Graphs & Trees

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Slides acknowledgements: Luana Micallef, and Alex Bigelow (Univ. Utah)

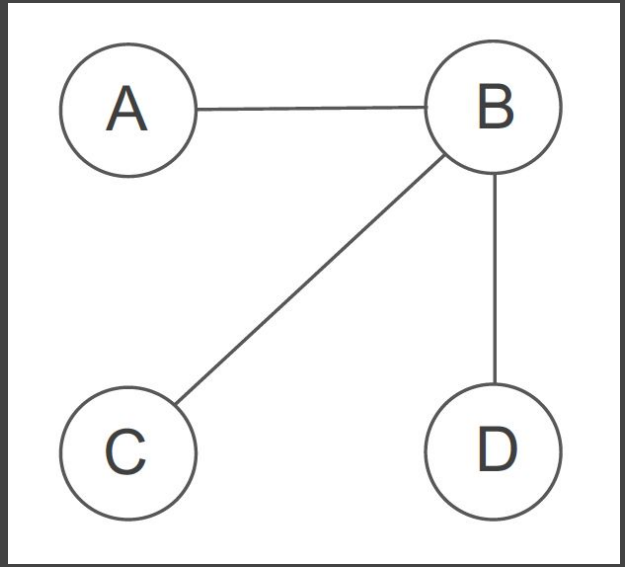
What is a graph?

A graph G consists of a collection of vertices (or nodes) V, and a set of edges E consisting of vertex pairs.

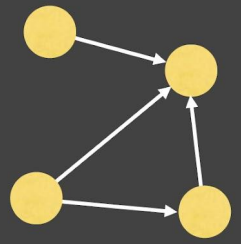
G = (V, E)

where V = { A, B, C, D }

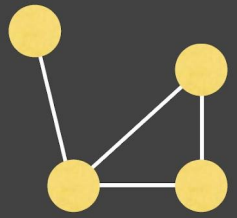
E = { (A, B), (B, C), (B, D) }



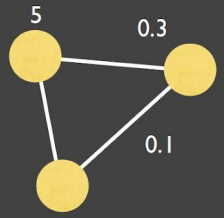
A bunch of definitions



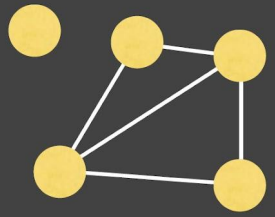
A directed graph



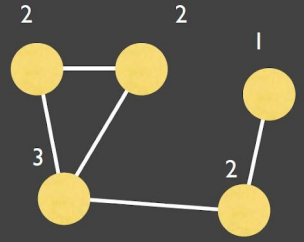
An undirected graph



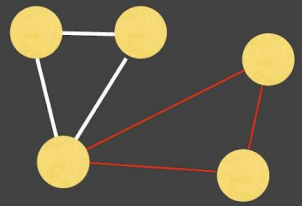
Weighted



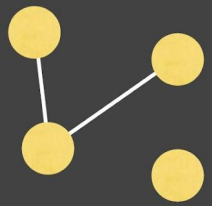
Unconnected



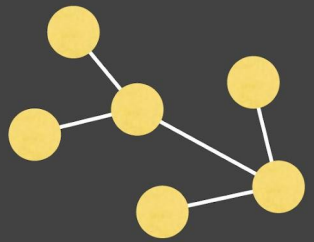
Node degrees



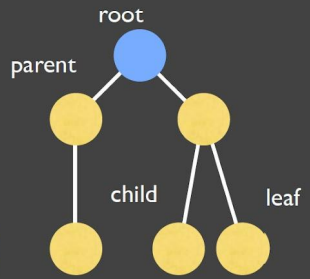
A cycle



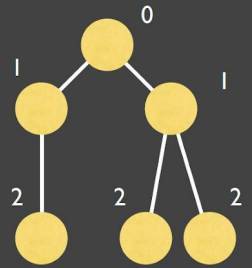
An acyclic graph



A connected acyclic graph,
a.k.a. a **tree**

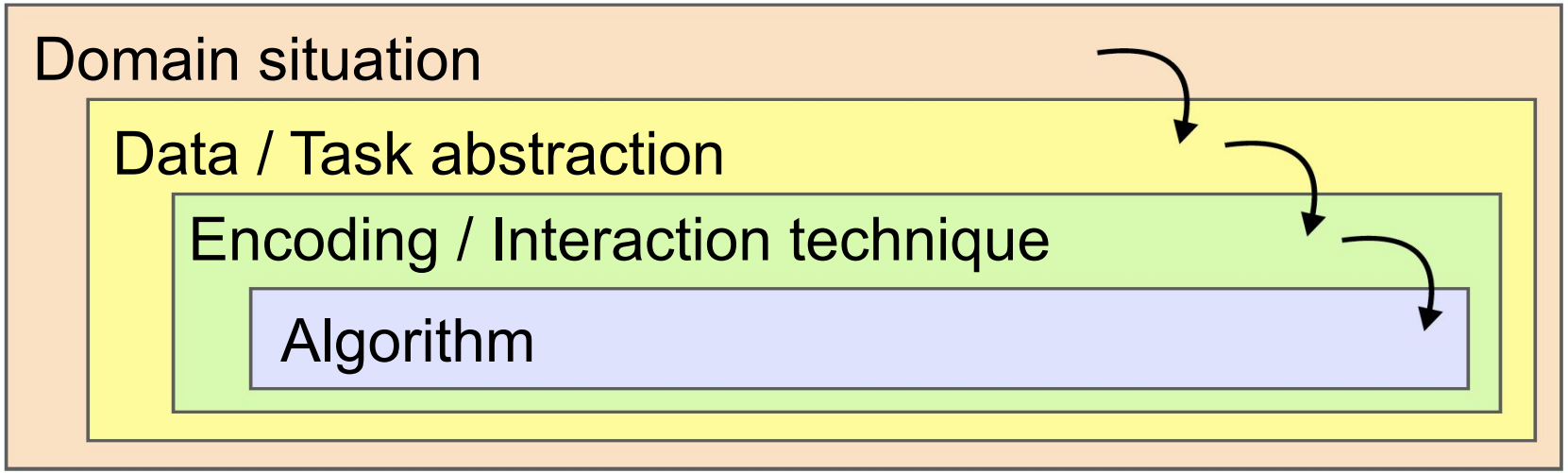


A rooted tree
or hierarchy



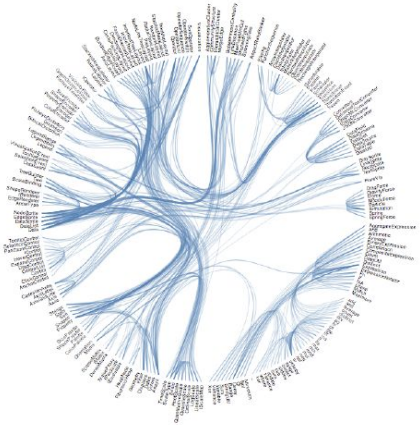
Node depths

Data abstraction: Graph / Tree

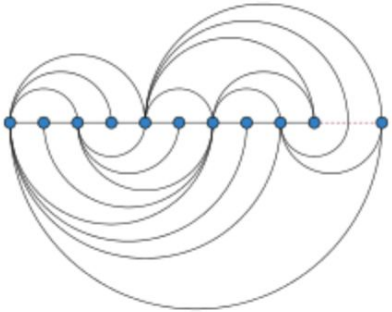


Node-link diagrams

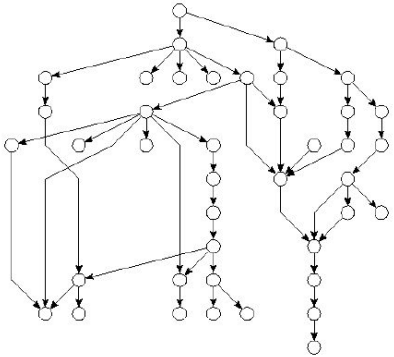
force-directed layout



circular layout



linear layout

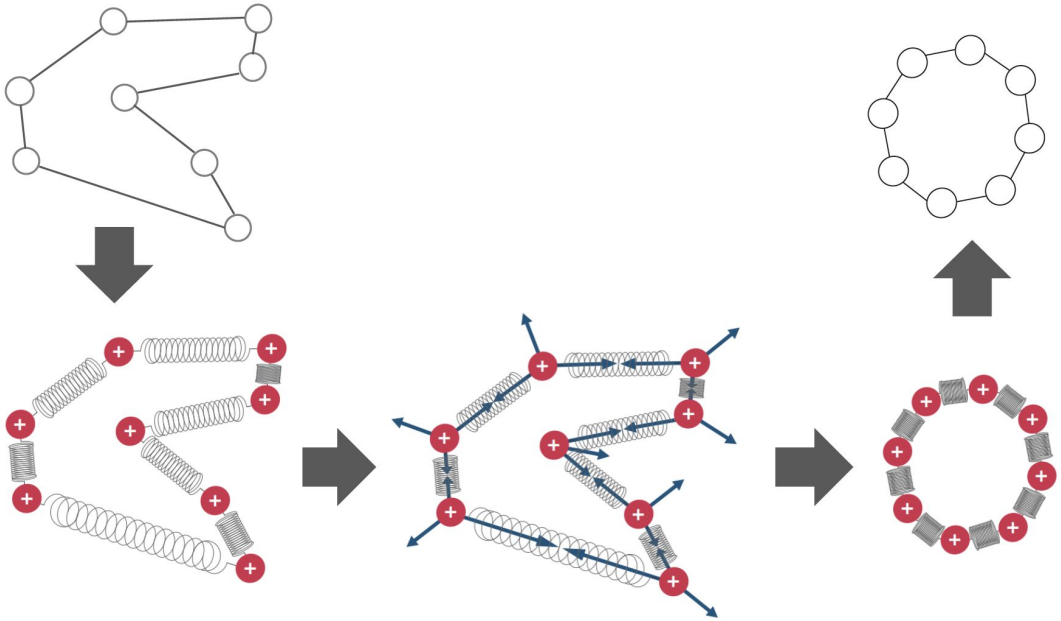


layered layout

Force-directed layout

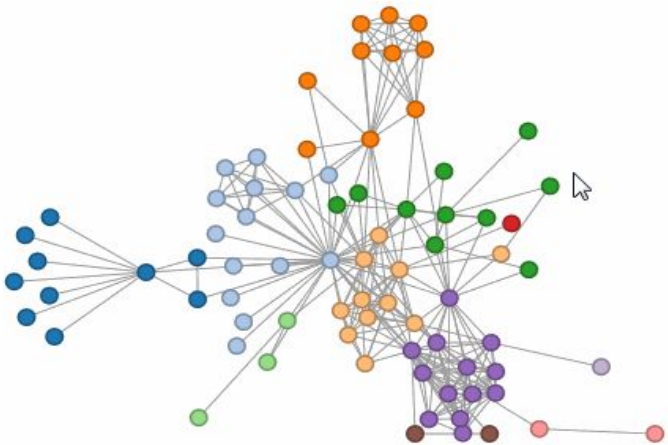
Physics model

- Edges = springs
- Nodes = repulsive particles



Force-directed layout

+ Flexible and aesthetic layout;
+ Able to add custom forces;
- Difficult to find the same node twice.



https://beta.observablehq.com/@mbostock/d3-force-directed-graph

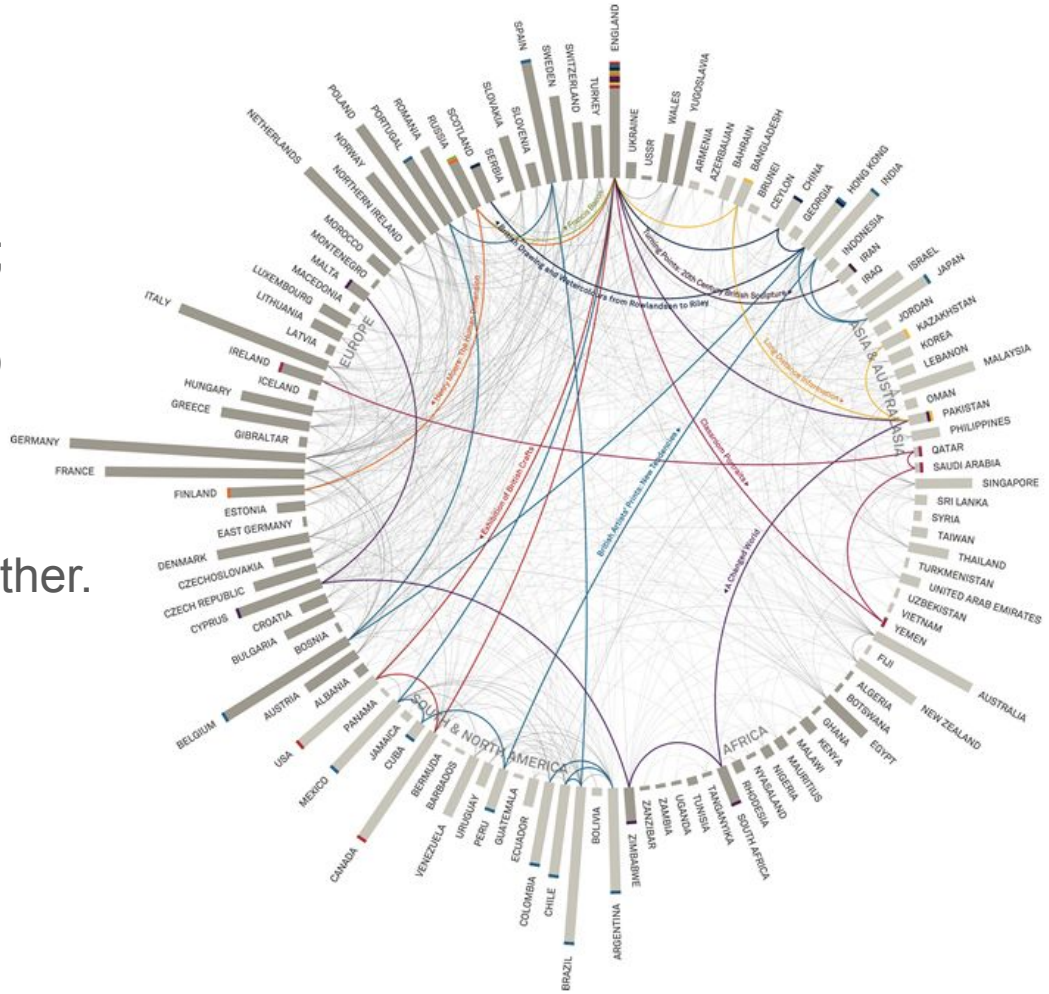
Circular layout

Able to show various node attributes;

Nodes should be ordered carefully to

reduce edge crossings and;

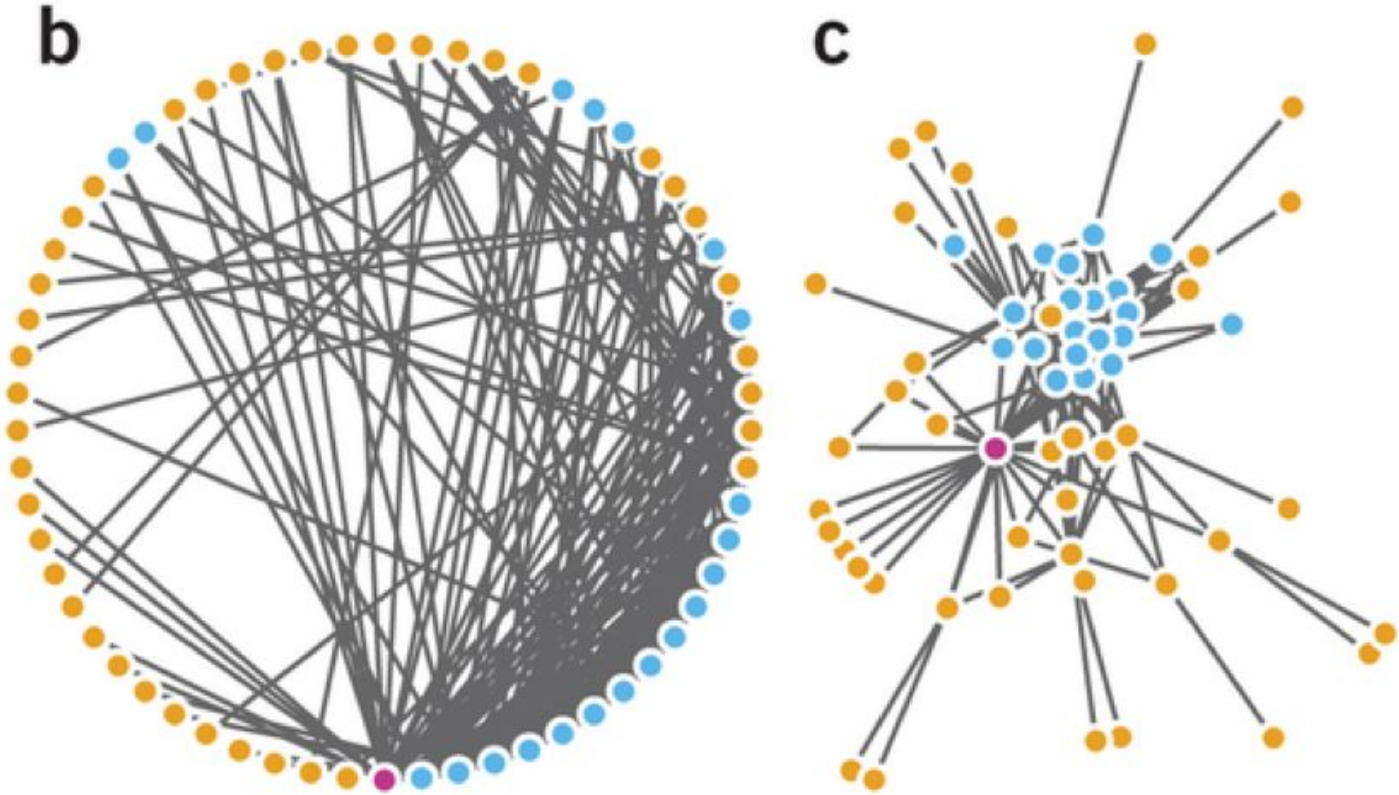
place adjacent nodes close together.



http://www.keepthinking.it/media/w720/project_details/bcva_wc_wheel.png

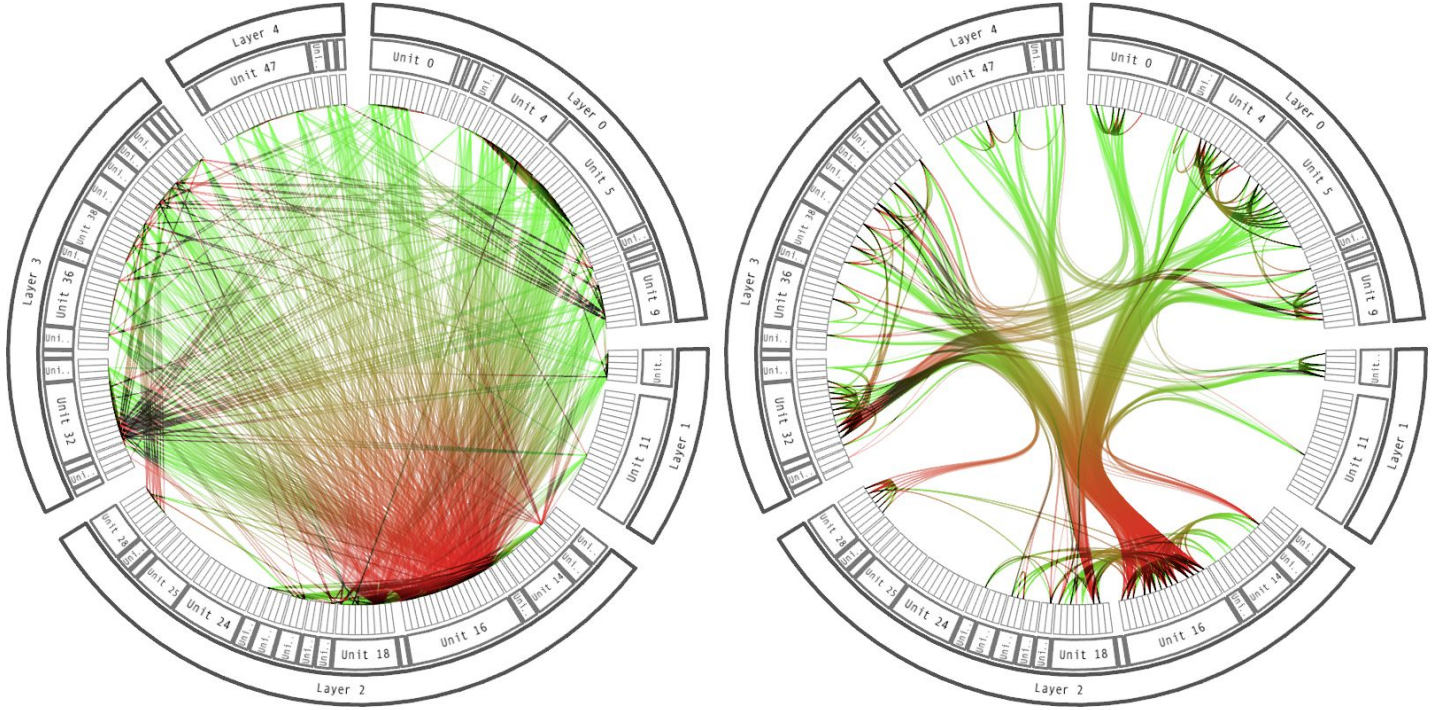
https://medium.com/kineviz-blog/visualizing-node-link-graphs-84a40a9b2fcc

Force-directed layout: higher data-ink ratio; easier to find clusters.



Circular layout

Adjacent edges can be bundled to reduce visual clutter.



[Holten, 2006]

http://storiesthroughdata.blogs.lincoln.ac.uk/2012/02/12/network-and-relationship-visualisation/

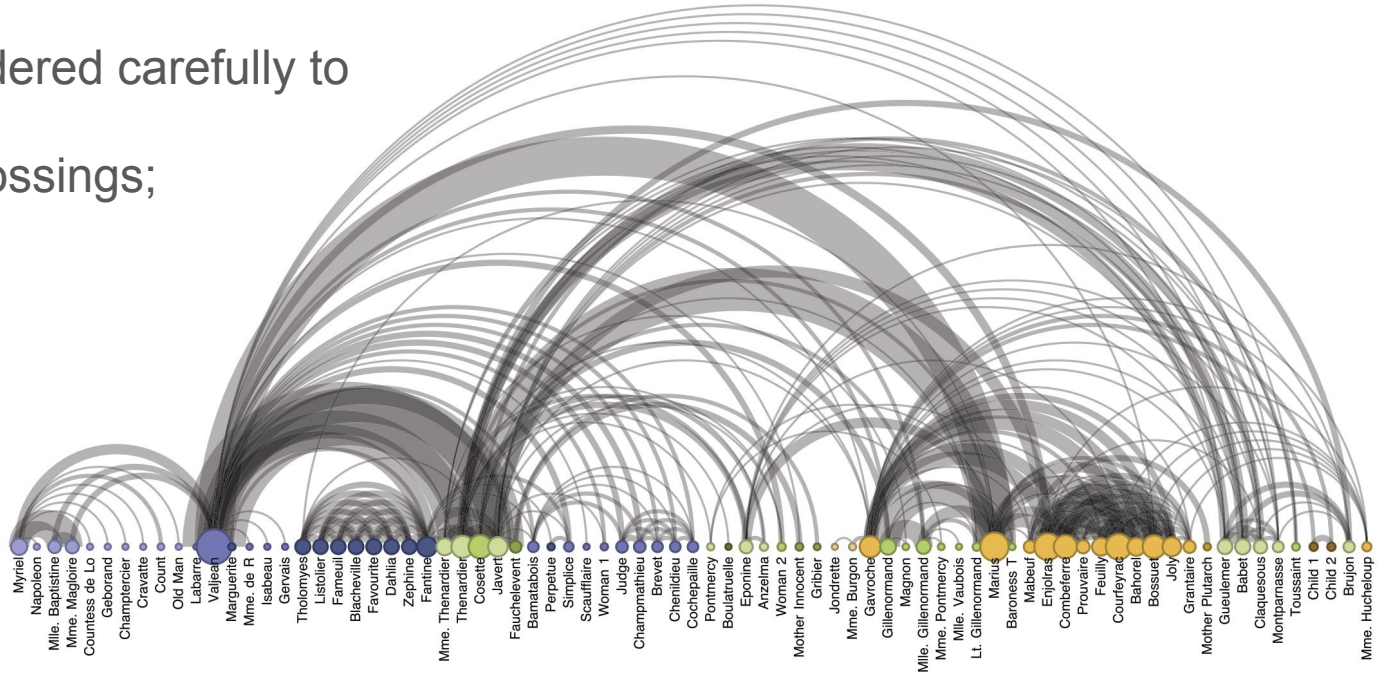
Linear layout (arc diagrams)

Able to show various node attributes;

Nodes should be ordered carefully to

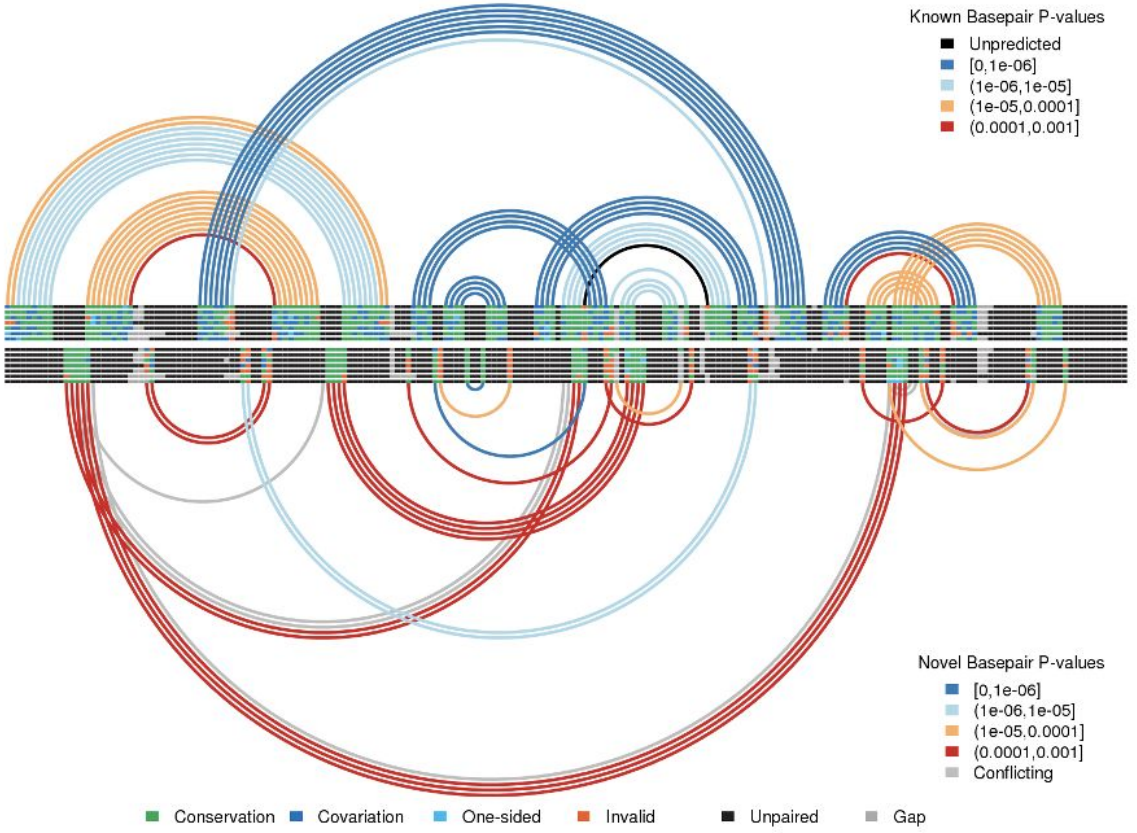
reduce edge crossings;

reveal clusters.

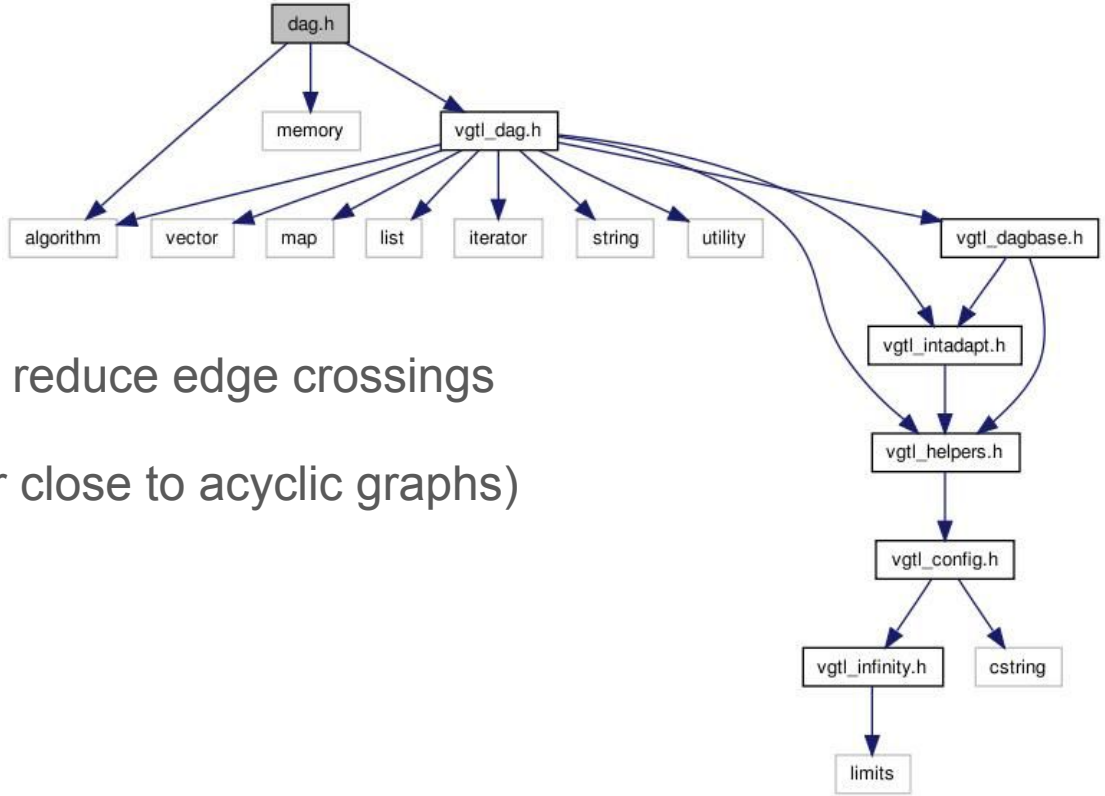


http://www.e-rna.org/r-chie/images/overlapcov.png

Linear layout (arc diagrams)



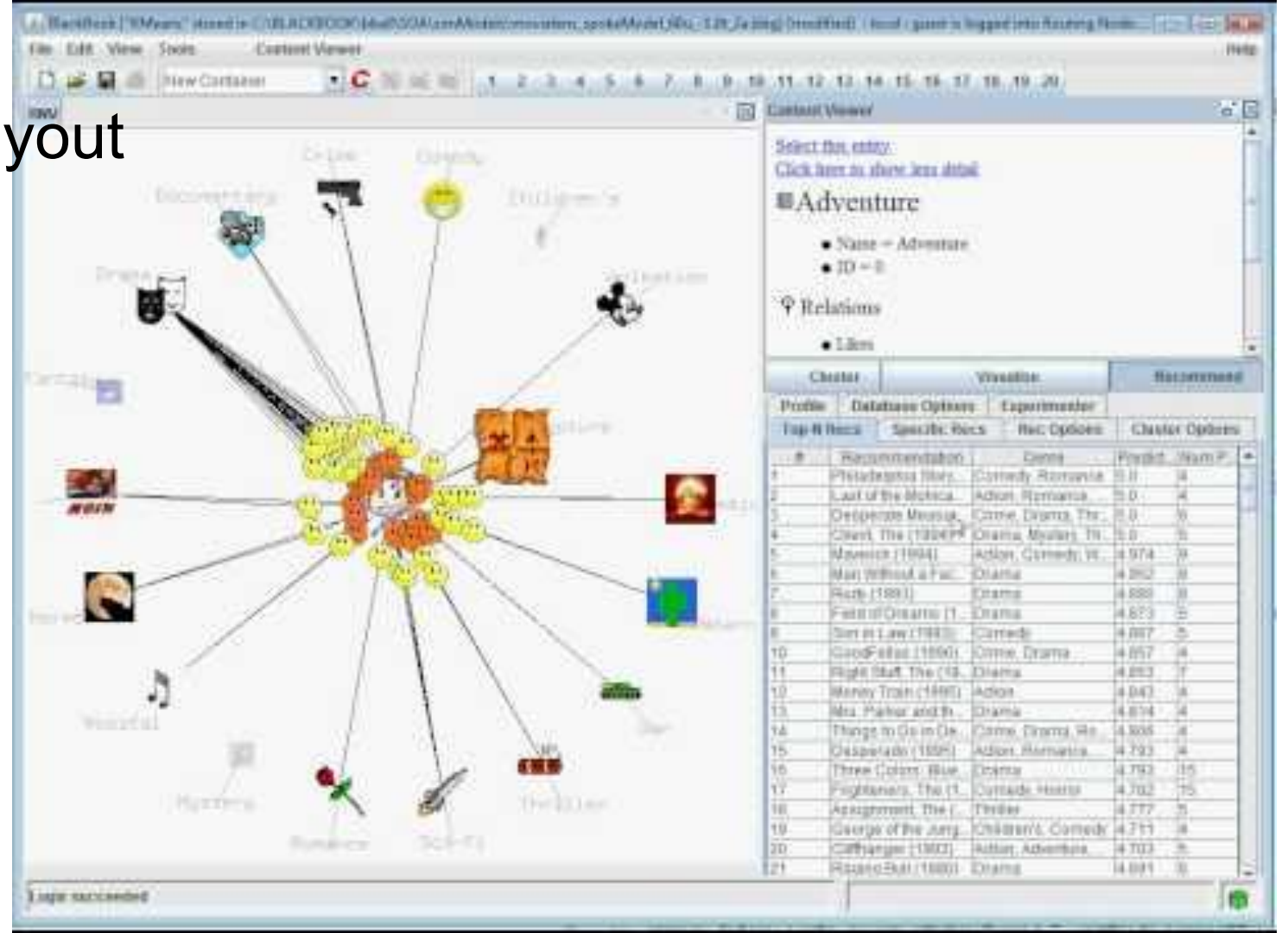
Layered layout



Nodes on one layer are ordered to reduce edge crossings

Best for directed acyclic graphs (or close to acyclic graphs)

Layered layout

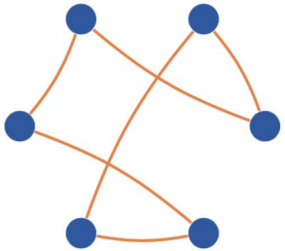


[PeerChooser, 2008]

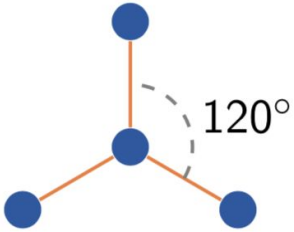
Purchase, H. C. Metrics for graph drawing aesthetics. *Journal of Visual Languages & Computing*, *2002*.
Bennett, Chris, et al. The aesthetics of graph visualization. *Computational aesthetics* 2007.

A few aesthetic criteria of graph layout

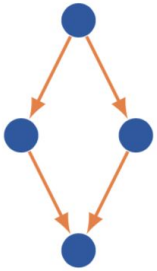
minimise
edge bends



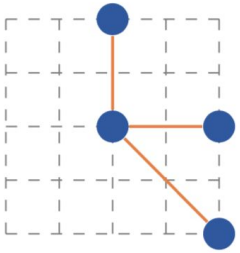
minimise
edge crosses



maximise
smallest angles



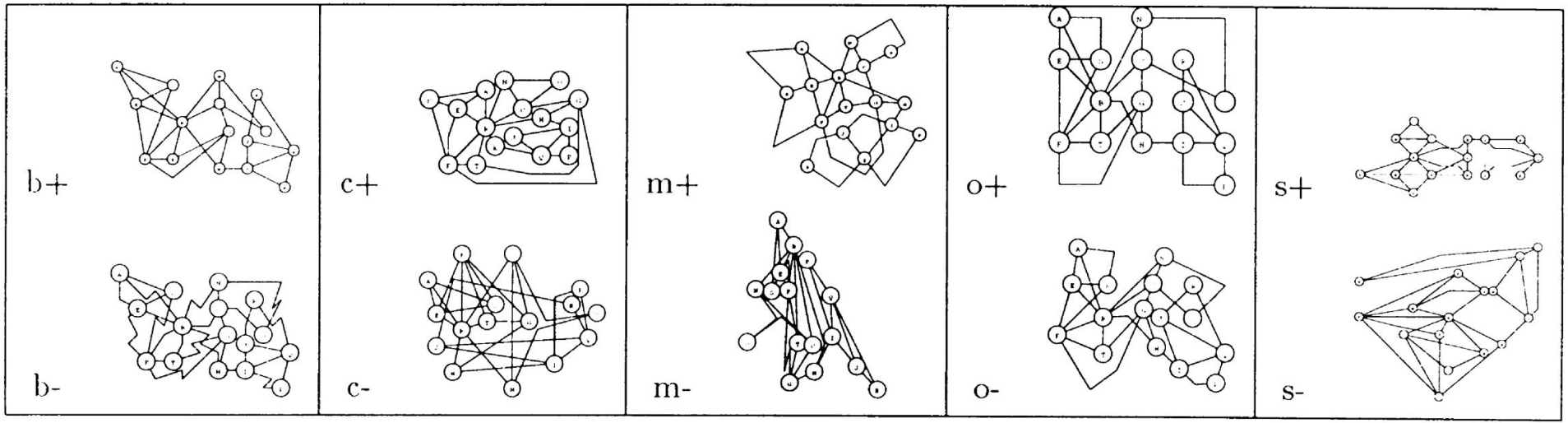
symmetry



orthogonality

Purchase, Helen C. Effective information visualisation: a study of graph drawing aesthetics and algorithms. *Interacting with computers* 13.2 (2000): 147-162.

A controlled experiment



Min. edge bends | Min. edge crosses | Max. min. angles | orthogonality | symmetry

A controlled experiment

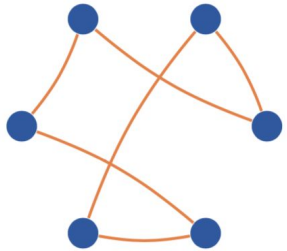
How long is **the shortest path** between two given nodes?

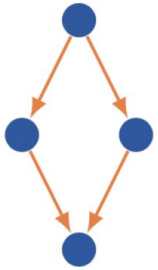
What is **the minimum number of nodes that must be removed** to **disconnect** two given nodes such that there is no path between them?

What is **the minimum number of edges that must be removed** to **disconnect** two given nodes such that there is no path between them?

A controlled experiment -- Results

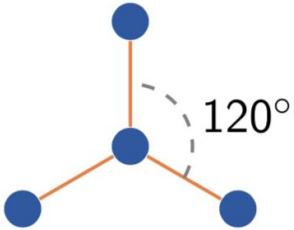
Strong:

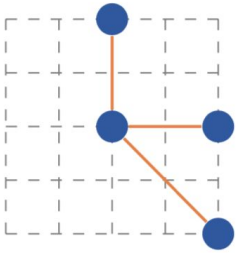




Weak:

Little effect:



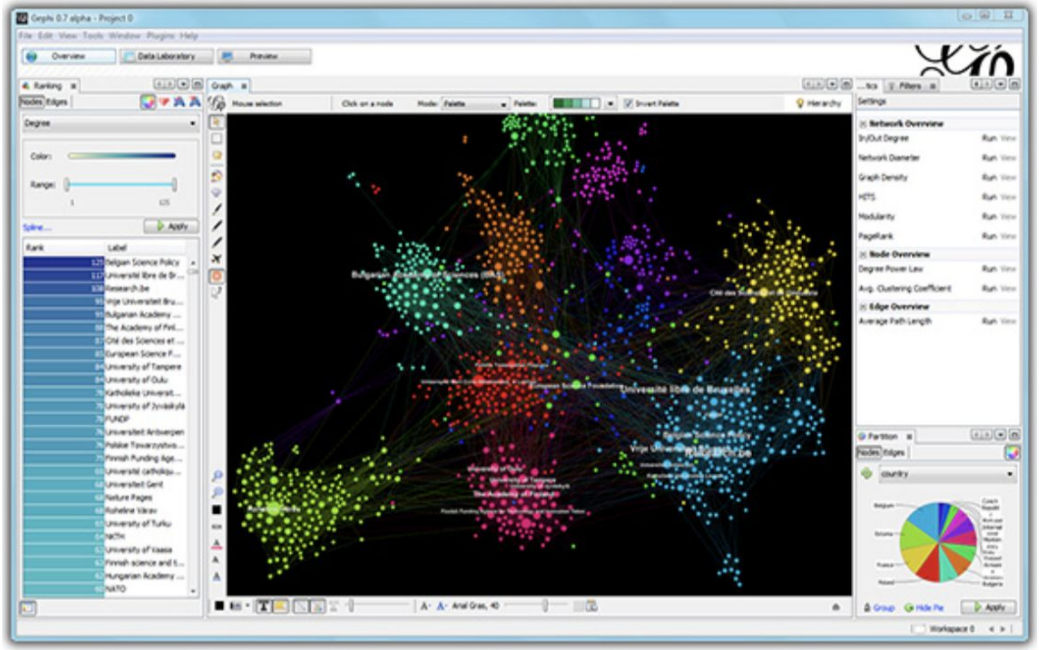


The Open Graph Viz Platform

Gephi is the leading visualization and exploration software for all kinds of graphs and networks. Gephi is open-source and free.

Runs on Windows, Mac OS X and Linux.

Learn More on Gephi Platform »



Download FREE
Gephi 0.9.2

Release Notes | System Requirements

- Features
- Quick start
- Screenshots
- Videos

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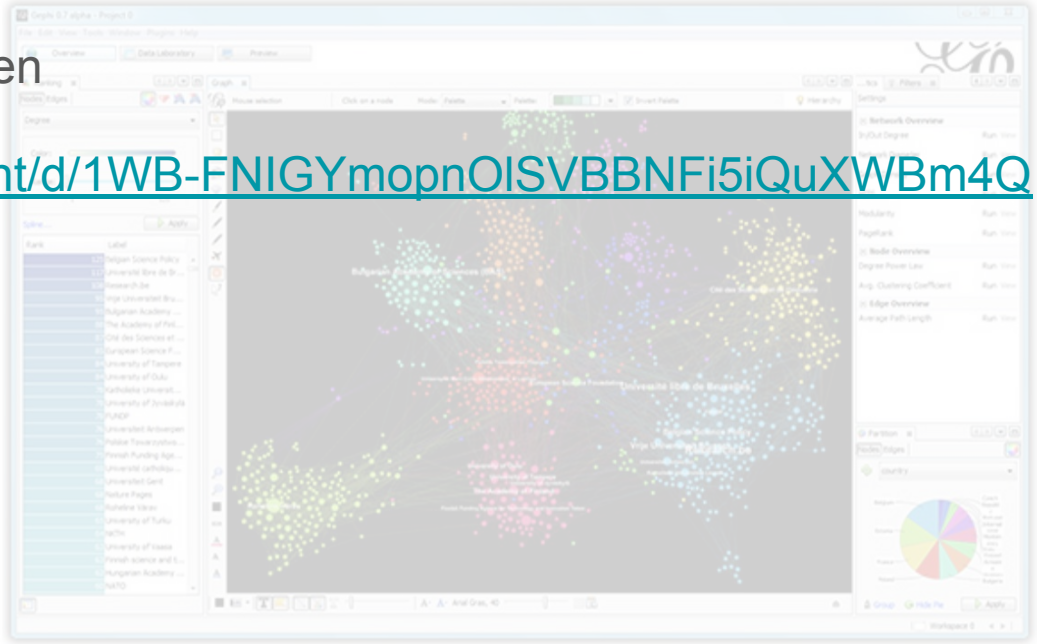
Donate

Gephi tutorial

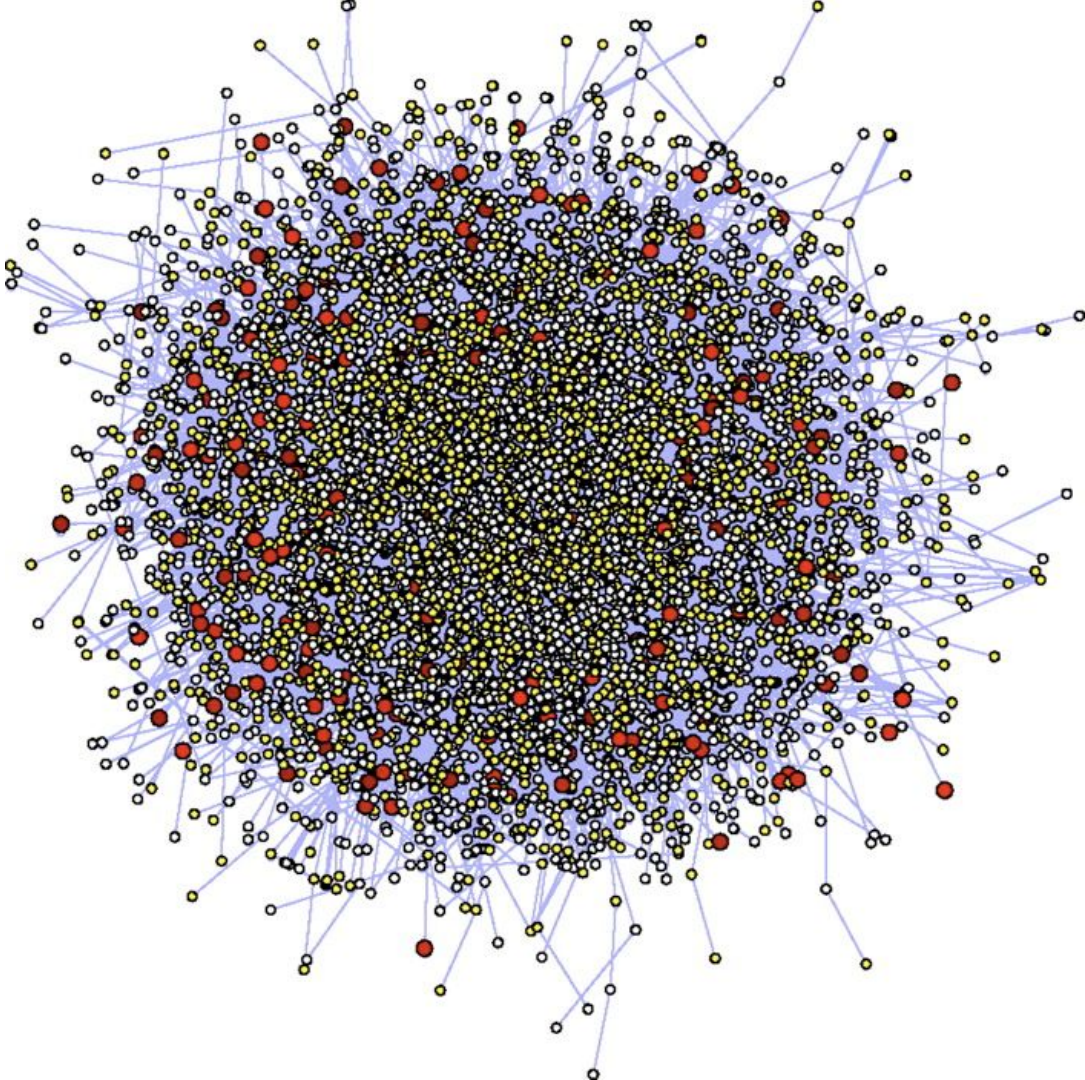
by Francisco Gutiérrez, KU Leuven

https://docs.google.com/document/d/1WB-FNIGYmopnOlSVBBNFi5iQuXWBm4QkfBPXjsh9mjk/edit?usp=sharing

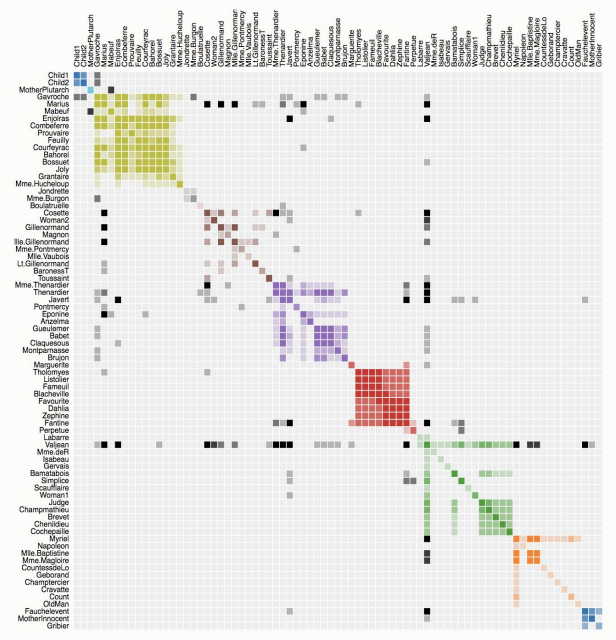


Node-link diagrams

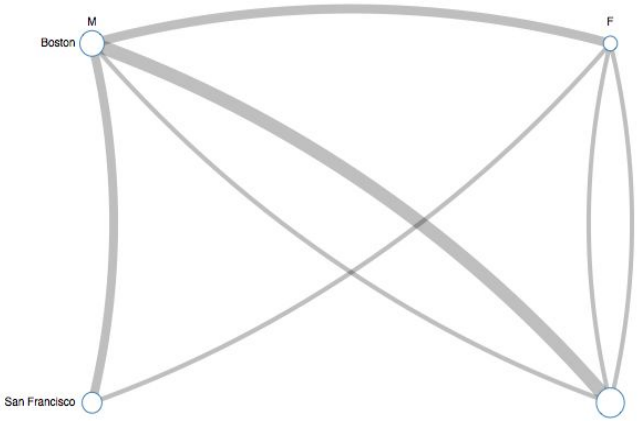
- \+ Intuitive
- \+ Can show overall structure, clusters, and paths
- \+ Flexible, many variations
- \- Not good for dense graphs
  - Hairball problem



Solutions for dense graphs

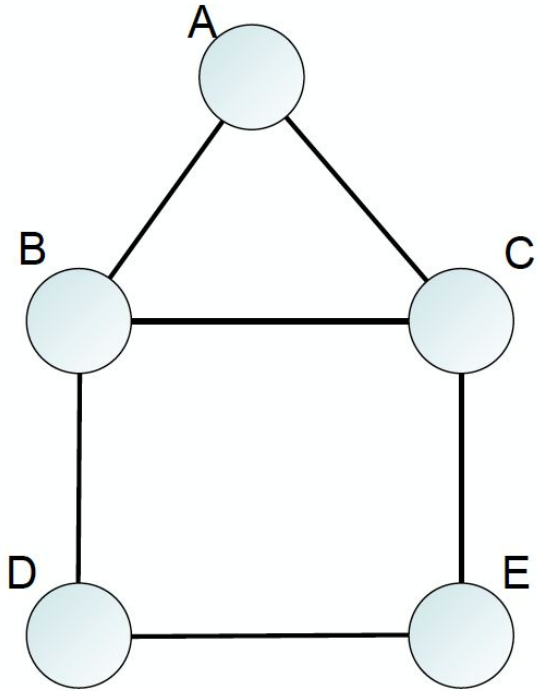


Adjacency matrix



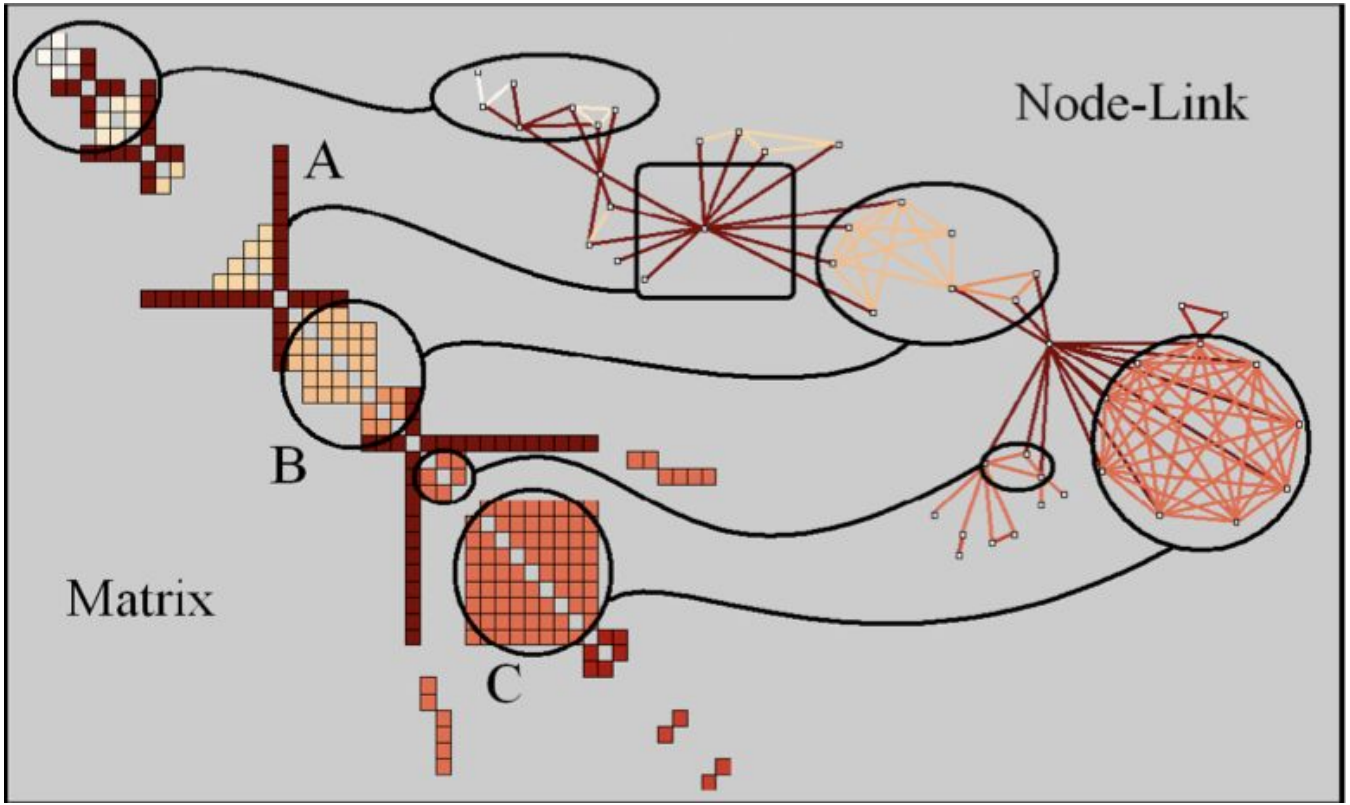
PivotGraph

Adjacency matrix

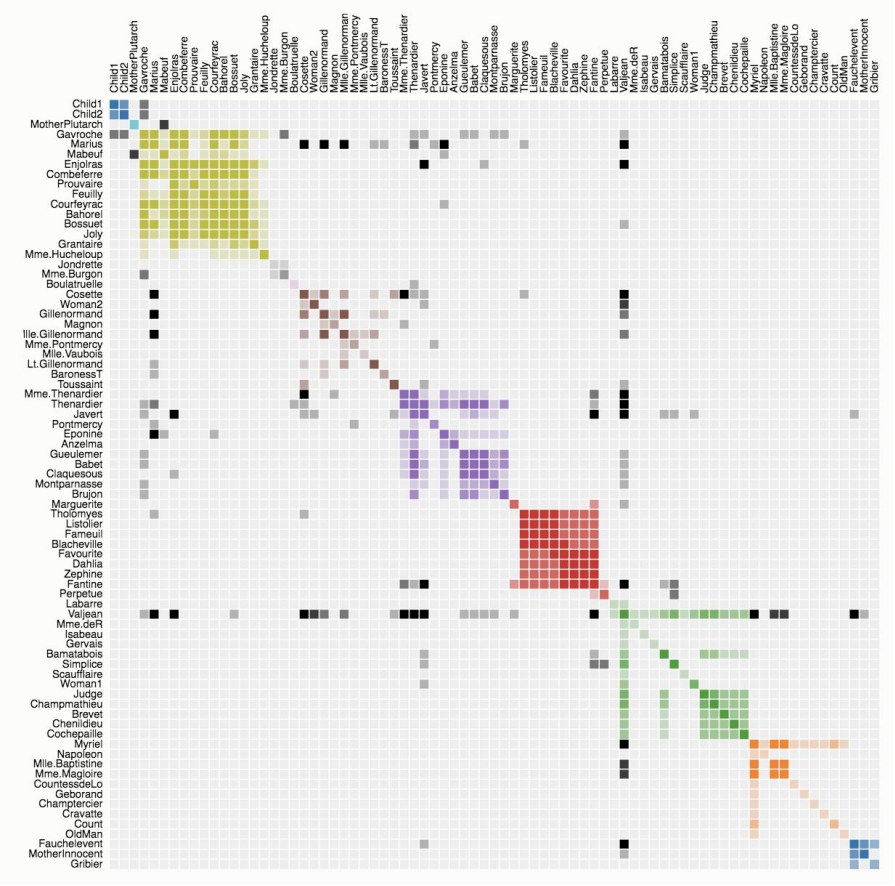


	A	B	C	D	E
A		■	■		
B	■		■	■	
C	■	■			■
D		■			■
E			■	■	

Patterns in adjacency matrix



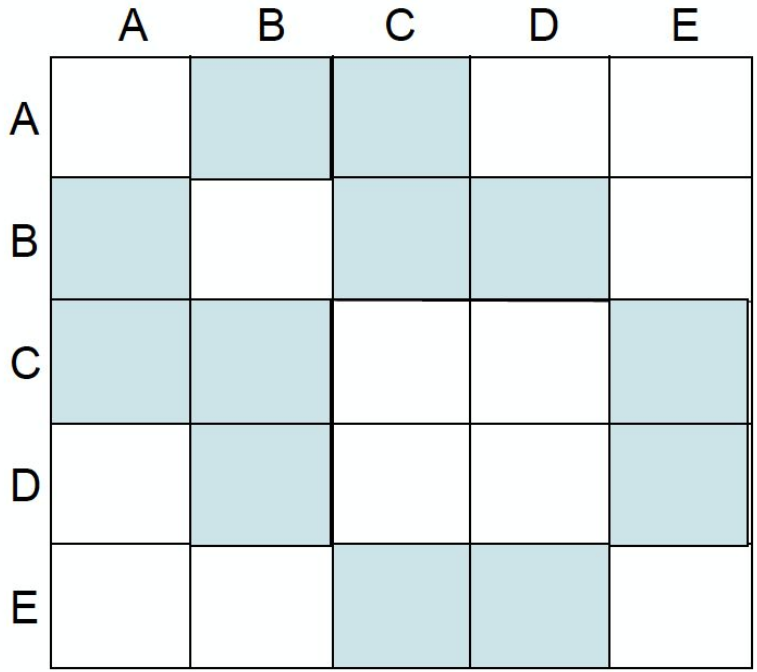
Adjacency matrix



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

Adjacency matrix

+ Great for dense graphs
+ Visually scalable
+ Can spot clusters
- Row order affects what you can see
- Abstract visualization
- Path-following is difficult

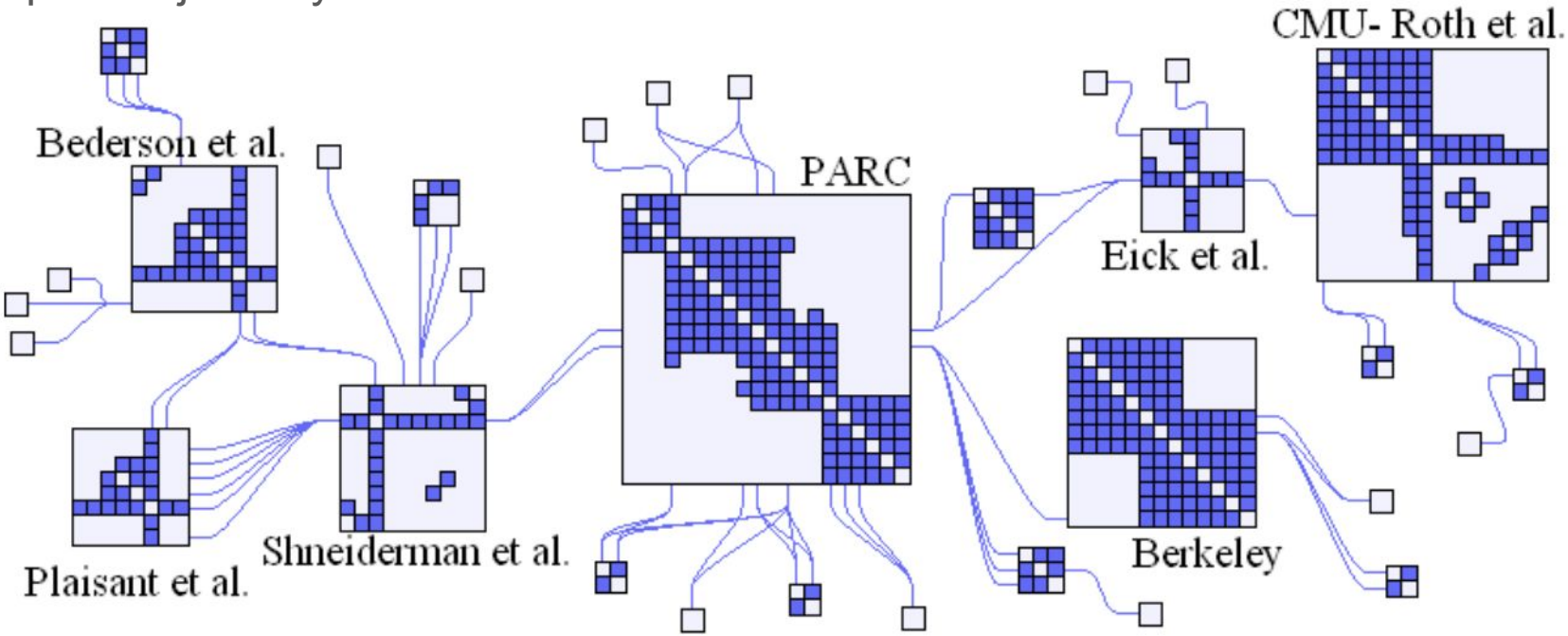


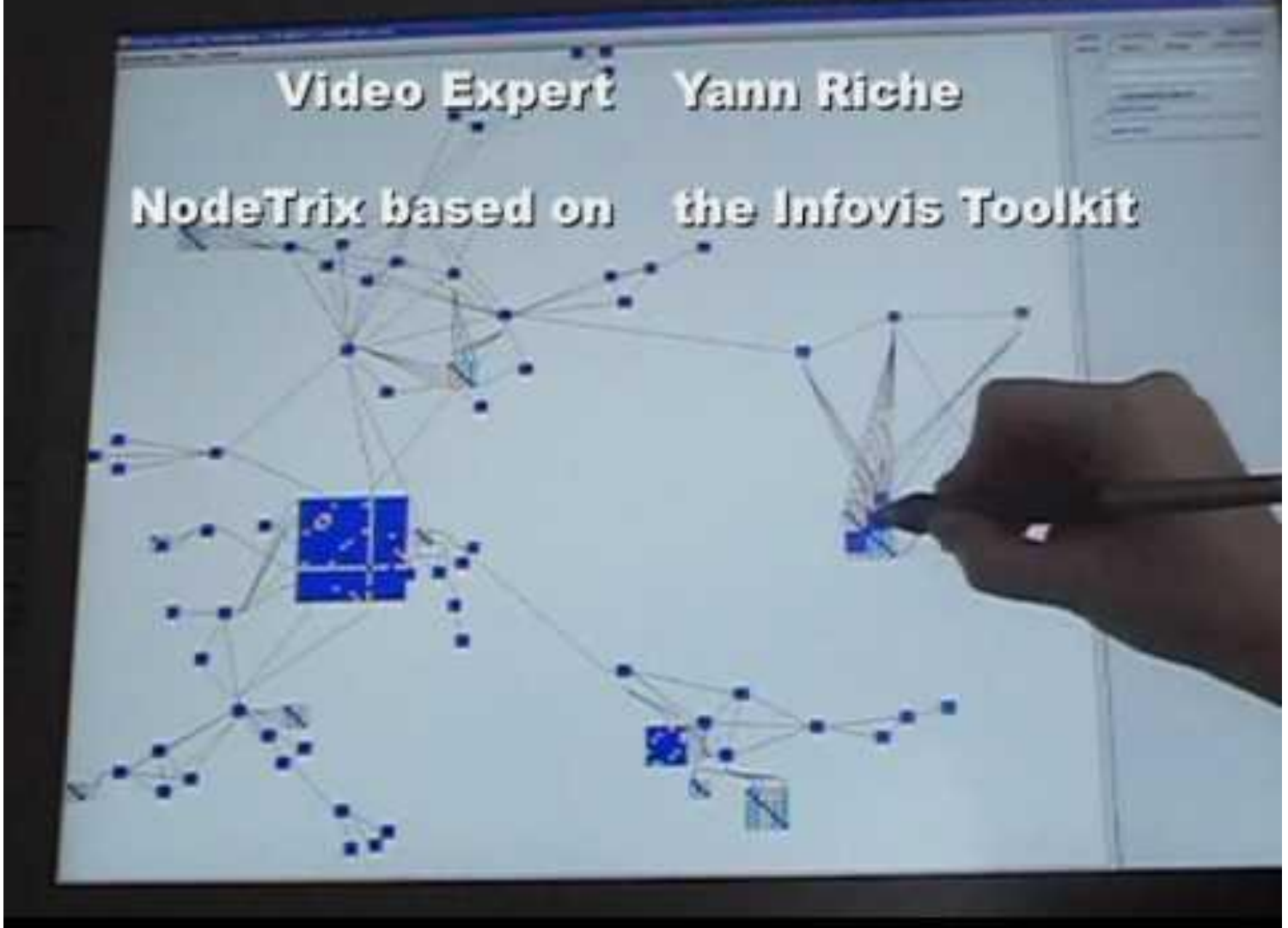
[NodeTrix, 2007]

Combining node-link diagram and adjacency matrix

Large social networks: globally sparse but locally dense.

Graph + adjacency matrix

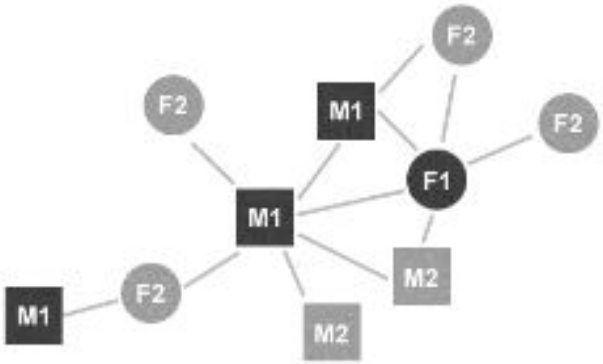


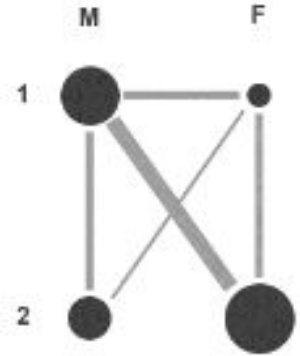

Video Expert Yann Riche
NodeTrix based on the Infovis Toolkit

http://www.cs.middlebury.edu/~candrews/showcase/infovis_techniques_s16/pivot_graph/website_pivotgraph.html

PivotGraph

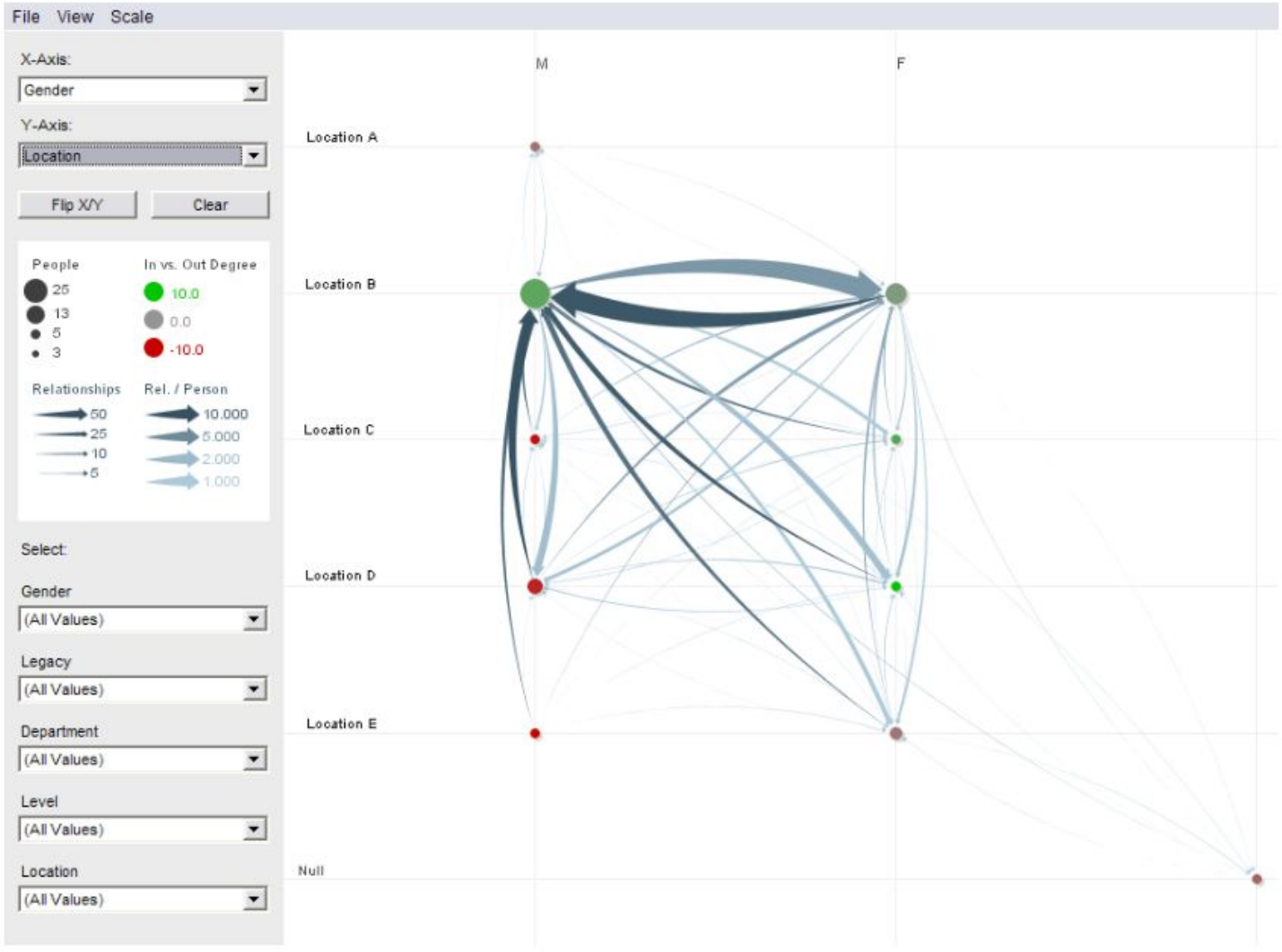
Derived from **categorical node attributes**.
It starts with a selection of dimensions in a set of multivariate, connected data.
It then **aggregates** the data into **discrete categories**.





Size of nodes and edges related to number of aggregated original nodes and edges.

PivotGraph


File View Scale
X-Axis:
Gender
Y-Axis:
Location
Flip X/Y
Clear
People
25
13
5
3
In vs. Out Degree
10.0
0.0
-10.0
Relationships
50
25
10
5
Rel. / Person
10.000
5.000
2.000
1.000
Select:
Gender
(All Values)
Legacy
(All Values)
Department
(All Values)
Level
(All Values)
Location
(All Values)
M
F
Location A
Location B
Location C
Location D
Location E
Null

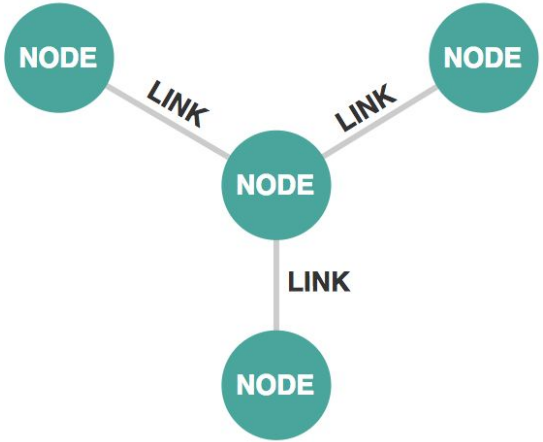
http://www.cs.middlebury.edu/~candrews/showcase/infovis_techniques_s16/pivot_graph/website_pivotgraph.html

PivotGraph

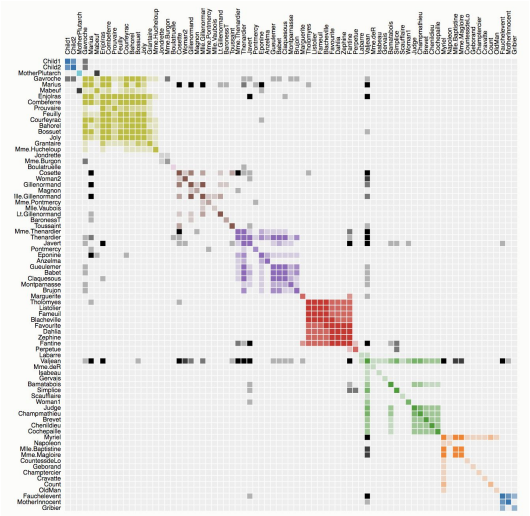
+ Good for seeing **trends** in multivariate data.
+ Clearly displays **the relative strength or size of connections** between vertices.
+ Because it aggregates data, it's very **scalable and good for large data sets**.

- Results in some **loss of information**, as only **a limited number of dimensions** can be displayed at a time.
- Only for **discrete-dimensional data**.
- Only **be used for data with some sort of connectivity** (email correspondence, social networks, etc.).

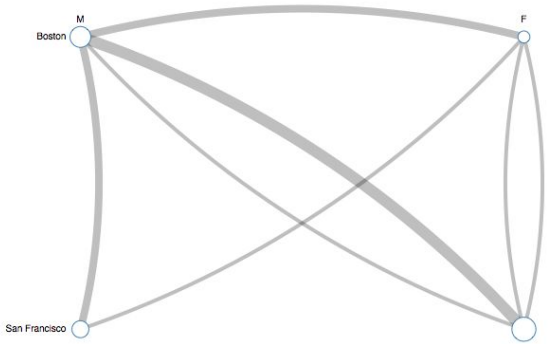
Visualizing graphs



Node-link diagrams



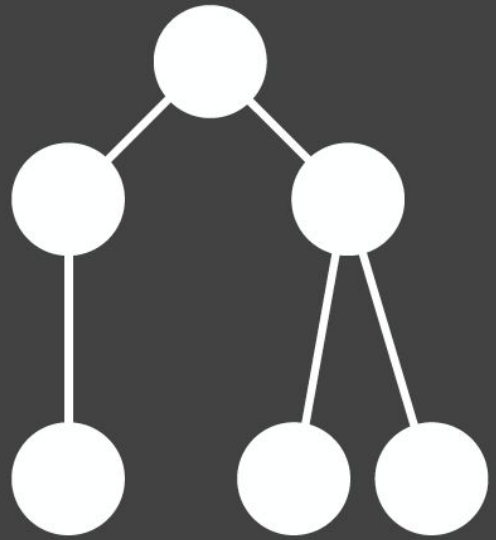
Adjacency matrices



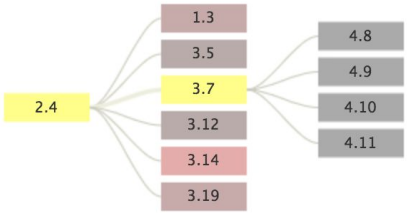
PivotGraph

Trees

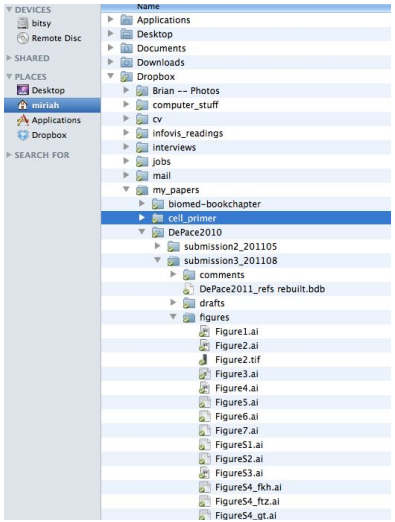
A graph with **one root node** and various leaf nodes (parent-child relation), and **only one path between any two nodes**.



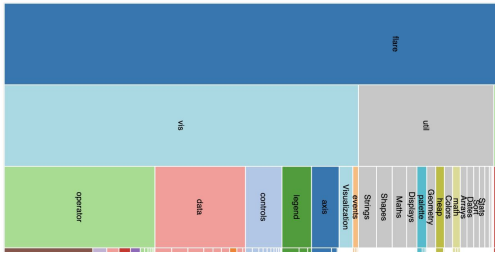
Visualizing trees

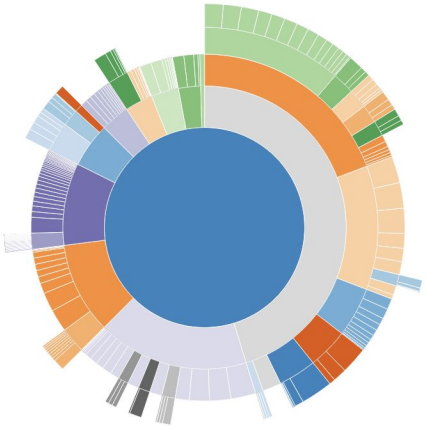


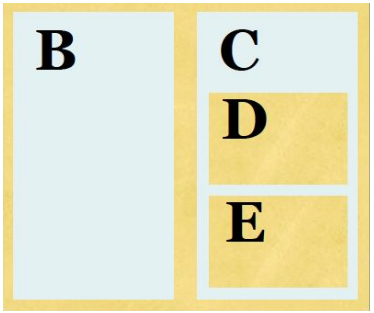
Node-link diagrams



Indentation







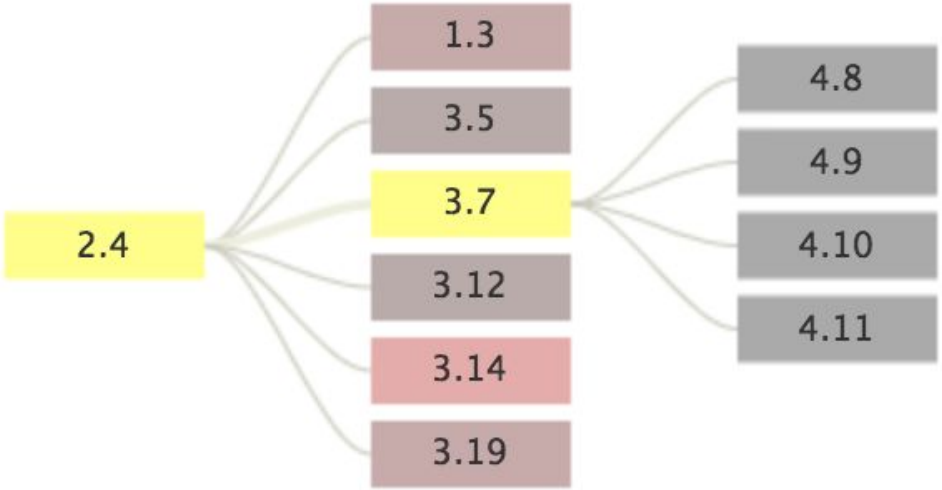
Space-filling techniques

Node-link diagrams

Nodes are distributed in space, connected by **straight or curved lines**;

Typical approach is to use 2D space to break apart **breadth and depth**;

Often **space** is used to communicate **hierarchical orientation**.



https://philogb.github.io/jit/static/v20/Jit/Examples/Spacetree/example1.html
http://mbostock.github.io/d3/talk/20111018/tree.html

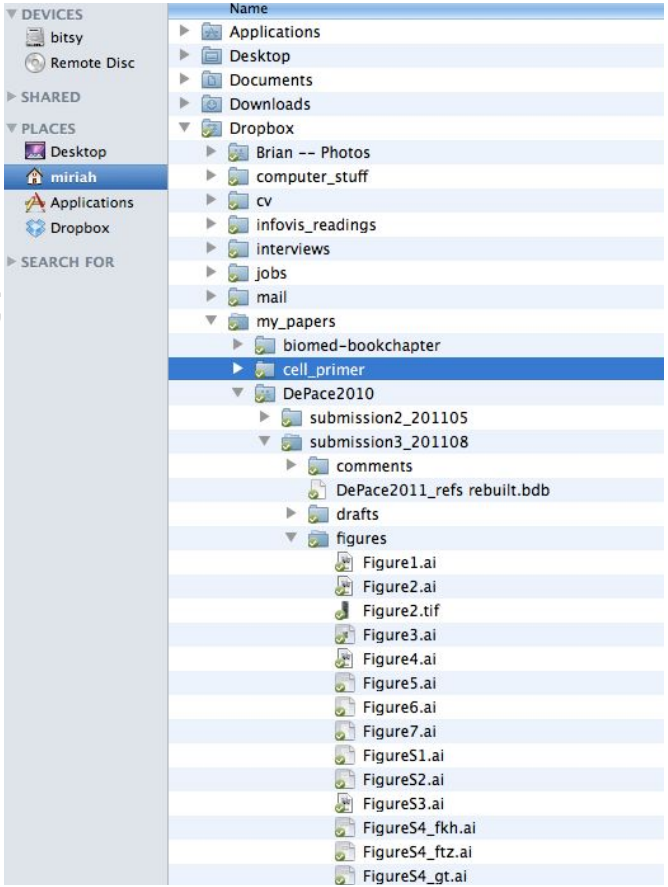
Indentation

Place all items along vertically spaced rows;

Indentation used to show parent/child relationships;

Commonly used as a component in an interface;

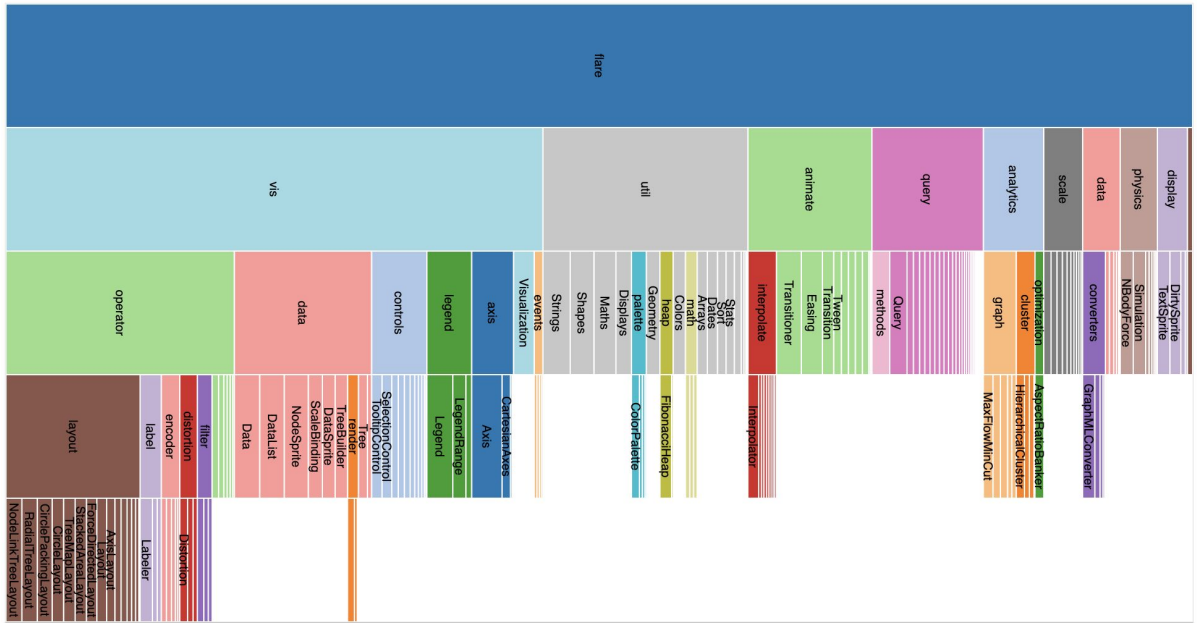
Often requires **a great deal of scrolling**.



Space-filling techniques -- Icicle layout

Using adjacency to represent hierarchy.

A length encoding for the size of nodes.

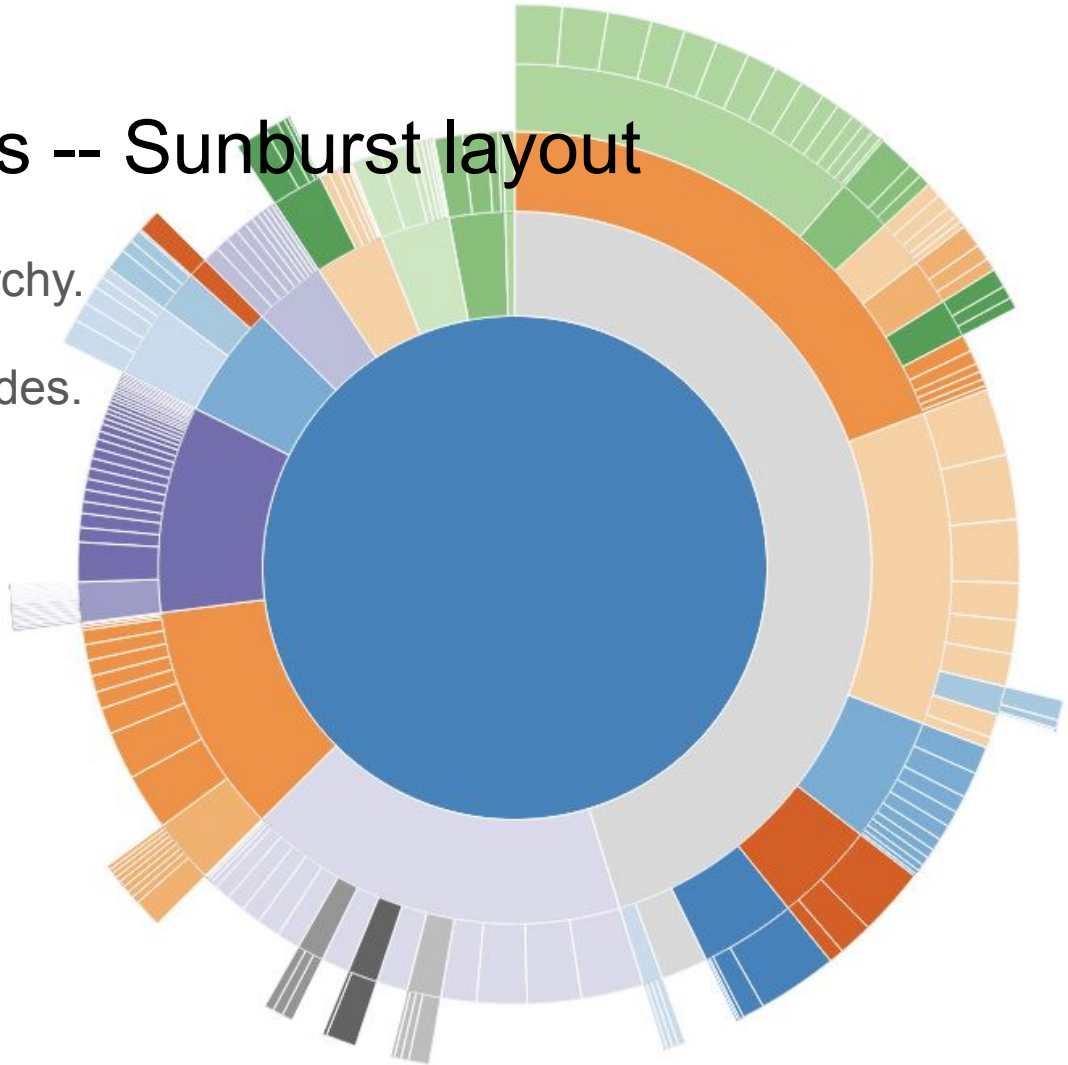


https://observablehq.com/@d3/zoomable-icicle

Space-filling techniques -- Sunburst layout

Using adjacency to represent hierarchy.

A length encoding for the size of nodes.

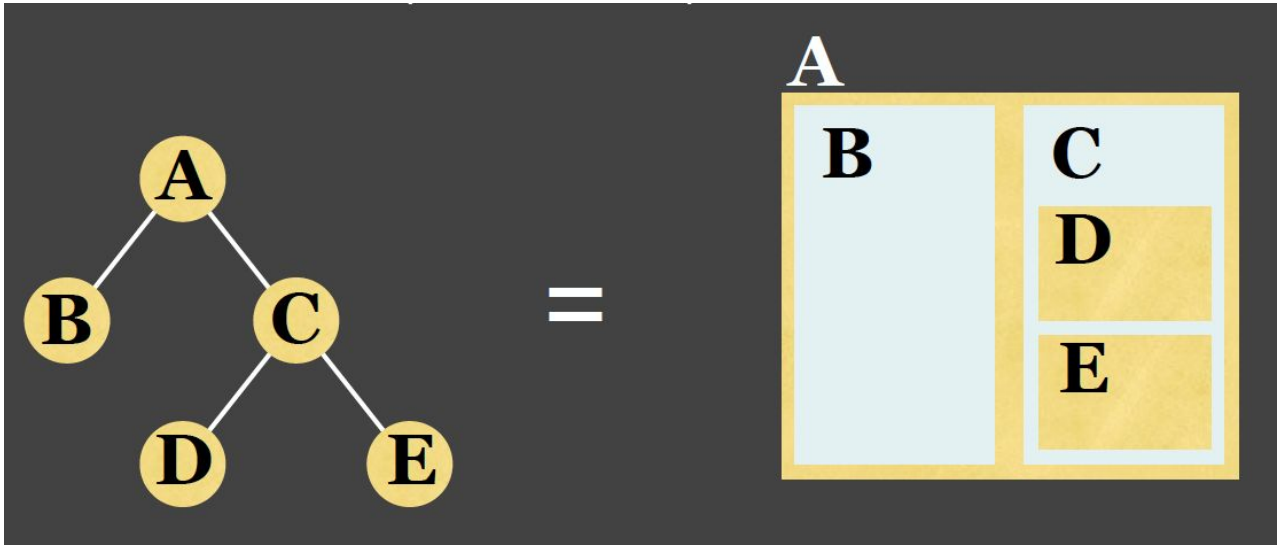


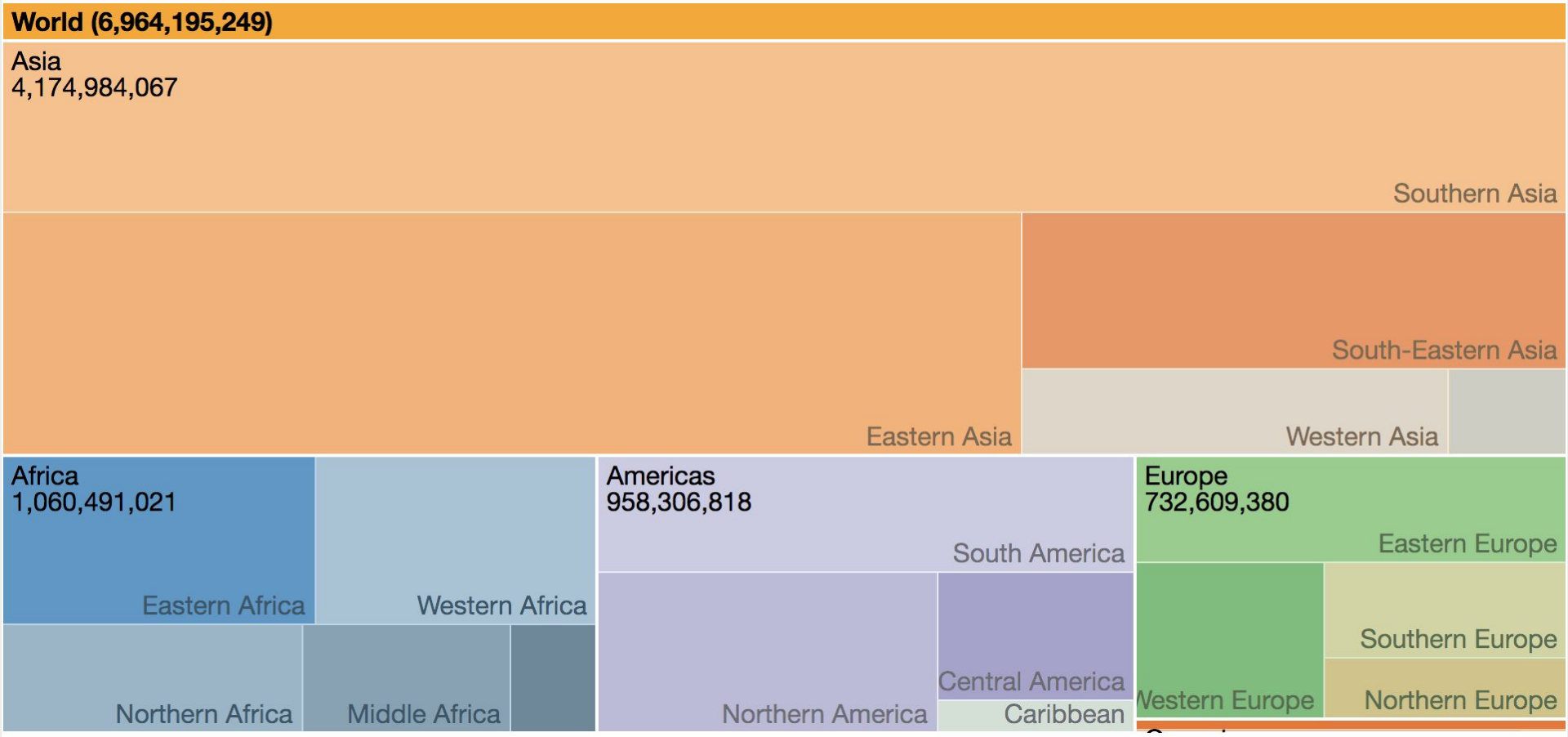
https://bl.ocks.org/kerryrodden/7090426
https://observablehq.com/@d3/zoomable-sunburst

Space-filling techniques -- Treemaps

Using **containment** to represent hierarchy;

Pack a lot of info into a limited space.

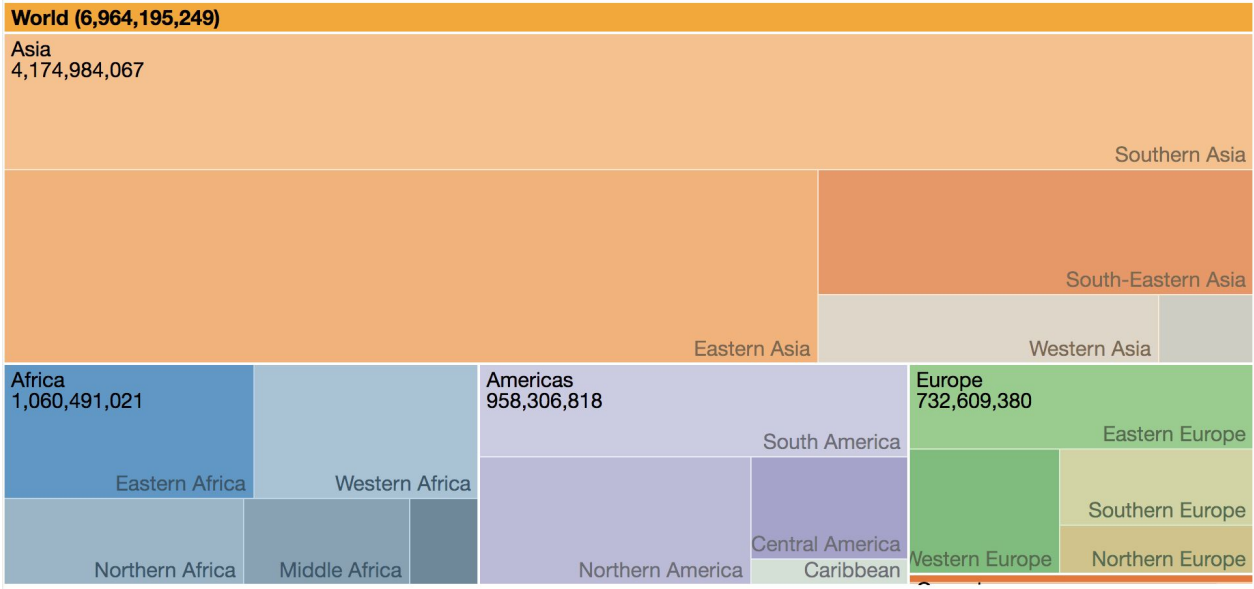




http://bl.ocks.org/ganeshv/6a8e9ada3ab7f2d88022

Treemaps

+ provides single view of entire tree
+ easy to spot small / large node
- difficult to accurately read depth



How to cite this site?

Check out other surveys!

treevis.net - A Visual Bibliography of Tree Visualization 2.0 by Hans-Jörg Schulz

v.06-SEP-2018

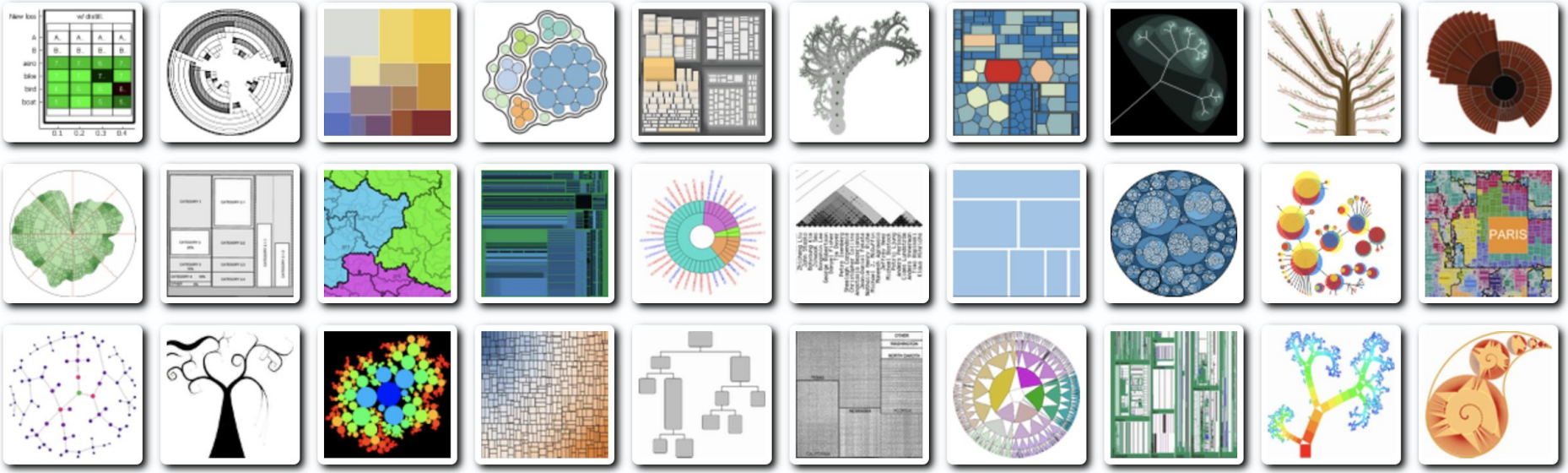
Dimensionality: All

Representation: All

Alignment: All

Fulltext Search

Techniques Shown: 306

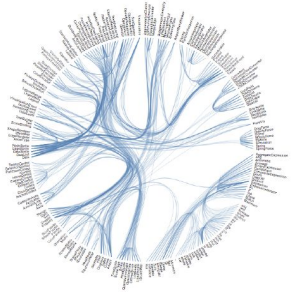


http://treevis.net/

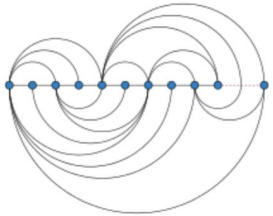
Recap -- Graphs

Node-link diagrams

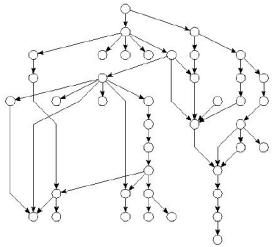
force-directed layout



circular layout

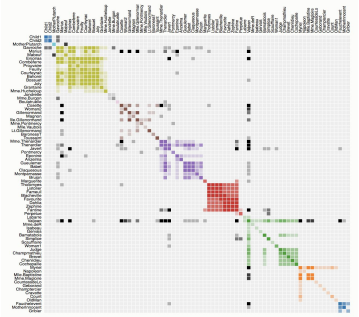


linear layout

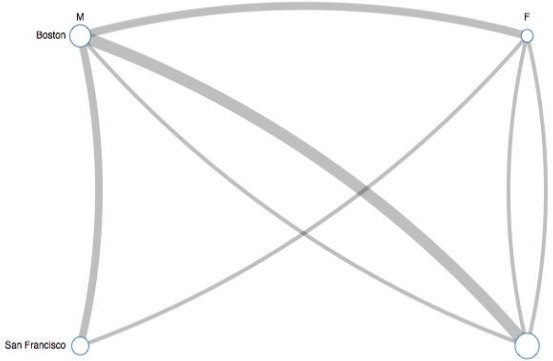


layered layout

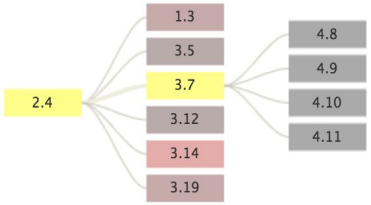
Adjacency matrix

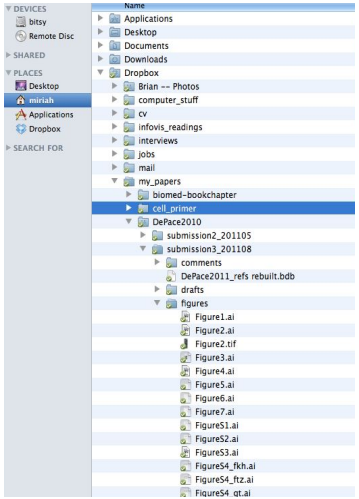


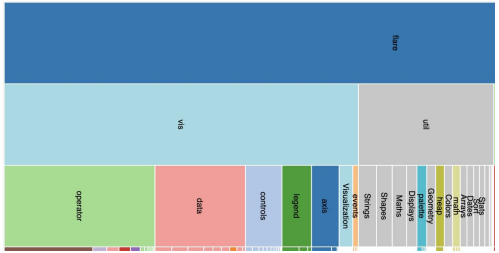
PivotGraphs

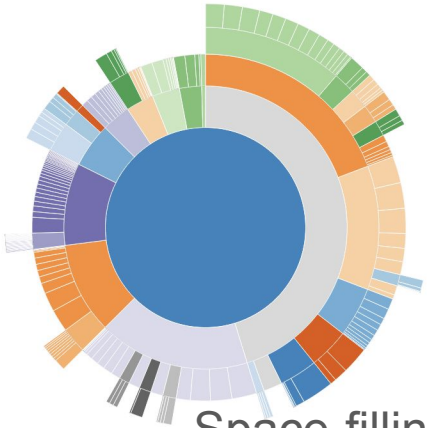


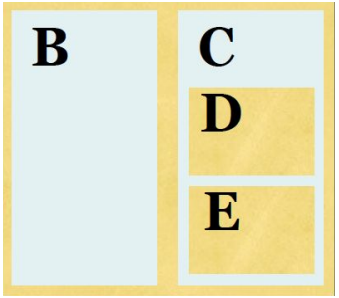
Recap -- Trees











Node-link diagrams Indentation Space-filling techniques