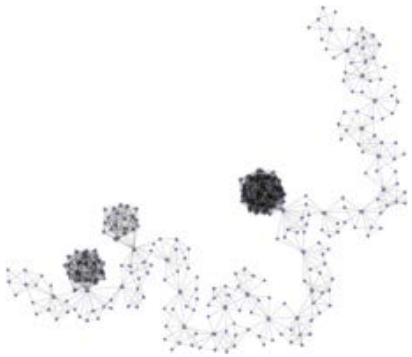
B

“Diagram A is better than diagram B because diagram A shows the structure of the graph, and diagram B does not show the structure.”

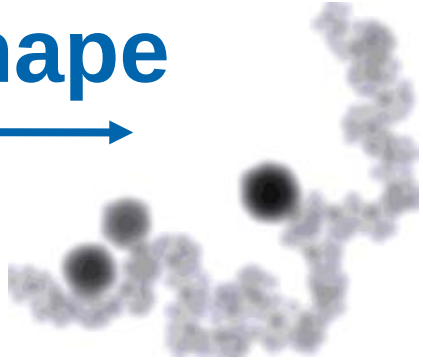
Shape



draw



shape

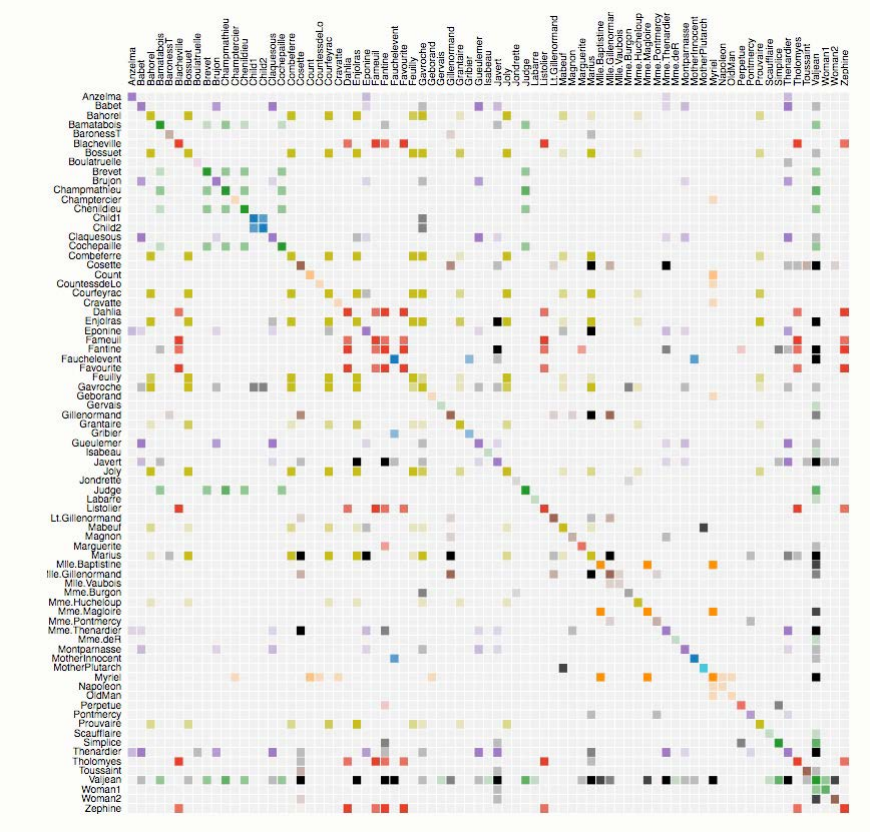


For a good quality drawing: the shape of the drawing should be faithful to the input graph.

Peter Eades et al. (Graph Drawing 2015). Shape-Based Quality Metrics for Large Graph Visualization.

Alternative representations

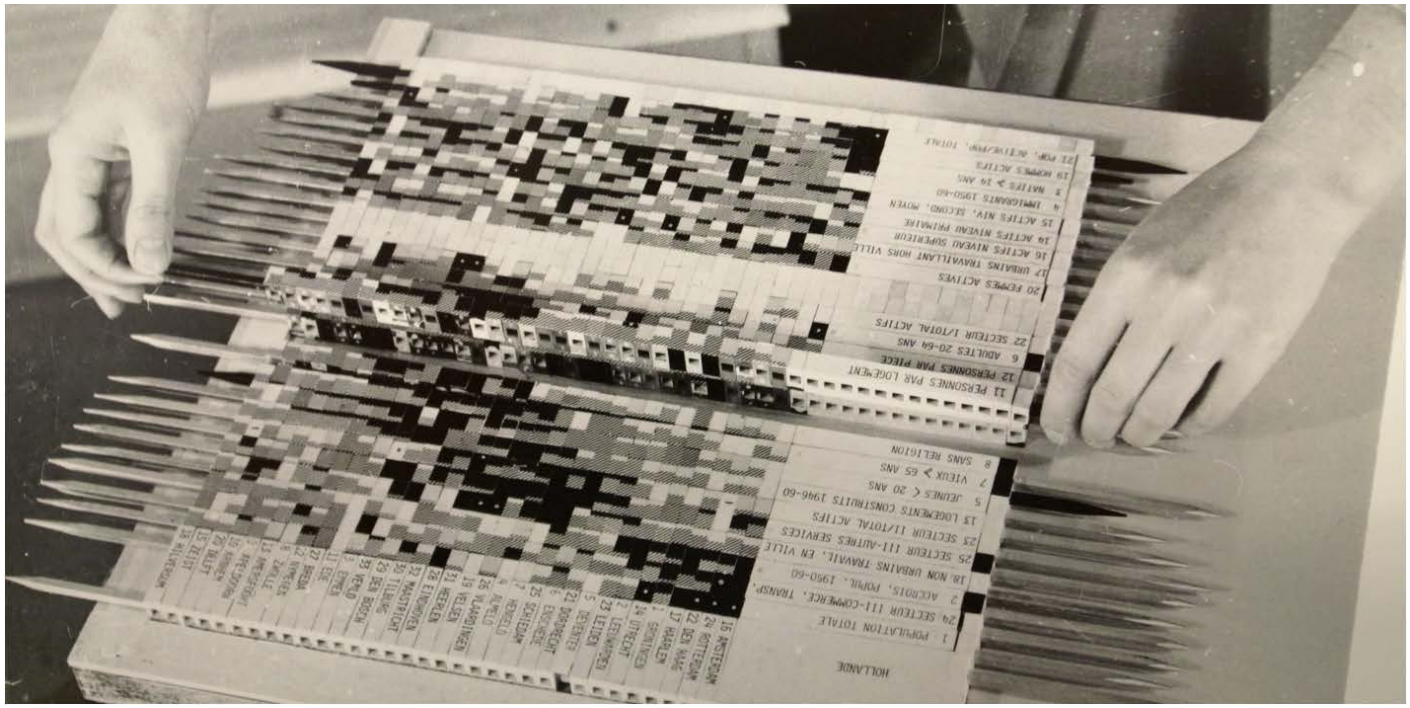
Adjacency Matrix



https://bost.ocks.org/mike/miserables/

Michael Behrisch, et al. (EuroVis STARs 2016). Matrix Reordering Methods for Table and Network Visualization.

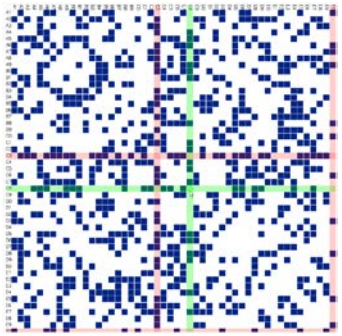
Adjacency Matrix (physical)

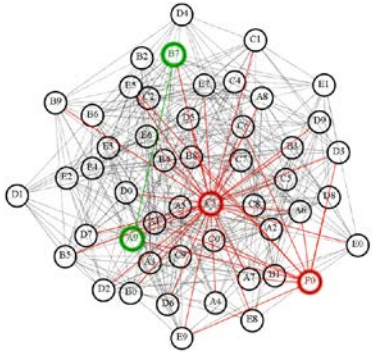


Jacques Bertin, 1968

http://www.aviz.fr/wiki/uploads/Bertifier/bertifier-authorversion.pdf

Matrix or Node-link?



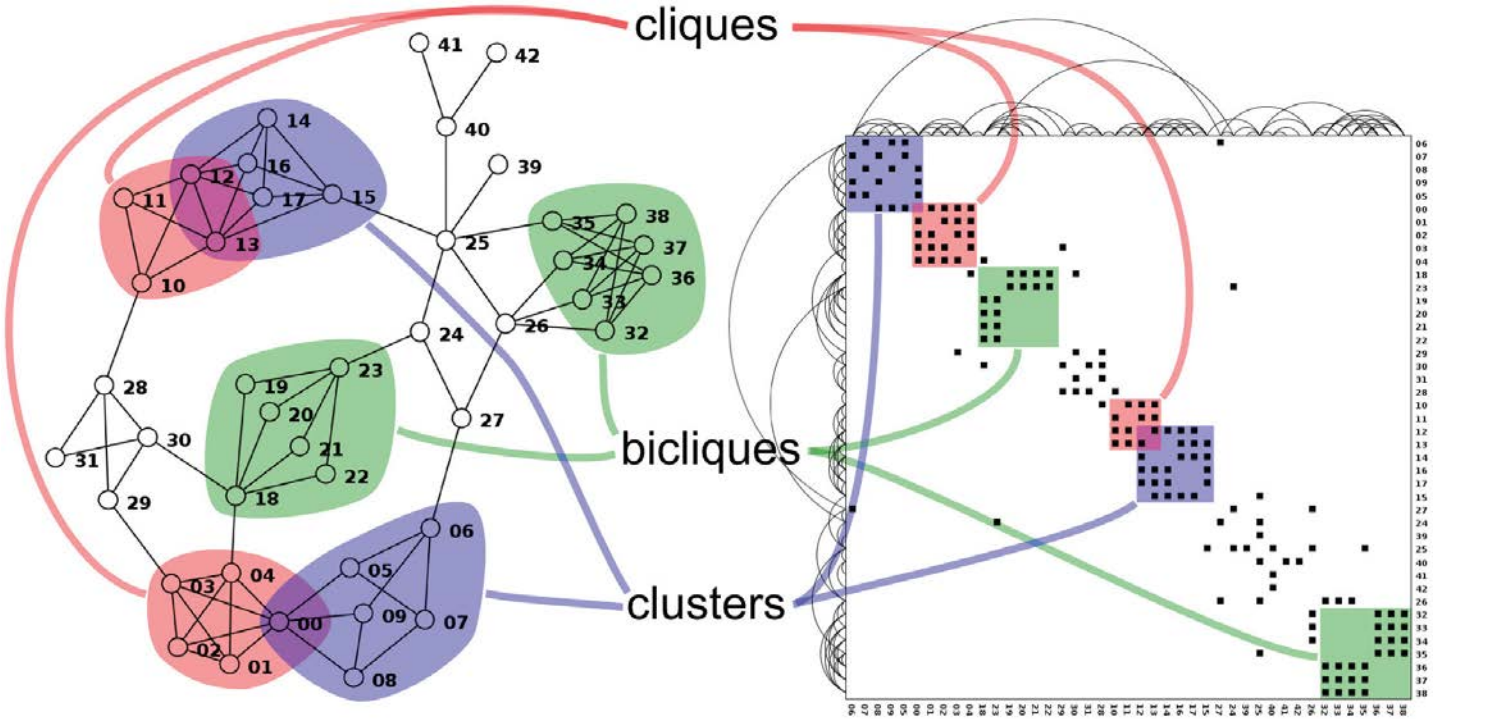


- Study
  - 36 users
  - 9 networks
  - 7 tasks —> measure time & errors
- Results
  - **Node-link** only for:
    - small graphs (~20 nodes)
    - path finding tasks
  - Else **Matrix**
- Limitations

Ghoniem et al. (InfoVis 2004). A Comparison of the Readability of Graphs Using Node-Link and Matrix-Based Representations.

Patterns in different views

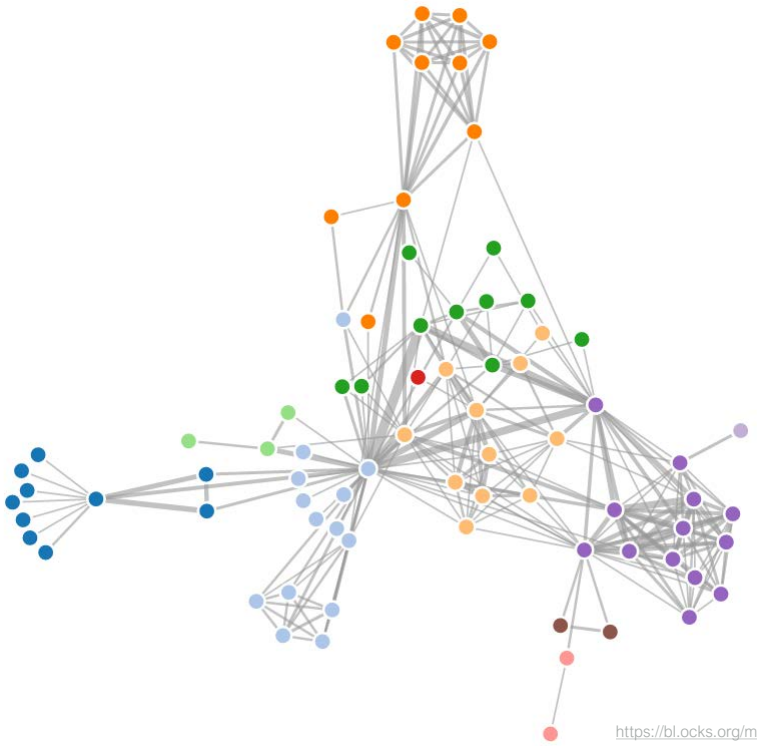
- Node-link views and Matrix views
- Both can show cliques and clusters



[McGuffin 12, Figure 6]

Additional encodings

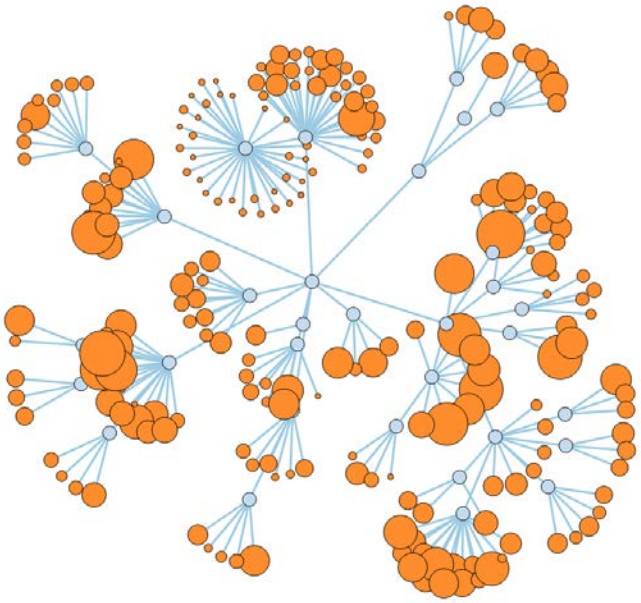
Color and width



Additional encodings

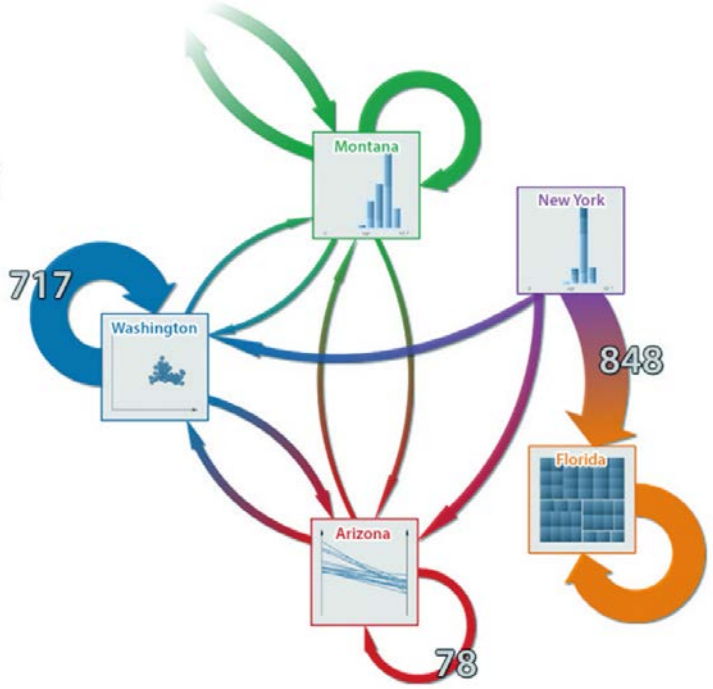
- Nodes, e.g. through color
- Edges, e.g. stroke-width

Size



http://mbostock.github.io/d3/talk/20111116/force-collapsible.html

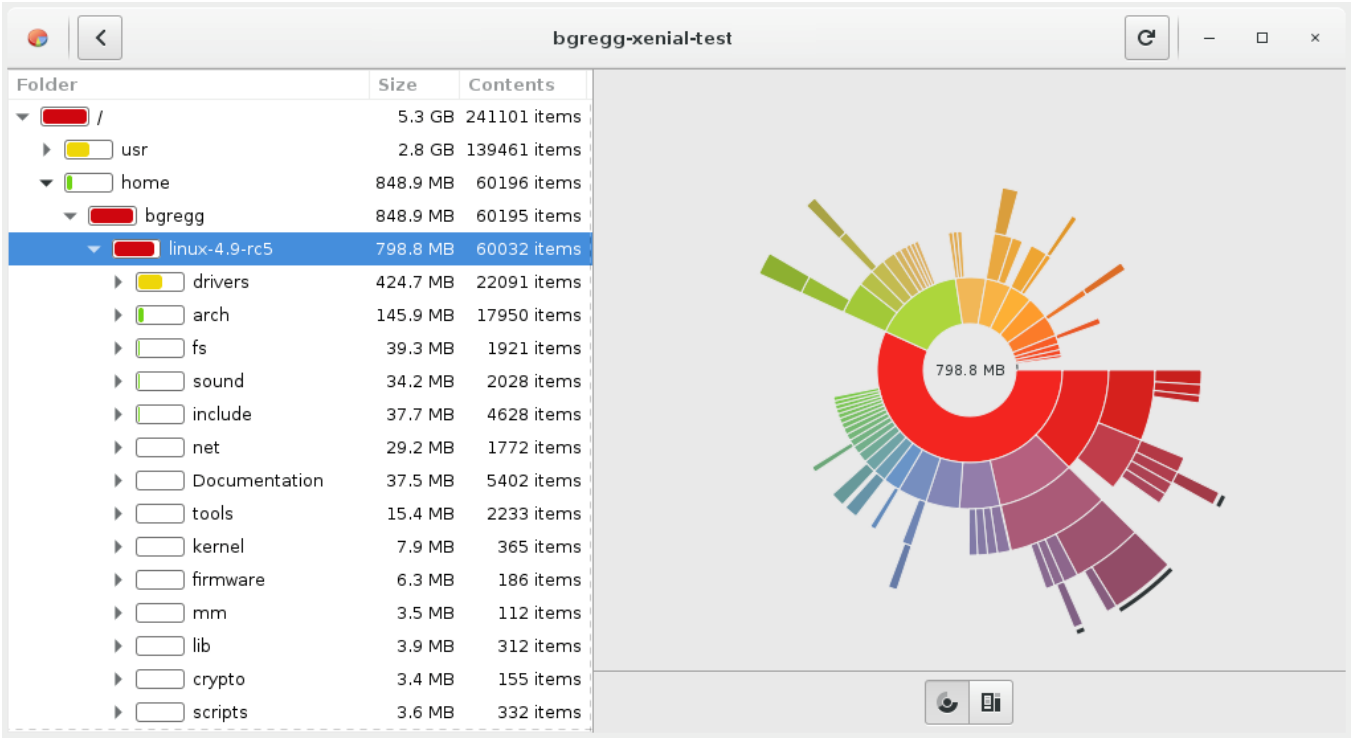
More complex data



Stef van den Elzen and Jarke J. van Wijk (InfoVis 2014)
Multivariate Network Exploration and Presentation:
From Detail to Overview via Selections and Aggregations

Combined methods

- Overcome limitations of individual method
- Example: Baobab disk space analyzer



Indented tree view

Sunburst view

Misc concerns

Animated Graphs

- static radial layouts: known algorithm
- dynamic: little previous work
  - DynaDAG [North, Graph Drawing 95]
  - DA-TU [Huang, Graph Drawing 98]
- minimize visual changes
- stay true to current dataset structure
- video

Animated Graphs

- polar interpolation

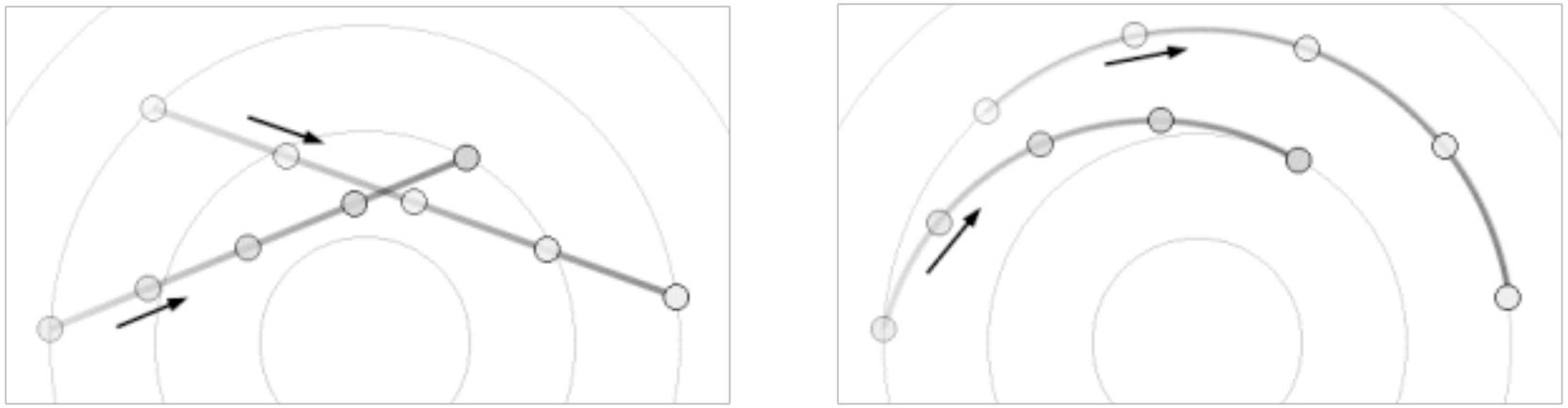


Figure 3. Interpolation in rectangular coordinates (left) can yield a confusing animation. Interpolation in polar coordinates (right) works better for radial layouts.

Yee et al. Animated Exploration of Graphs with Radial Layout

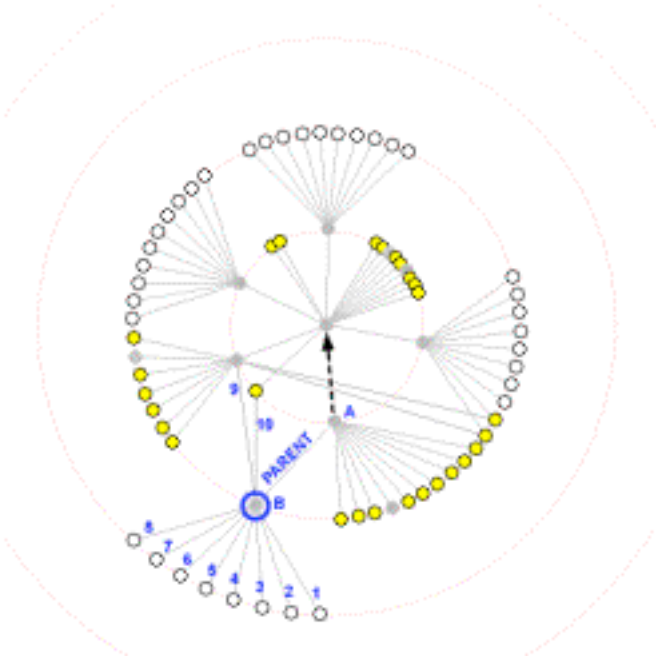
Animated Graphs

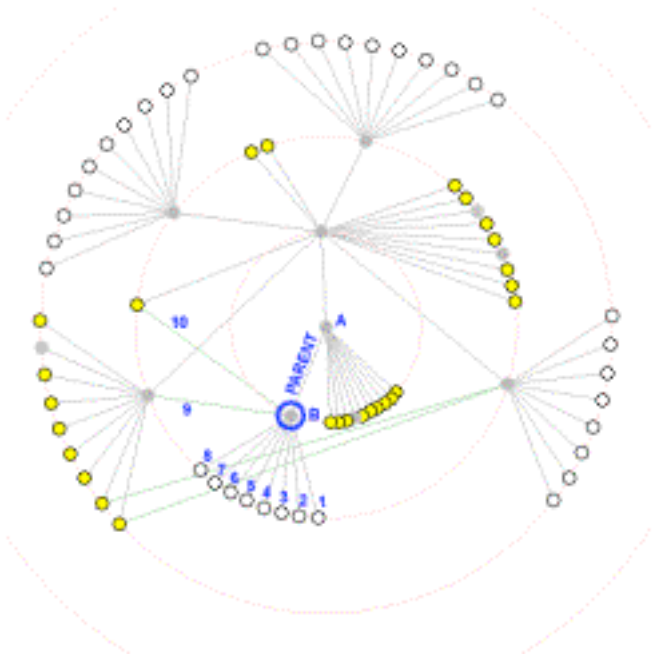
- maintain neighbor order

Yee et al. Animated Exploration of Graphs with Radial Layout

Animated Graphs

- maintain neighbor order





Yee et al. Animated Exploration of Graphs with Radial Layout

Small-World Networks

- high clustering, small path length
  - vs. random uniform distribution
- examples
  - social networks
  - movie actors
  - Web
  - software reverse engineering
- multiscale small-world networks
  - exploit these proper ties for better layout

On-line graph drawing

- required by ‘streaming data’
  - e.g. update graph with new/disappearing nodes and edges
- graph layout without knowing the final graph
- updates should be
  - visually easy to follow (minimal)
  - in real-time

Overview

- Spatial channel
  - Spatial attributes / keys
  - quantitative vs. categorical attributes
  - Keys: the importance of ordering
    - list (1D) vs. matrix (2D) vs. partition / subdivide (multiple D)
  - Spatial layout
    - rectilinear
    - parallel
    - radial
  - Spacefilling
  - Dense
- Linemarks
  - Connection
  - Containment
- Using color