ARC²S Group

Applied Research on Computational Complex Systems

Hierarchical Data and Graph Visualization

Prof. Giancarlo **Ruffo**

"Analisi e Visualizzazione di Reti Complesse" (9 credits)
Laurea Magistrale in **Informatica**
Università degli Studi di Torino
A.A. 2017/18

@giaruffo

INTRODUCTION

Hierarchical Data Visualization

Hierarchical Data

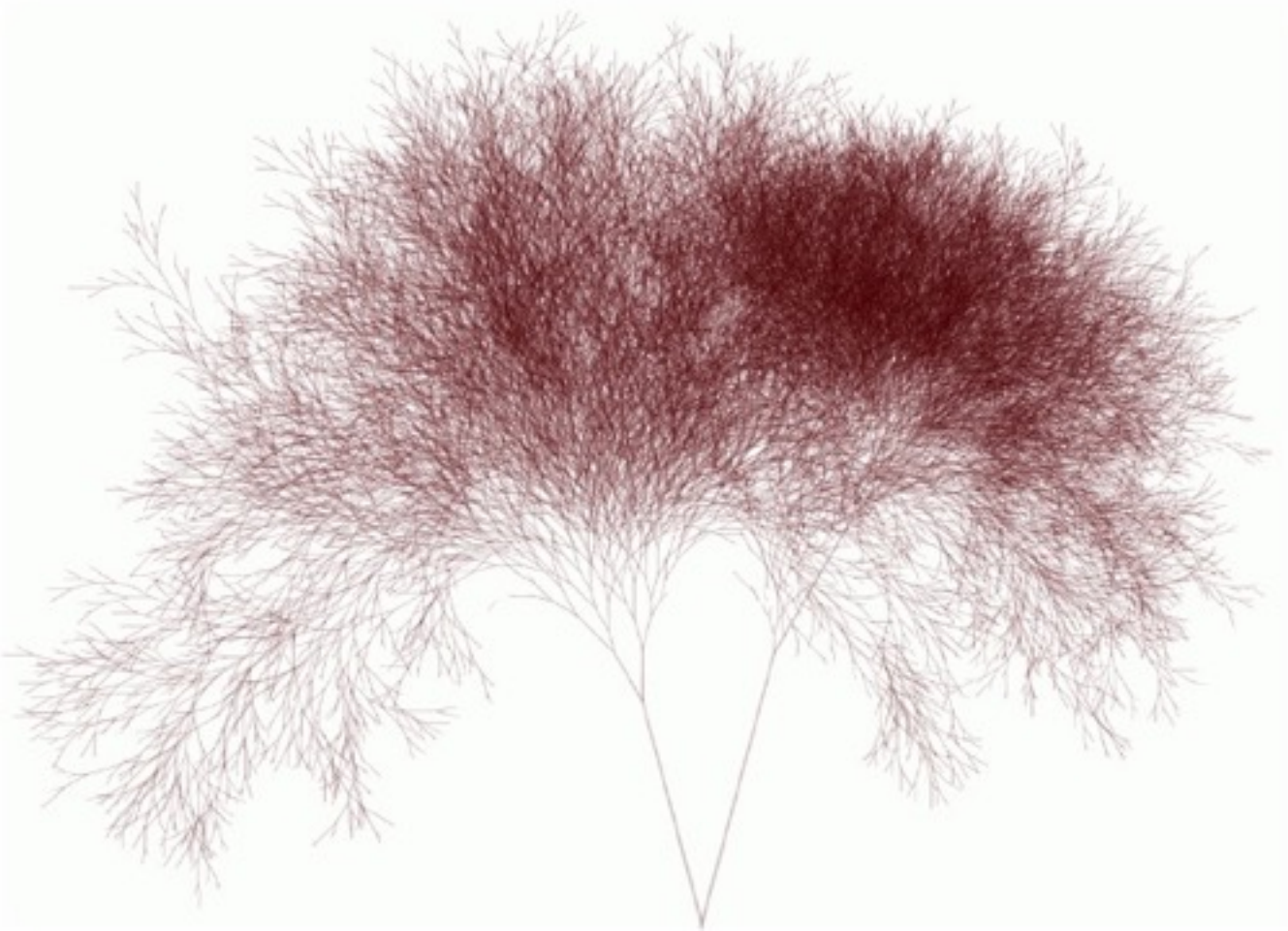
- Any data with some sort of hierarchy
  - *"Group of objects ranked so that everyone but the top most is subordinate to one above it."*
- Example hierarchy
  - Country: Italy
  - Region: Piedmont
  - Area: Turin
  - City: Turin
  - Municipal District: Madonna di Campagna

http://en.wiktionary.org/wiki/hierarchy

Examples of Hierarchical Data

- Evolutionary Tree
- Dendrograms
- File Directory Structure
- Dewey Decimal System
- Family History
- Organization Charts
- Outlines

Tree Structures



http://drunkmenworkhere.org/219

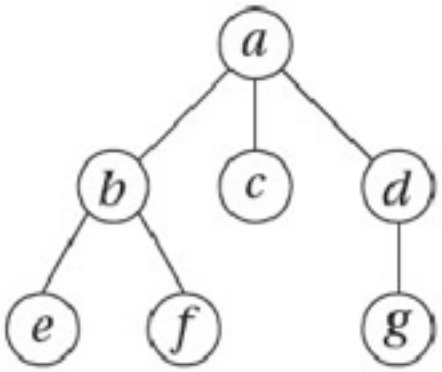
Tree Structures

- Used to model hierarchical data
- Special type of graph
  - Must be **acyclic**, i.e. has no cycles or loops
  - Must be **undirected**, i.e. arrow-less edges
  - Usually **rooted** (a single node at top)
  - Each **subgraph** is also a tree (**subtree**)

http://xlinux.nist.gov/dads/HTML/tree.html

Tree Terminology

FIGURE 2.8: TREE TERMINOLOGY AND NOTATION



$$G = (N, E) \text{ where}$$
$$N = \{a, b, c, d, e, f, g\}$$
$$E = \{(a,b), (a,c), (a,d), (b,e), (b,f), (d,g)\}$$

Example tree $G = (N, E)$. Some observations: Each node has a unique label. Node a is the root node. Nodes a, b, and d are internal nodes. Nodes c, e, f, and g are leaf nodes. Node d is a parent node to node g, and node g is a child node to d. Nodes e and f share the same parent node b and are considered siblings.

Tree Visualization

- Node-Link Diagrams
  - Traditional node-link diagram
  - Dendograms
  - Hyperbolic trees
- Space-Filling Diagrams
  - Treemaps
  - Sunbursts

Considerations

- Is the hierarchical structure visible?
- What is the level of a specific node?
- What is the height of the tree?
- How many nodes on level *x*?
- Are the labels readable? All nodes visible?
- What type of interaction is supported?
  - Focus + Context
  - Overview + Detail
  - Zoom + Filter

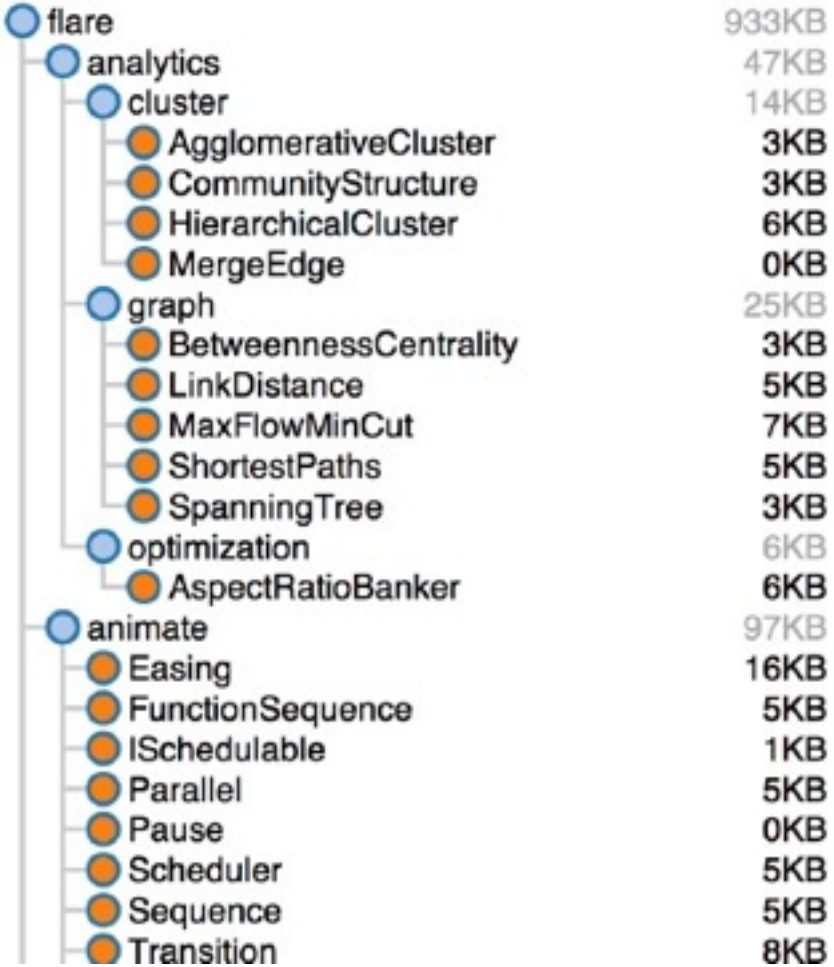
NODE-LINK DIAGRAMS

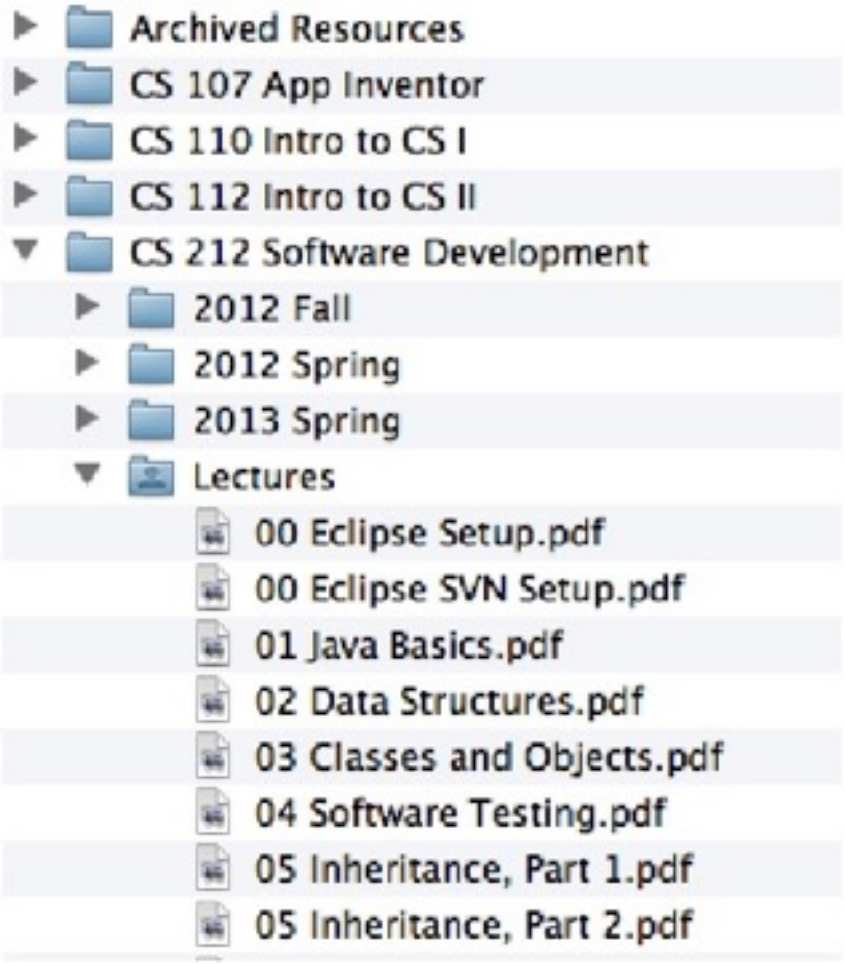
Tree Visualization

Node-Link Diagrams

- Indented Layout
  - Child nodes placed below parent and indented
  - Compact width
  - Height expands and shrinks
  - Often used to navigate file systems
  - Difficult to see all nodes of a specific level

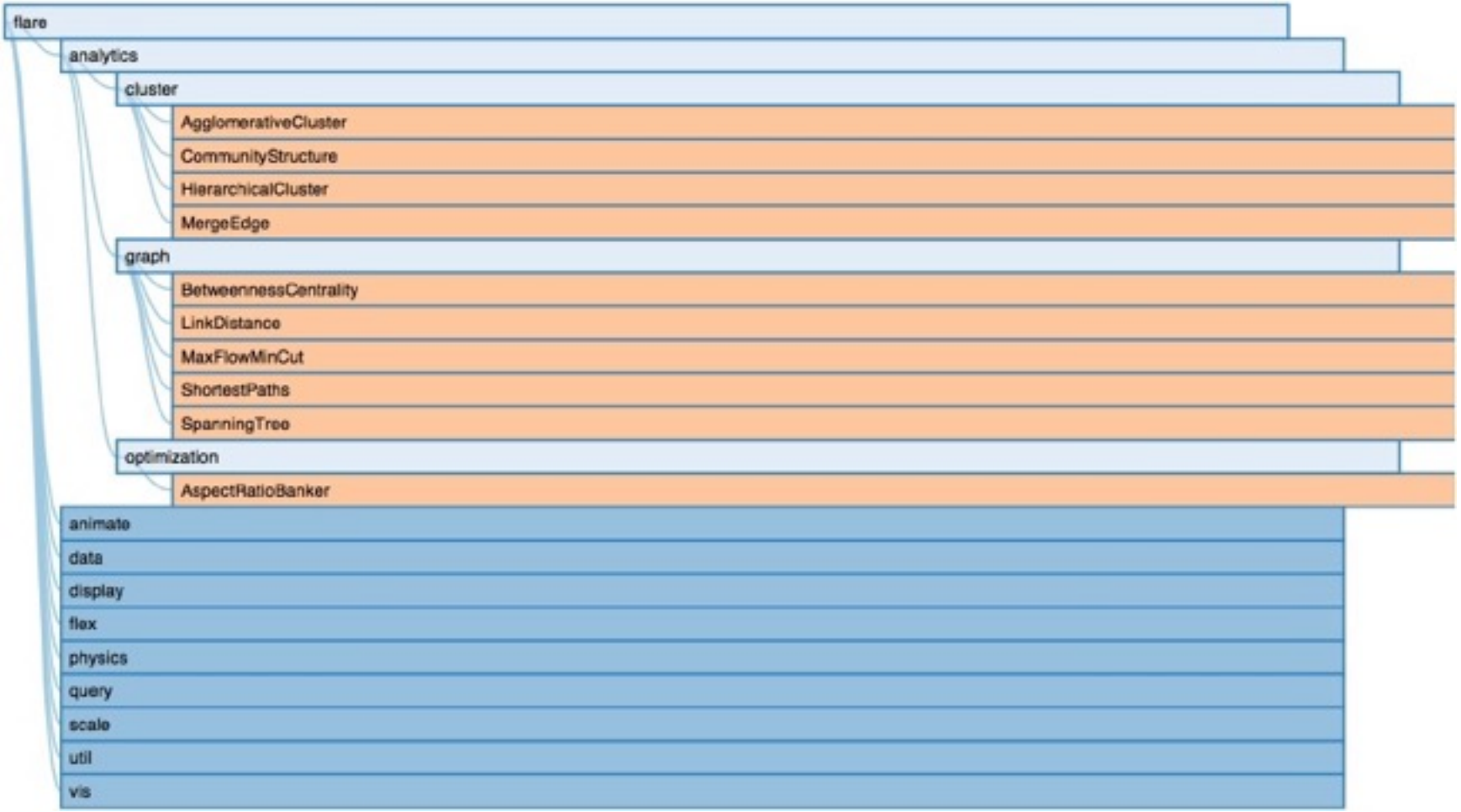
Indented Layout





http://mbostock.github.io/protovis/ex/indent.html

Indented Layout

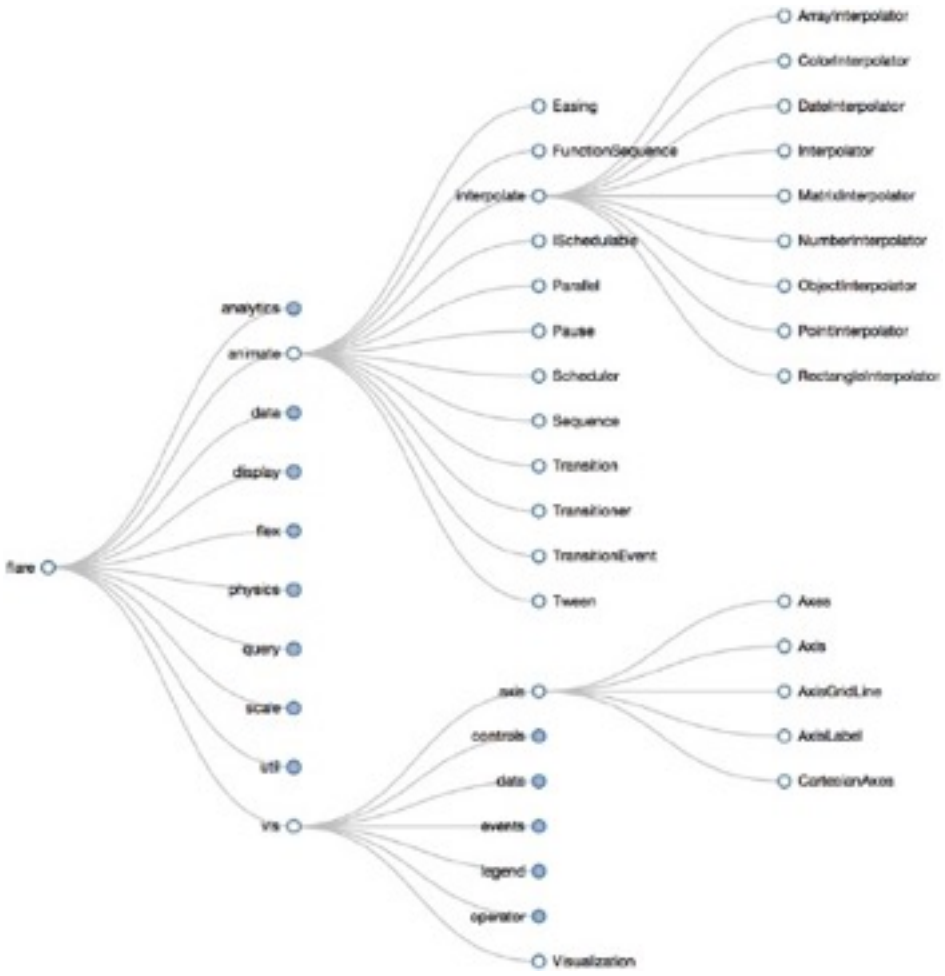


http://bl.ocks.org/mbostock/1093025

Node-Link Diagrams

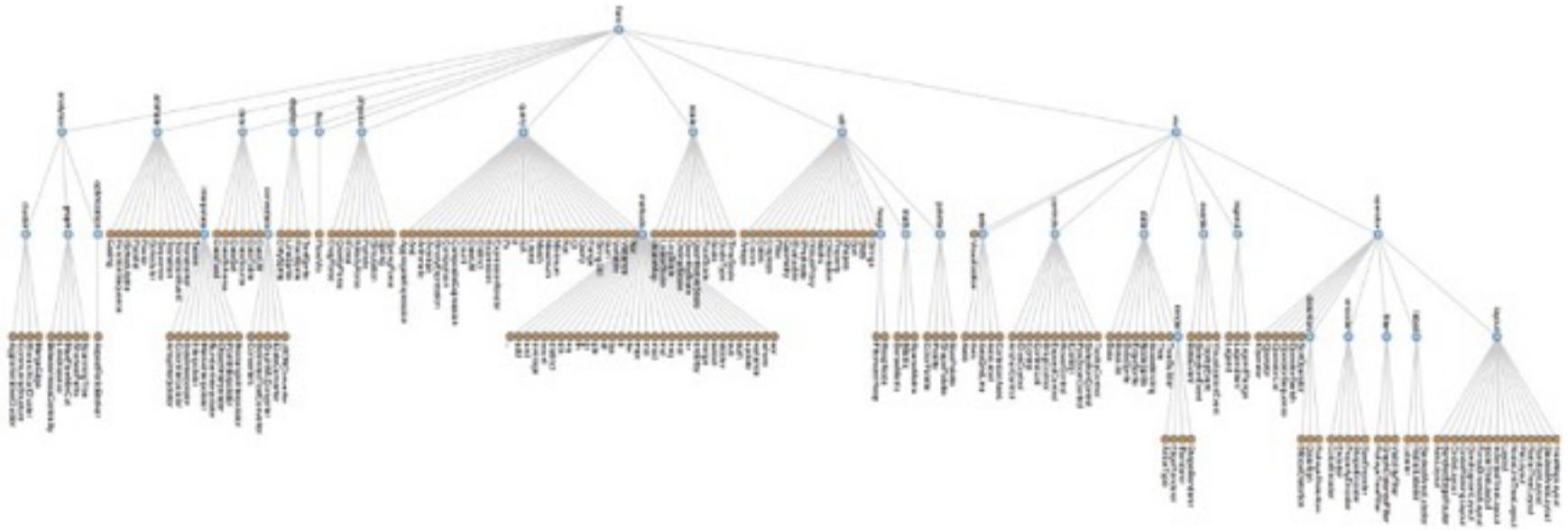
- Traditional Layout
  - Nodes laid out by level, root at top
  - Edges connect adjacent nodes
- Dendrogram
  - All leaves at bottom of diagram
  - Edges usually drawn with sharp corners
  - Often used to show clusters
    (sometimes called cluster layout)

Traditional Layout



http://mbostock.github.io/d3/talk/20111018/tree.html

Traditional Layout

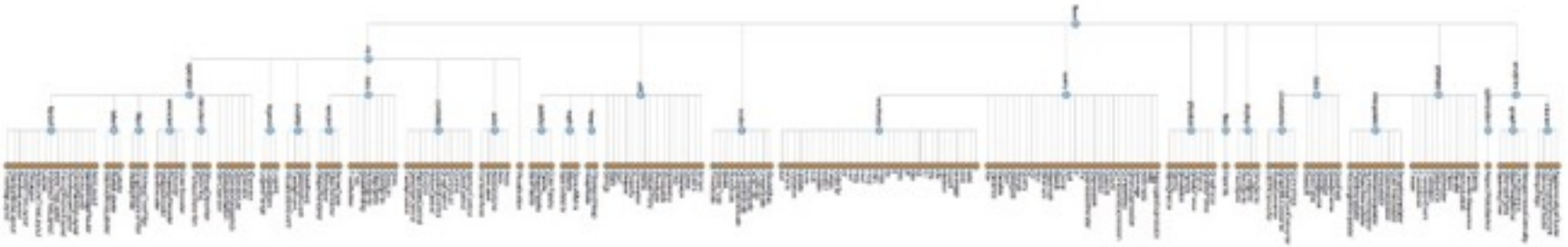


The Flare package tree laid out in horizontal layers. All the nodes in a given layer are at the same package depth.

Source: Flare Visualization Toolkit

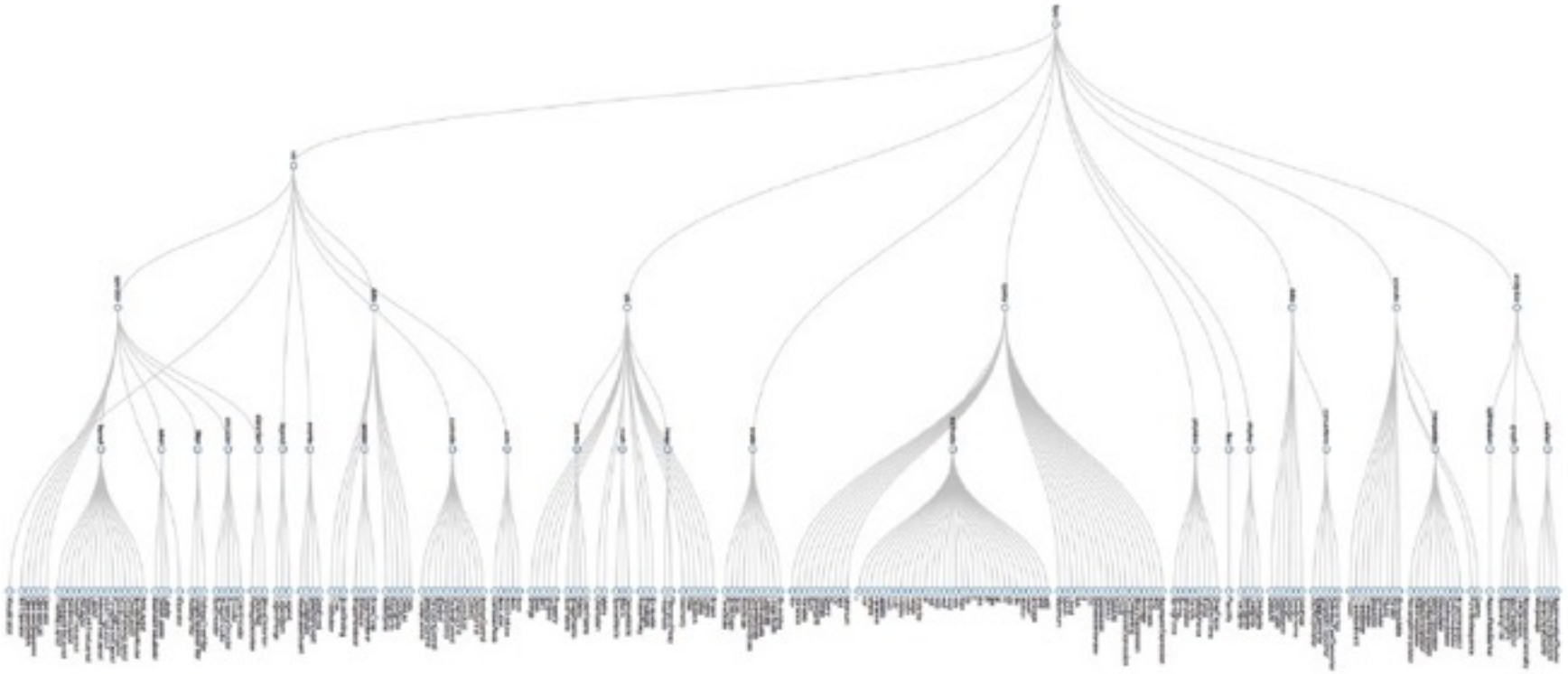
http://hci.stanford.edu/jheer/files/zoo/ex/hierarchies/tree.html

Dendrogram



http://mbostock.github.io/protovis/ex/dendrogram.html

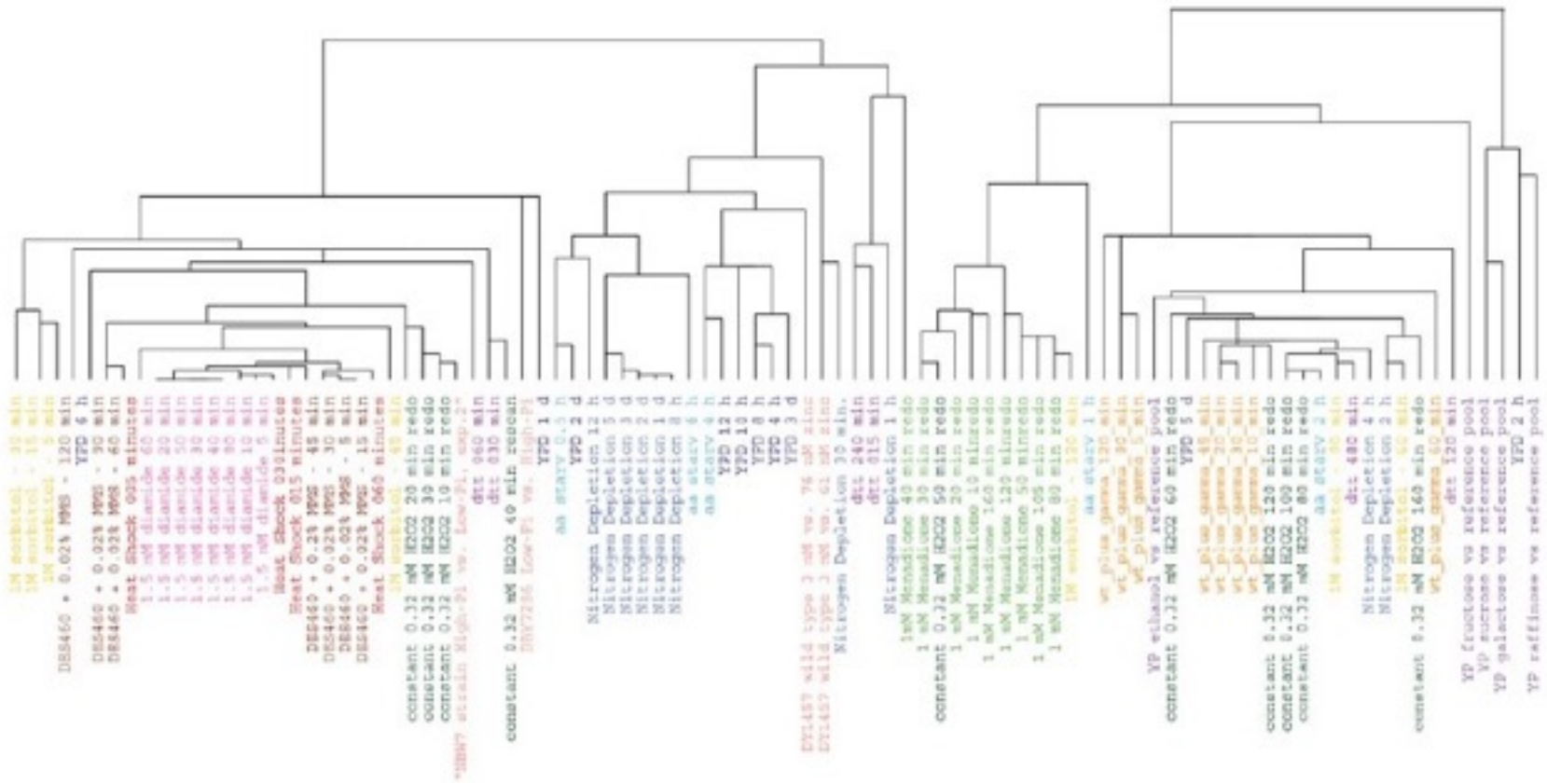
Dendrogram



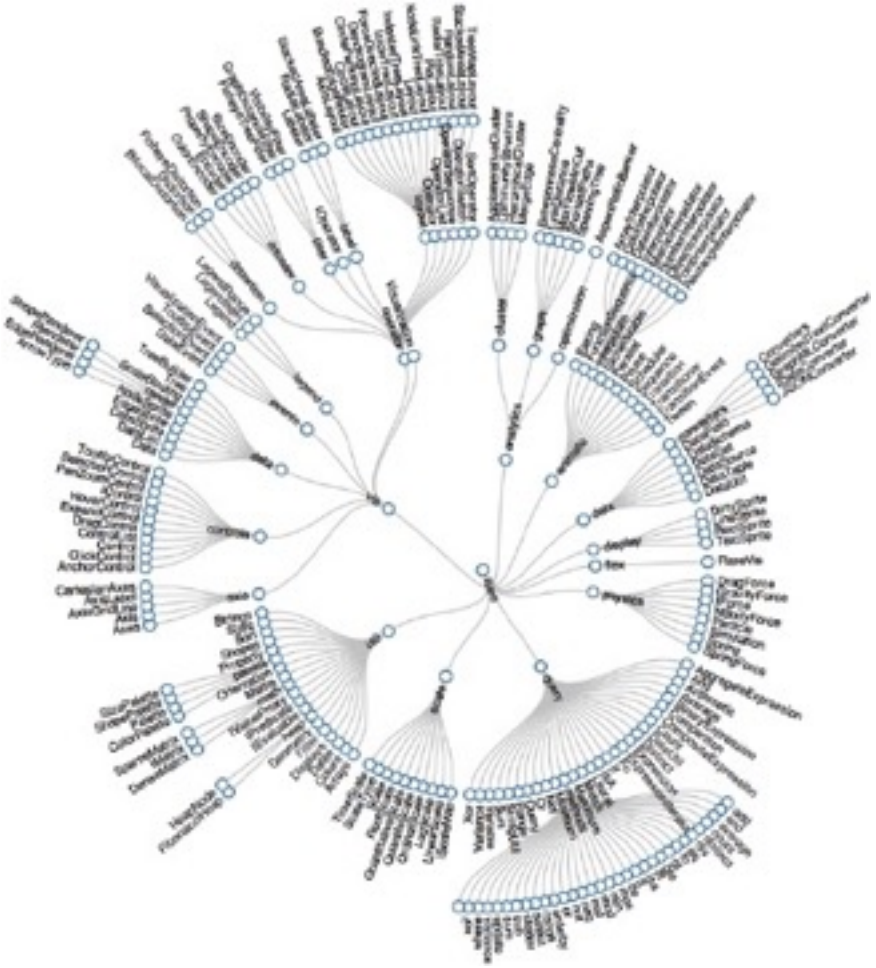
http://mbostock.github.io/protovis/ex/dendrogram.html

Dendrogram

Cluster 11: protein folding chaperones

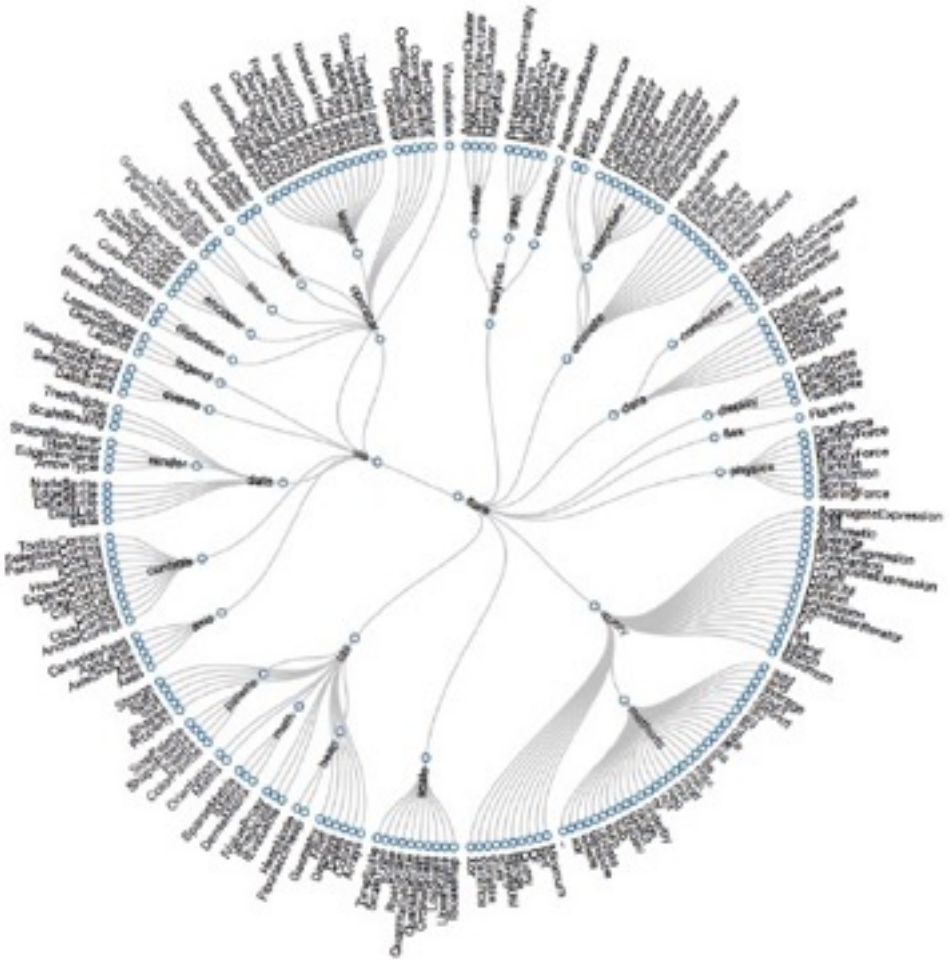


Circular Layout



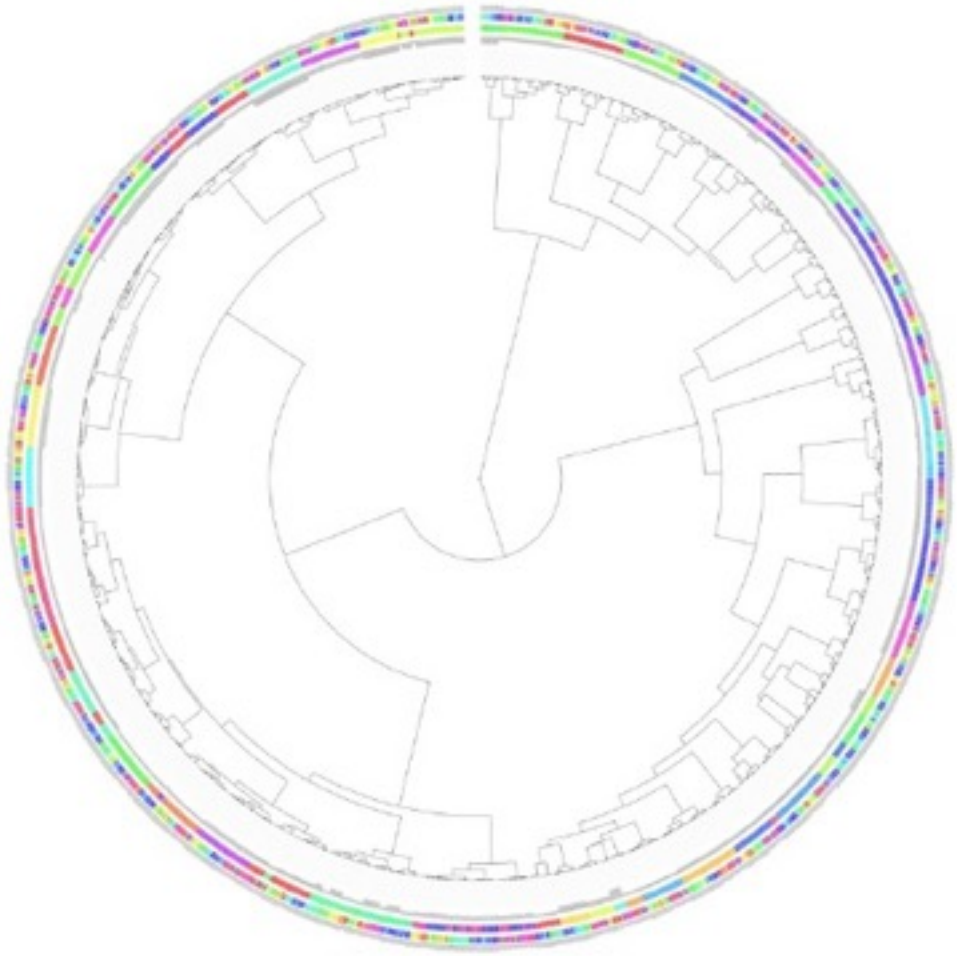
http://bl.ocks.org/mbostock/4063550

Circular Dendrogram



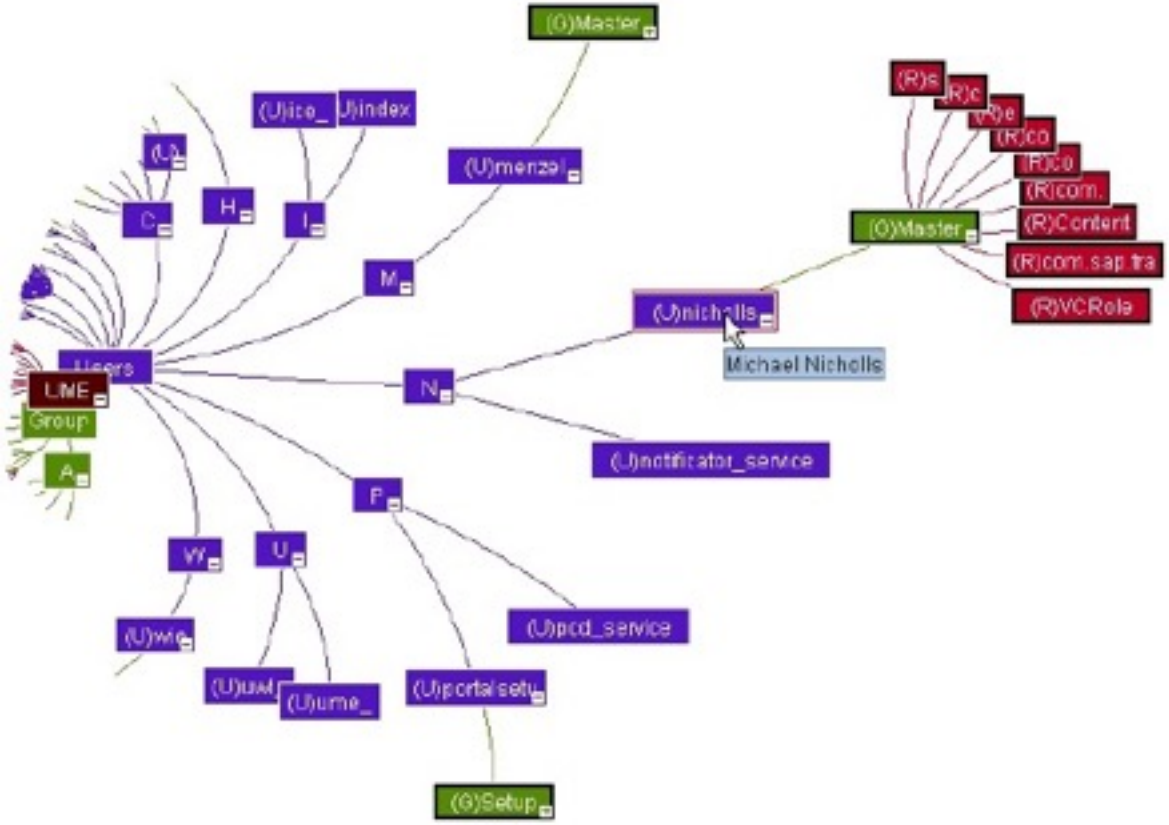
http://mbostock.github.io/d3/talk/20111018/cluster.html

Circular Dendrogram



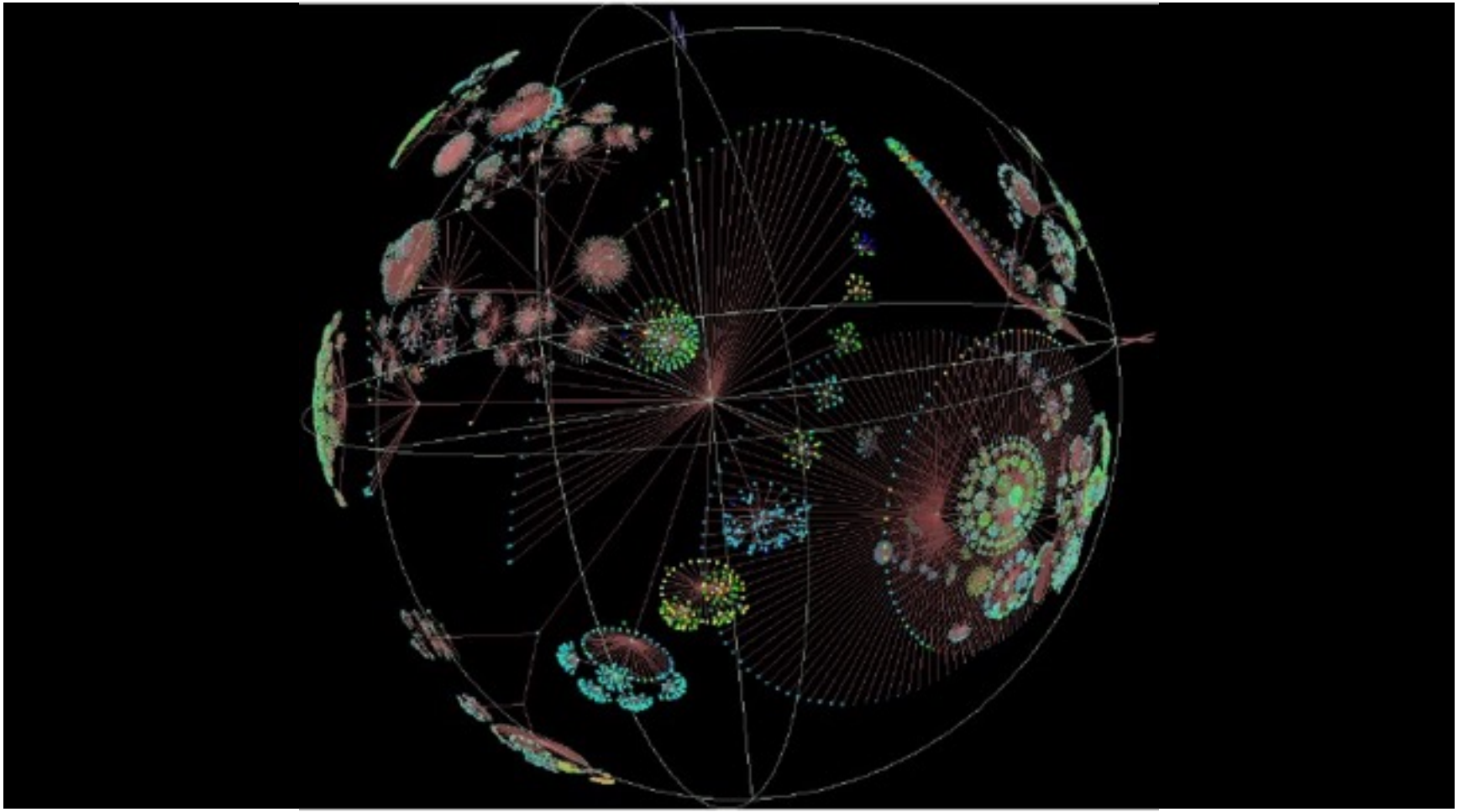
http://cs.jhu.edu/~razvanm/fs-expedition/2.6.x.html

Hyperbolic Tree



http://wiki.sdn.sap.com/wiki/display/EmTech/StarTree+examples

Hyperbolic Tree (3D)

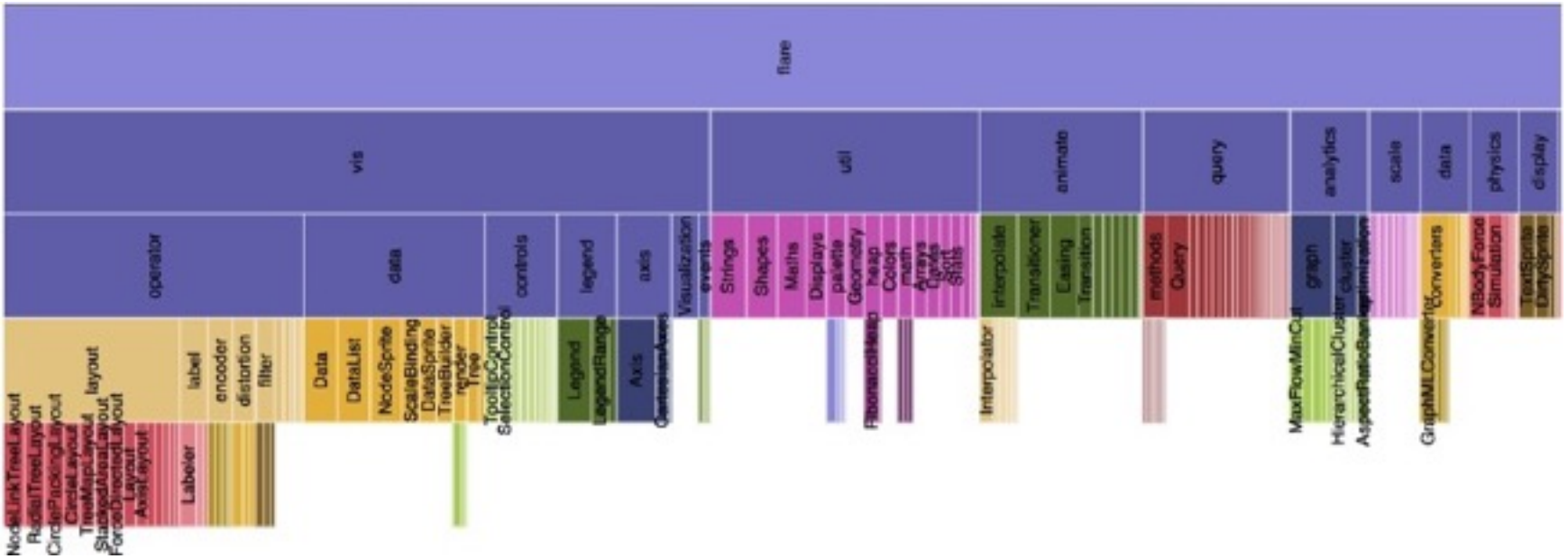


http://www.caida.org/tools/visualization/walrus/

SPACE-FILLING DIAGRAMS

Tree Visualization

Icicle Diagram



http://mbostock.github.io/protovis/ex/icicle.html

Icicle Diagram

http://mbostock.github.io/d3/talk/20111018/partition.html

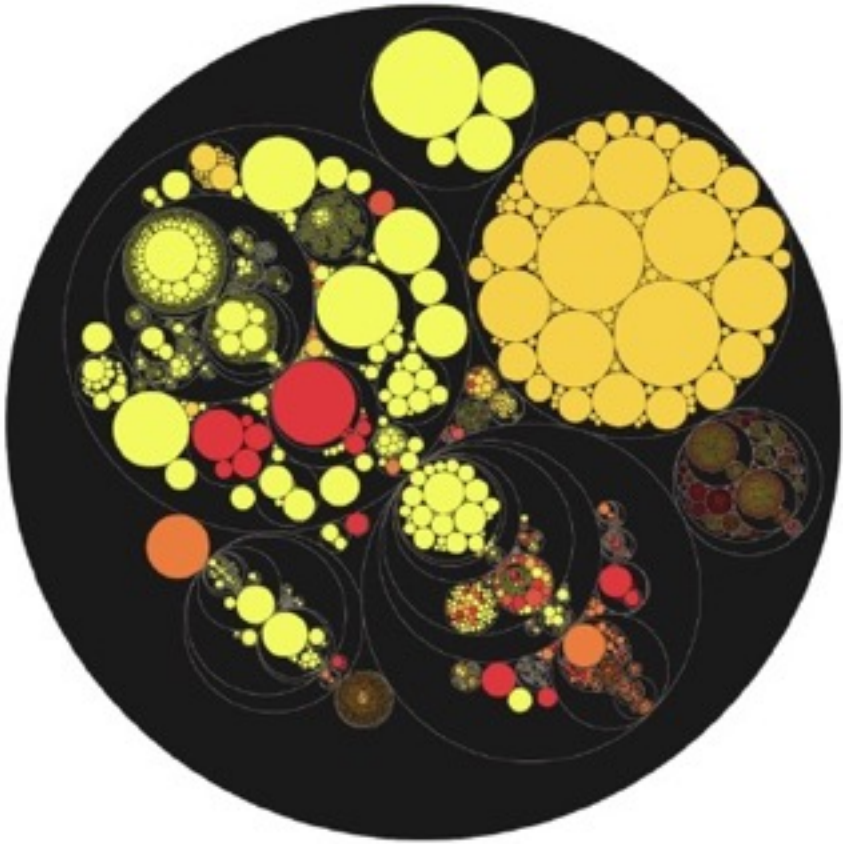
Sunburst Diagram

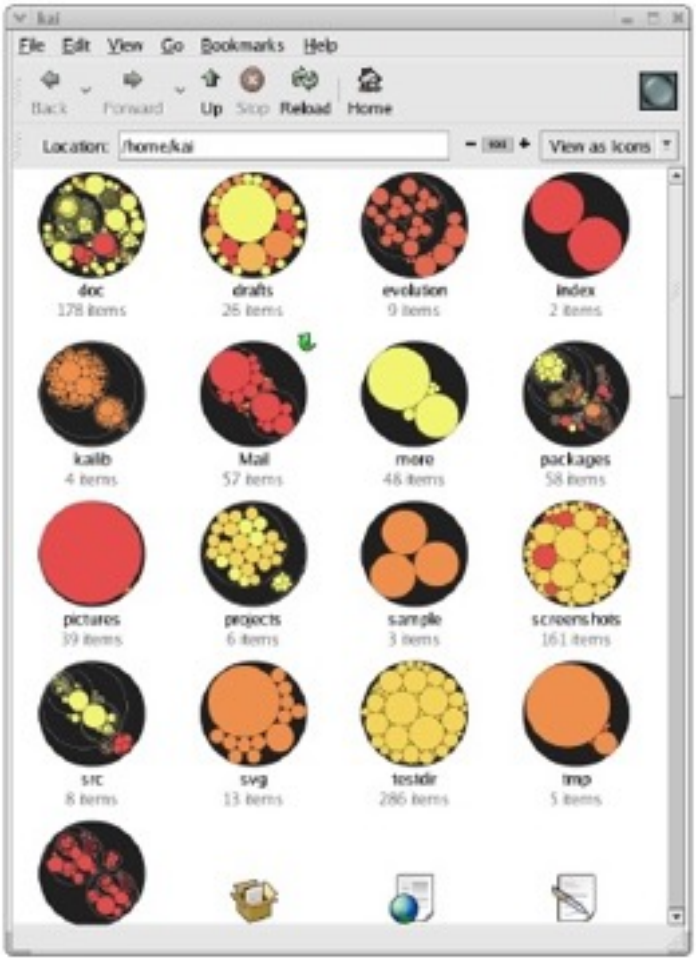
http://bl.ocks.org/mbostock/4063423

Circle Packing

http://mbostock.github.io/d3/talk/20111116/pack-hierarchy.html

Pebbles File Manager





http://lip.sourceforge.net/ctreemap.html

PRTG Network Monitor

https://prtg.paessler.com/help/general_layout.htm

TREEMAPS

Space-Filling Diagrams

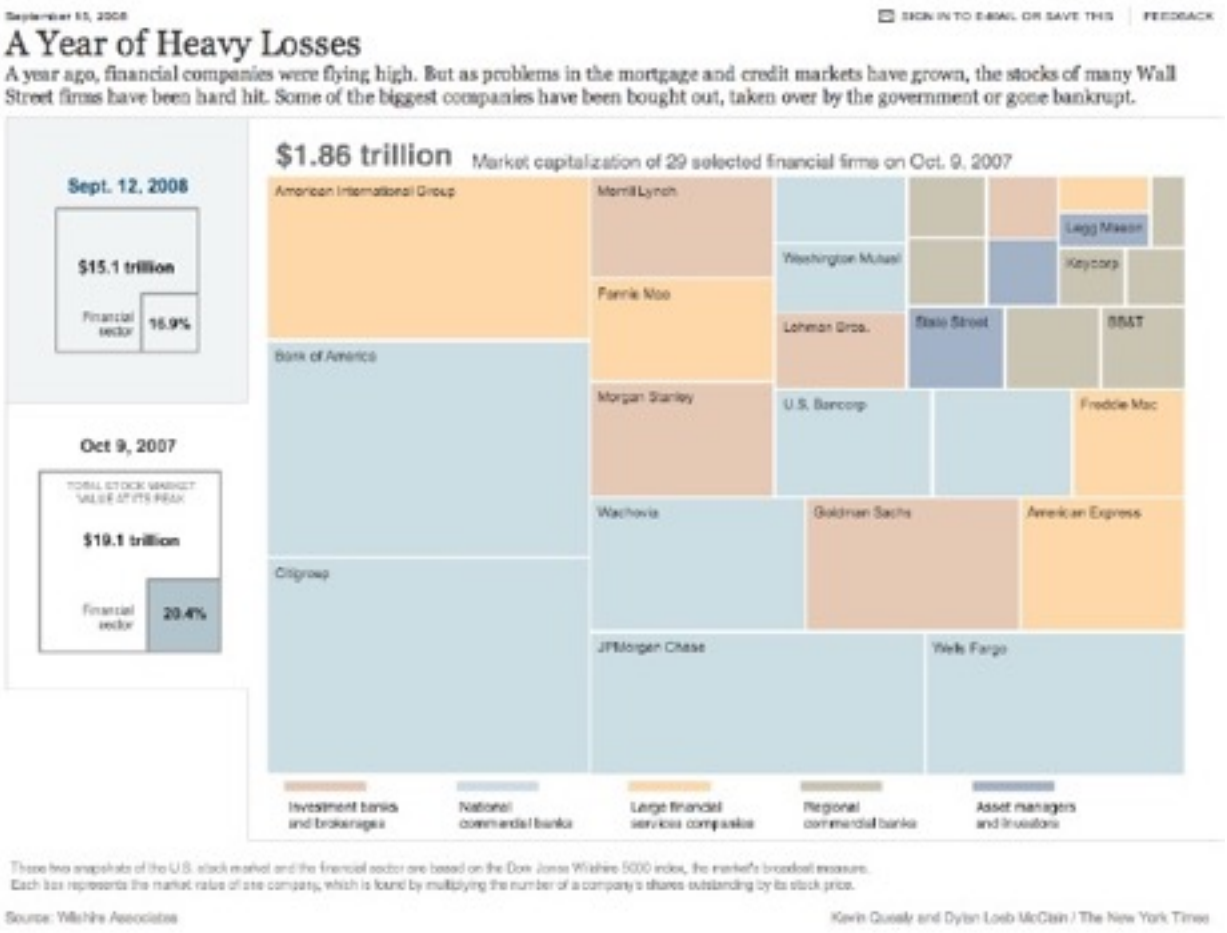
Treemaps

- Root is entire rectangle
- Recursively divide rectangles to show levels
- Two common visualization tasks
  - Promote comparison
  - Visualize hierarchy
- Task affects encoding
  - Use of color, outlines, shading, etc.
- See http://www.cs.umd.edu/hcil/treemap-history/

Treemaps

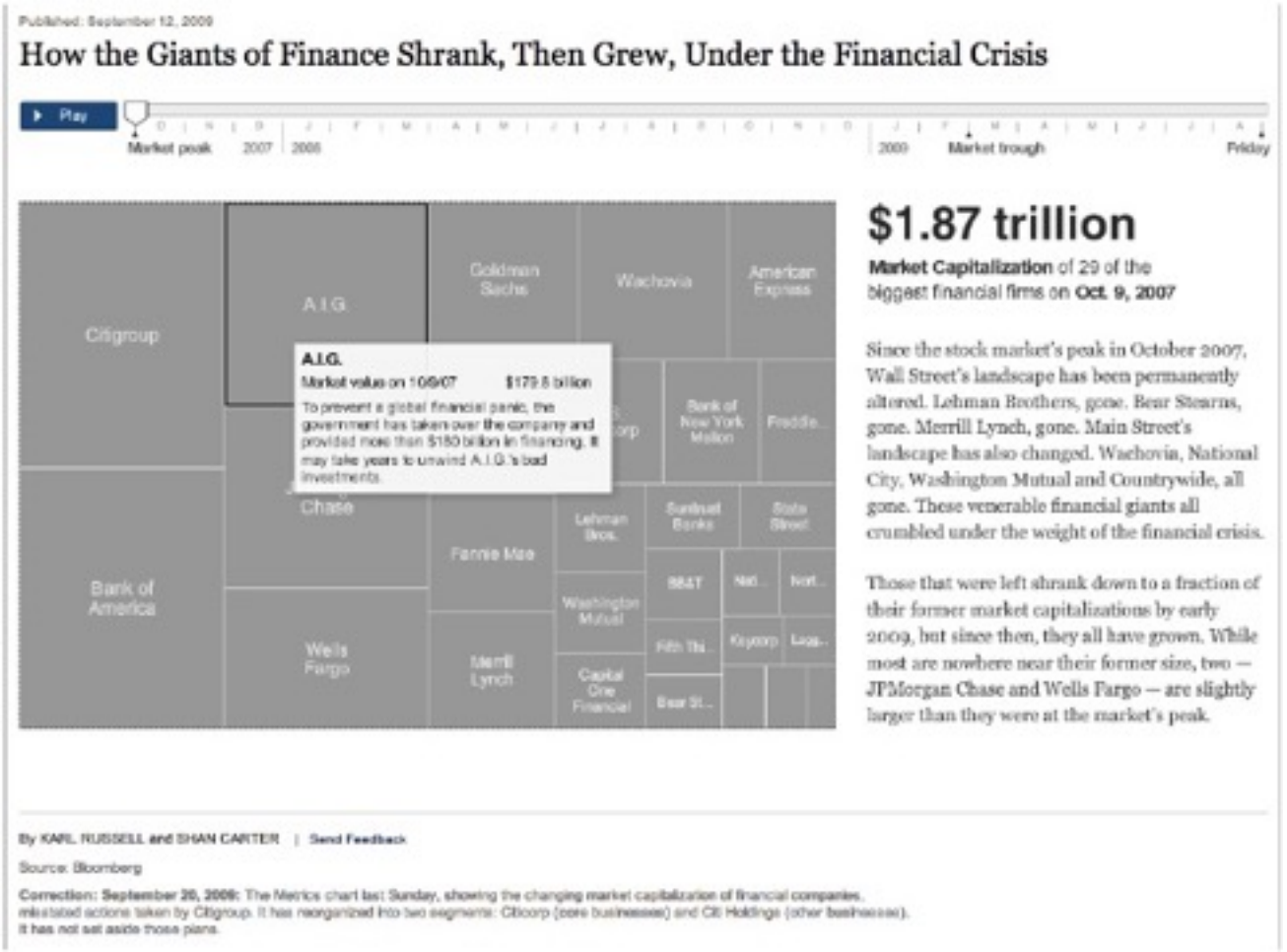
http://bl.ocks.org/mbostock/4063582

A Year of Heavy Losses



http://www.nytimes.com/interactive/2008/09/15/business/20080916-treemap-graphic.html

How the Giants of Finance Shrank



http://www.nytimes.com/interactive/2009/09/12/business/financial-markets-graphic.html

Billion-Dollar-O-Gram

http://www.informationisbeautiful.net/visualizations/the-billion-dollar-o-gram-2009/

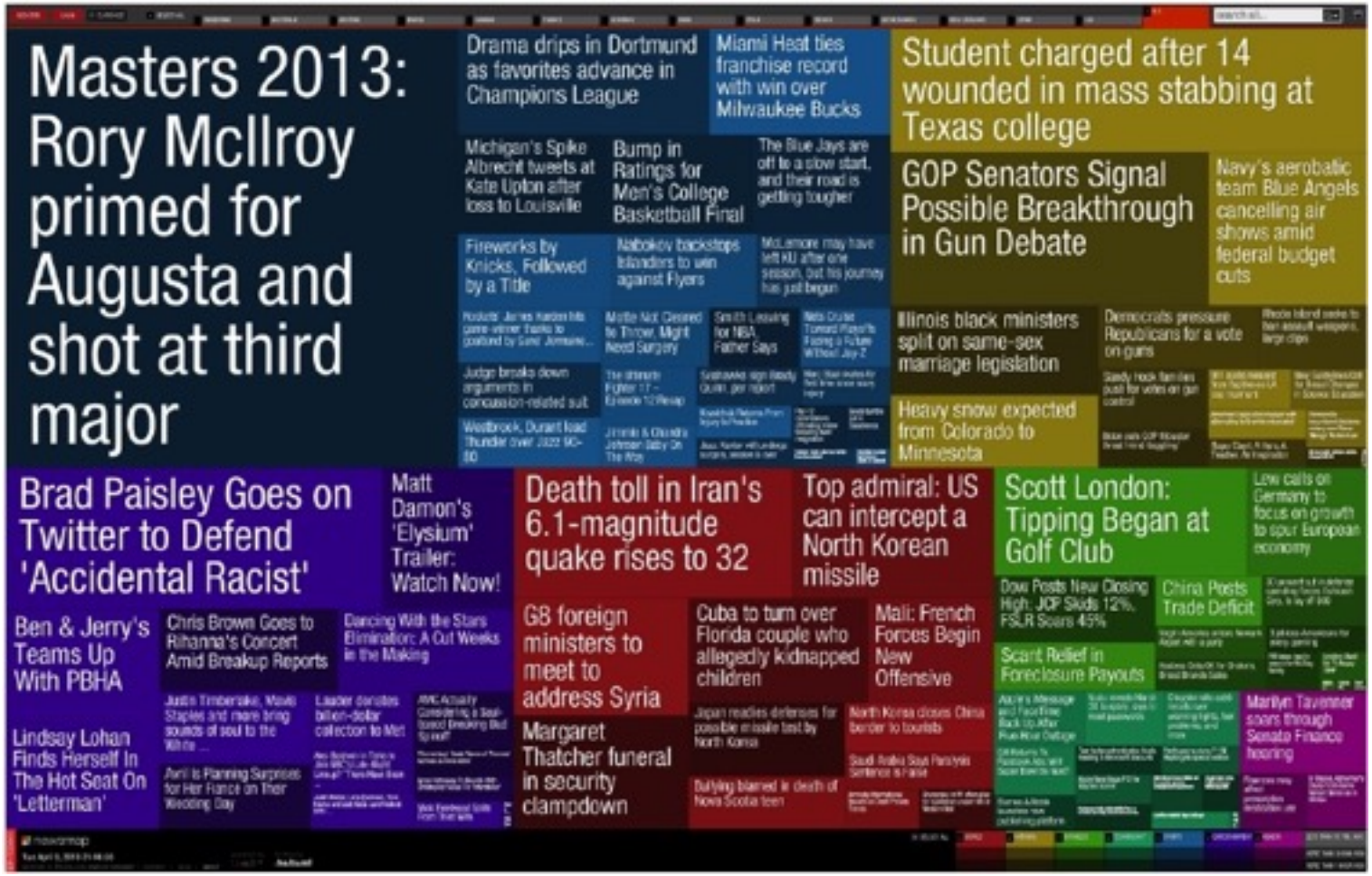
Billion-Dollar-O-Gram

http://www.informationisbeautiful.net/visualizations/the-billion-dollar-o-gram-2009/

Map of the Market

http://www.smartmoney.com/map-of-the-market/

News Map

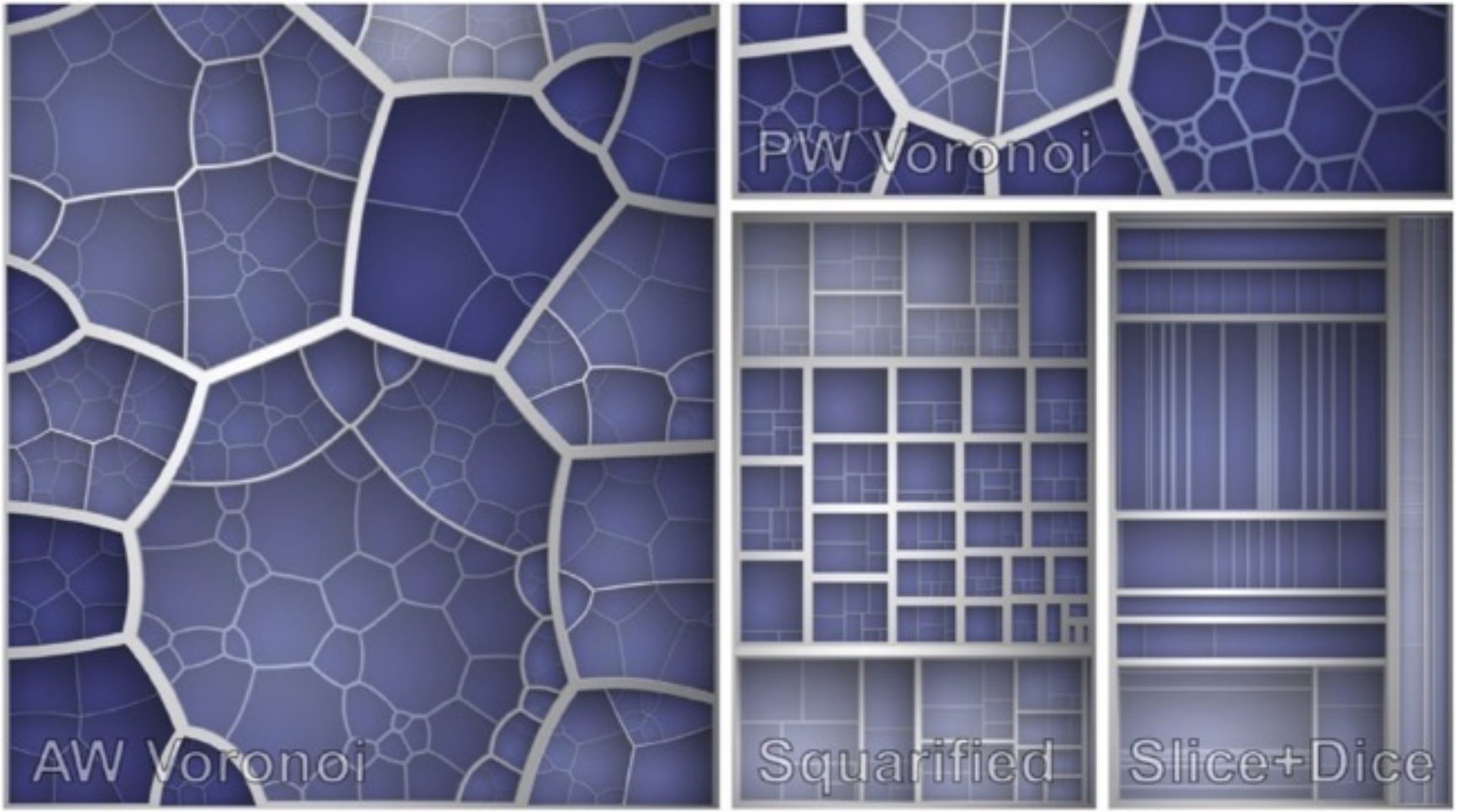


http://newsmap.jp/

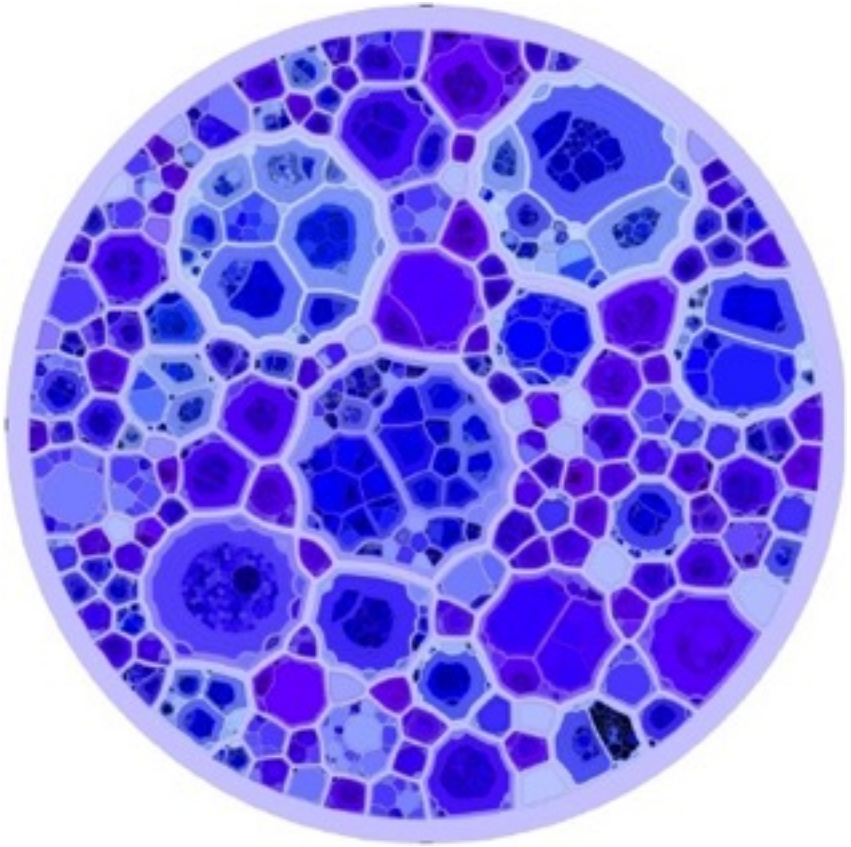
Cushion Treemap

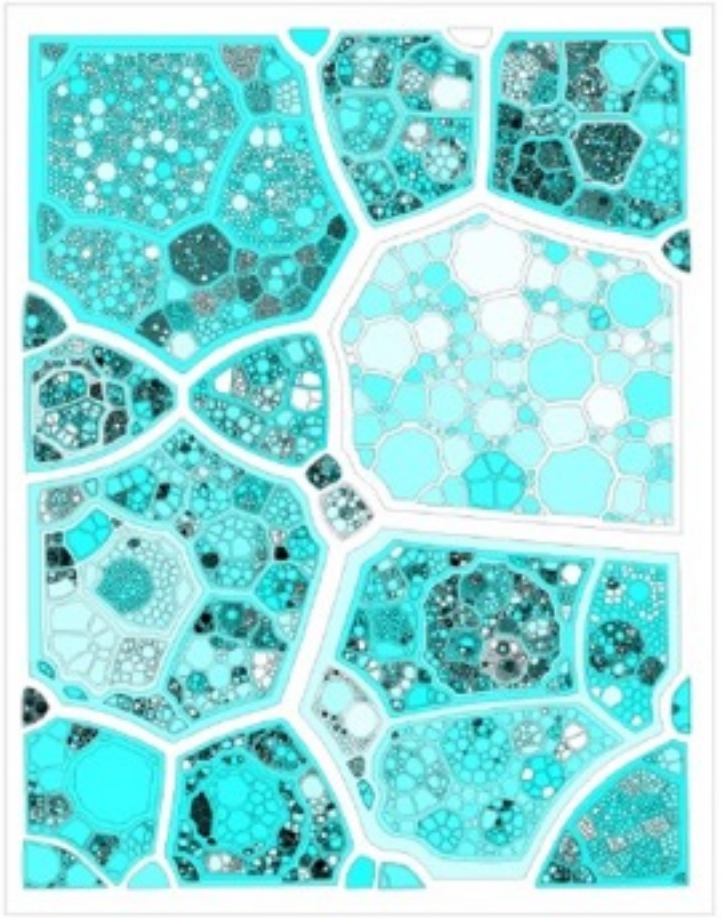
http://philogb.github.io/jit/static/v20/Jit/Examples/Treemap/example3.html

Voronoi Treemaps



Voronoi Treemaps



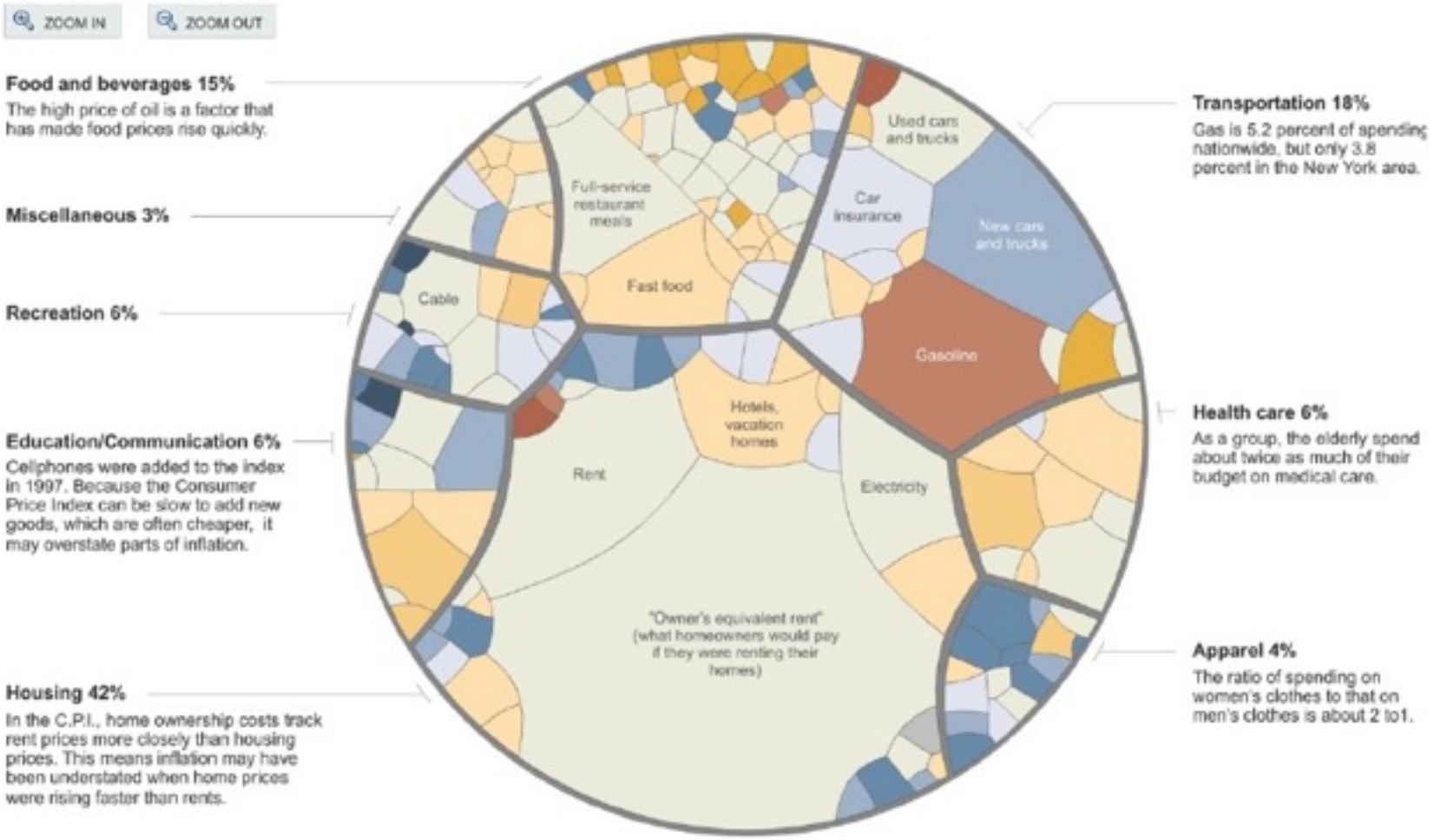


http://graphics.uni-konstanz.de/~deussen/php/voronoitreemaps.php

KEGG-Orthology Treemap

http://www.nature.com/ncomms/journal/v1/n9/full/ncomms1137.html

All of Inflation's Little Parts



http://www.nytimes.com/interactive/2008/05/03/business/20080403_SPENDING_GRAPHIC.html

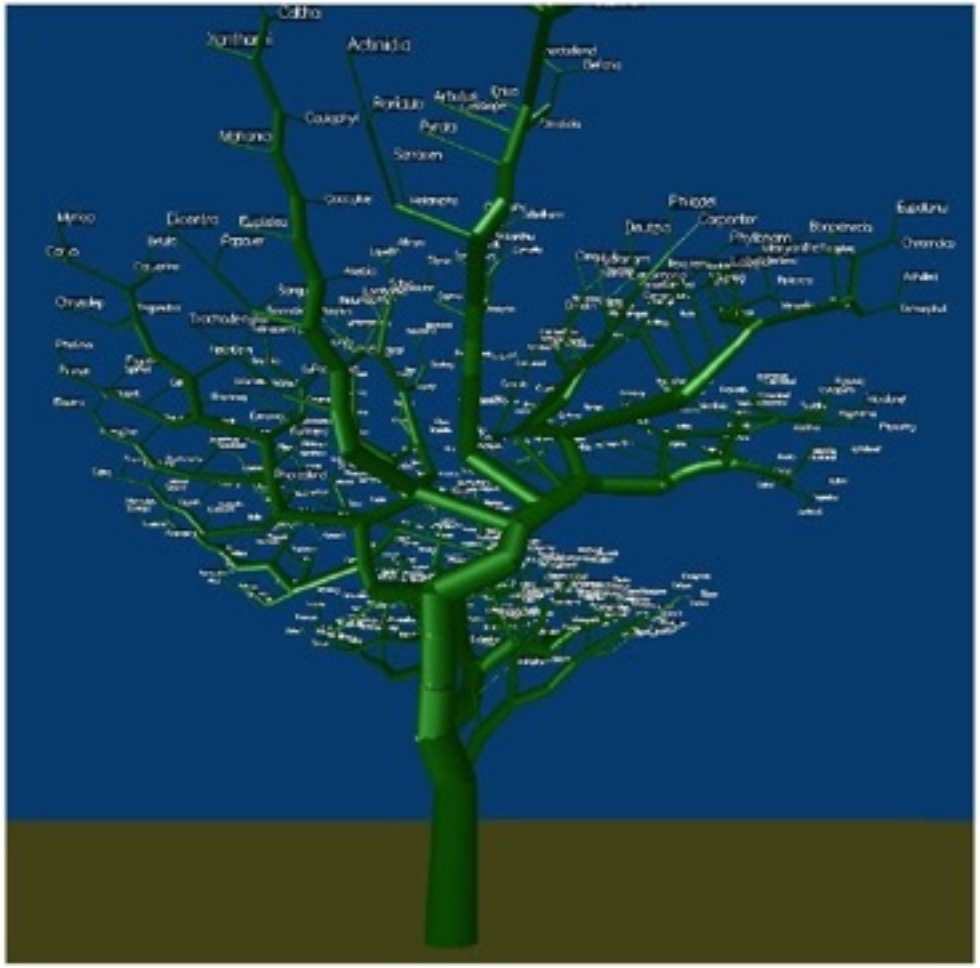
TREE OF LIFE

Case Study

Tree of Life

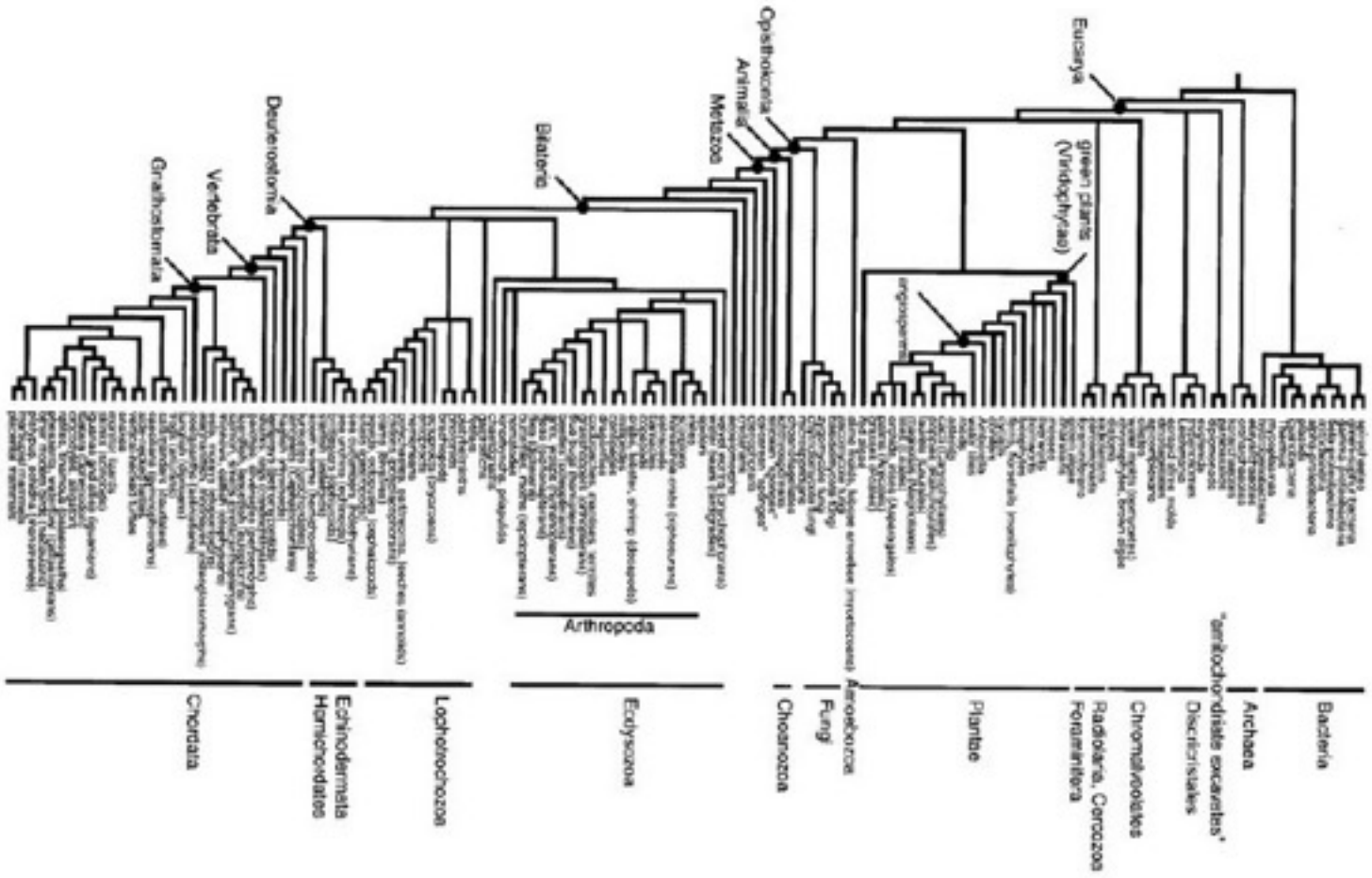
- Specifically phylogenetic tree of life
  - Evolutionary tree, showing where species branch
- Can be thousands to tens of thousands of nodes
- Many tools for the ToL exist using different visualization techniques
- See http://tolweb.org/tree/phylogeny.html

Paloverde



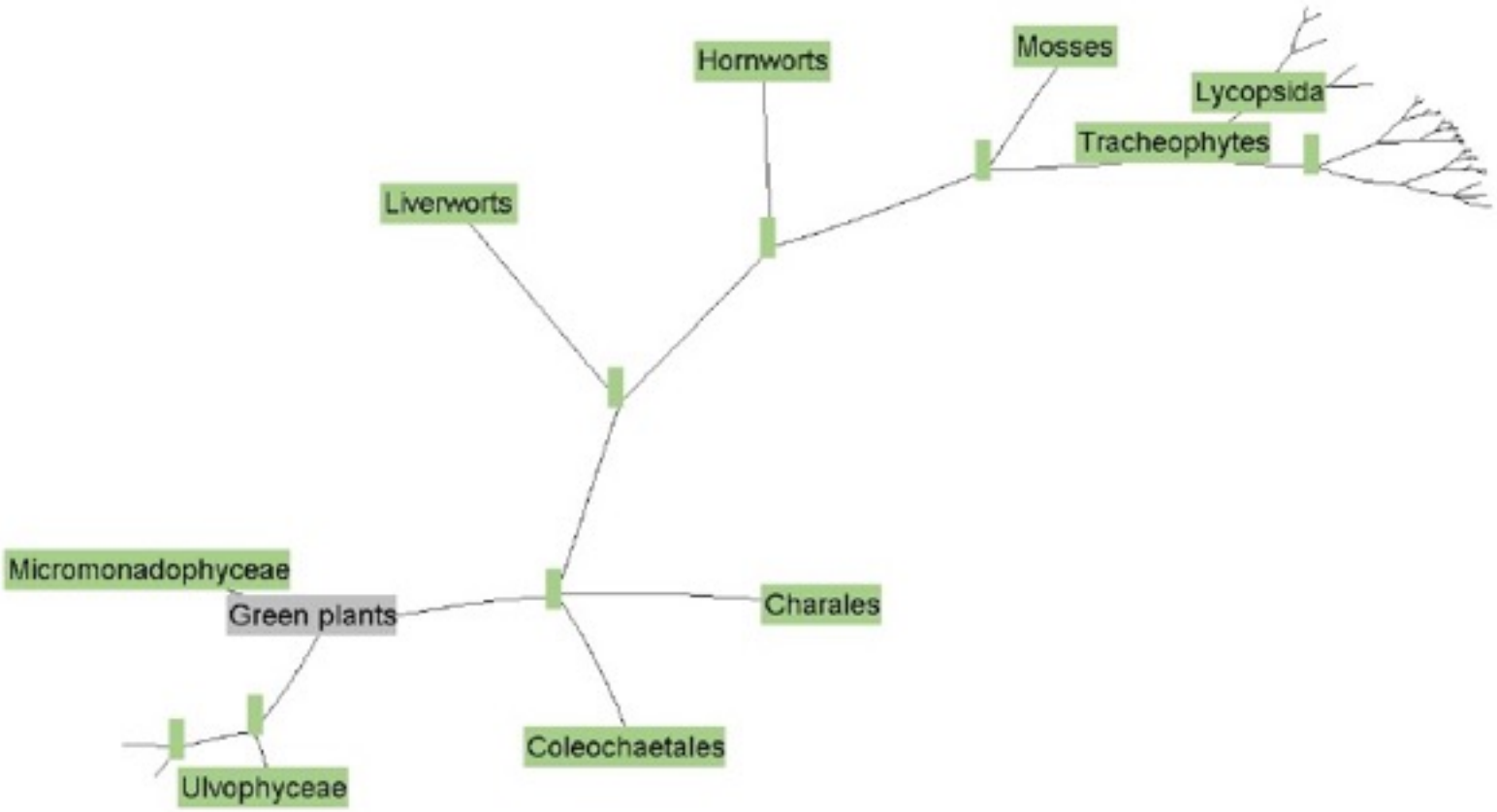
http://loco.biosci.arizona.edu/paloverde/paloverde.html

Teachable ToL



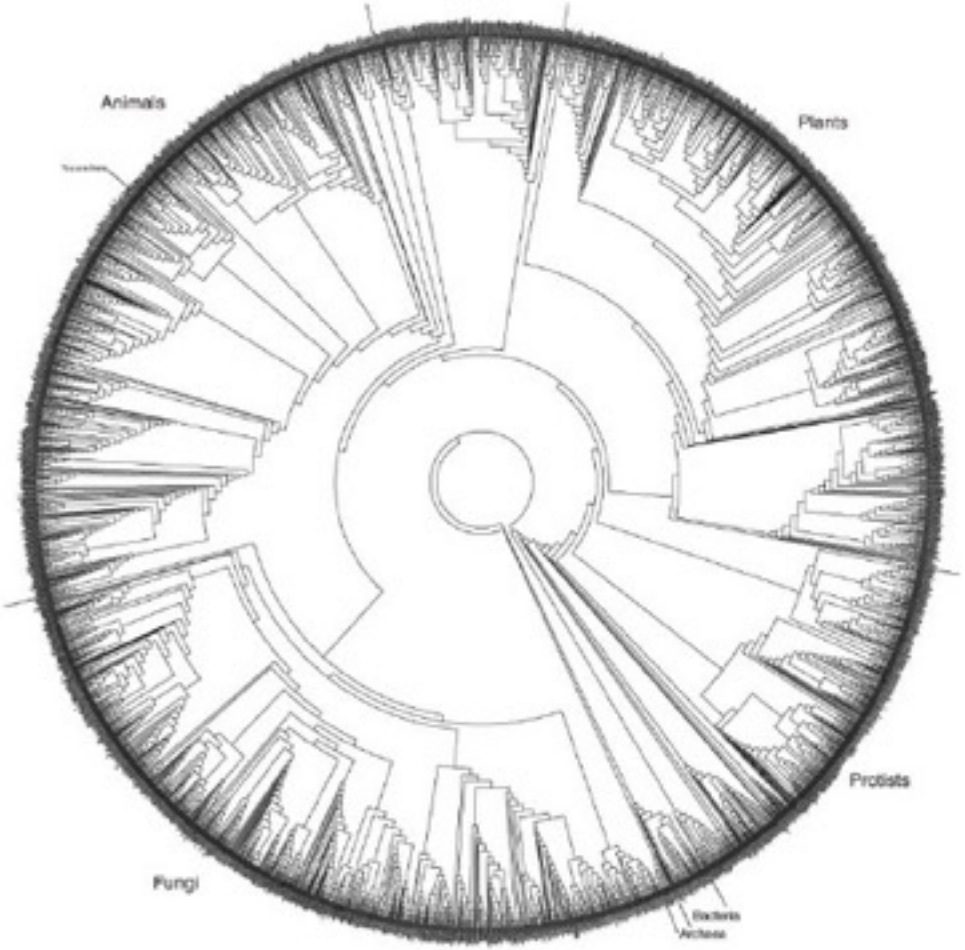
http://www.rebeccashapley.com/cipres/telescoping.htm

Hyperbolic ToL (Plants Only)



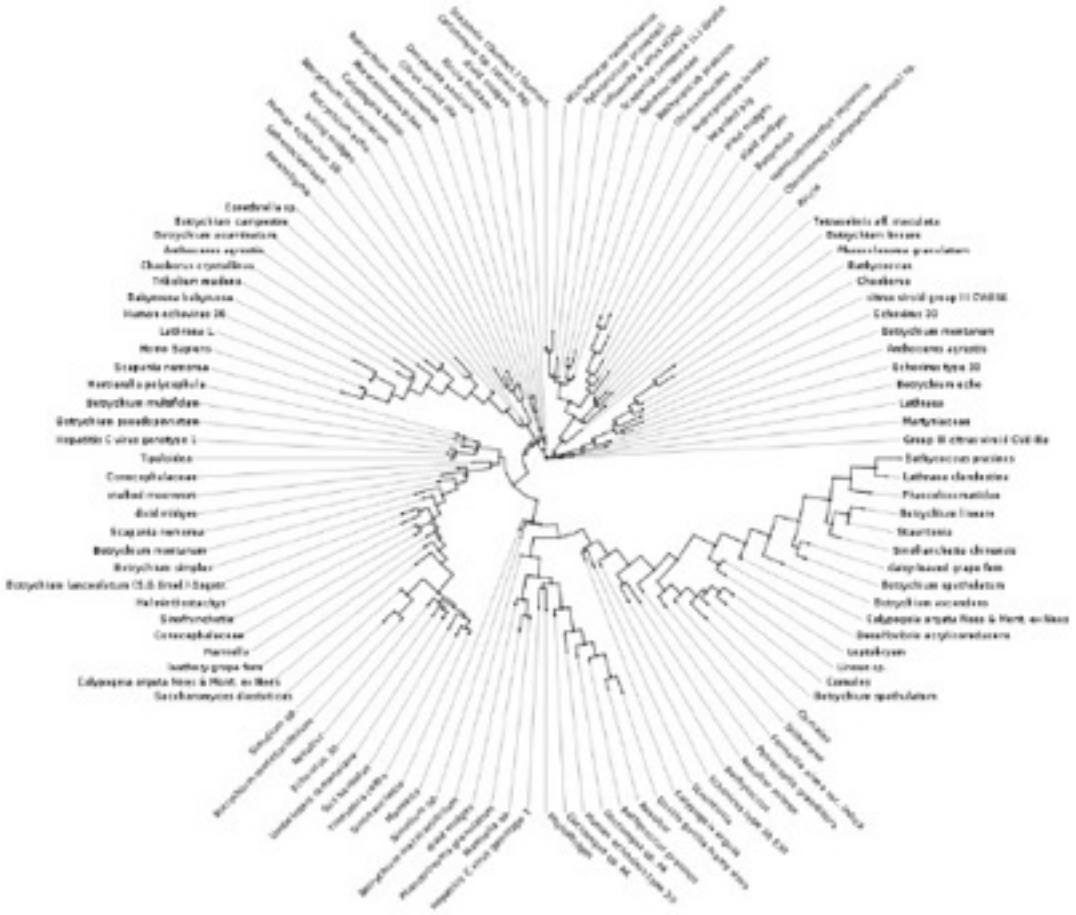
http://ucjeps.berkeley.edu/TreeofLife/hyperbolic.php

Subset of 3,000 Species



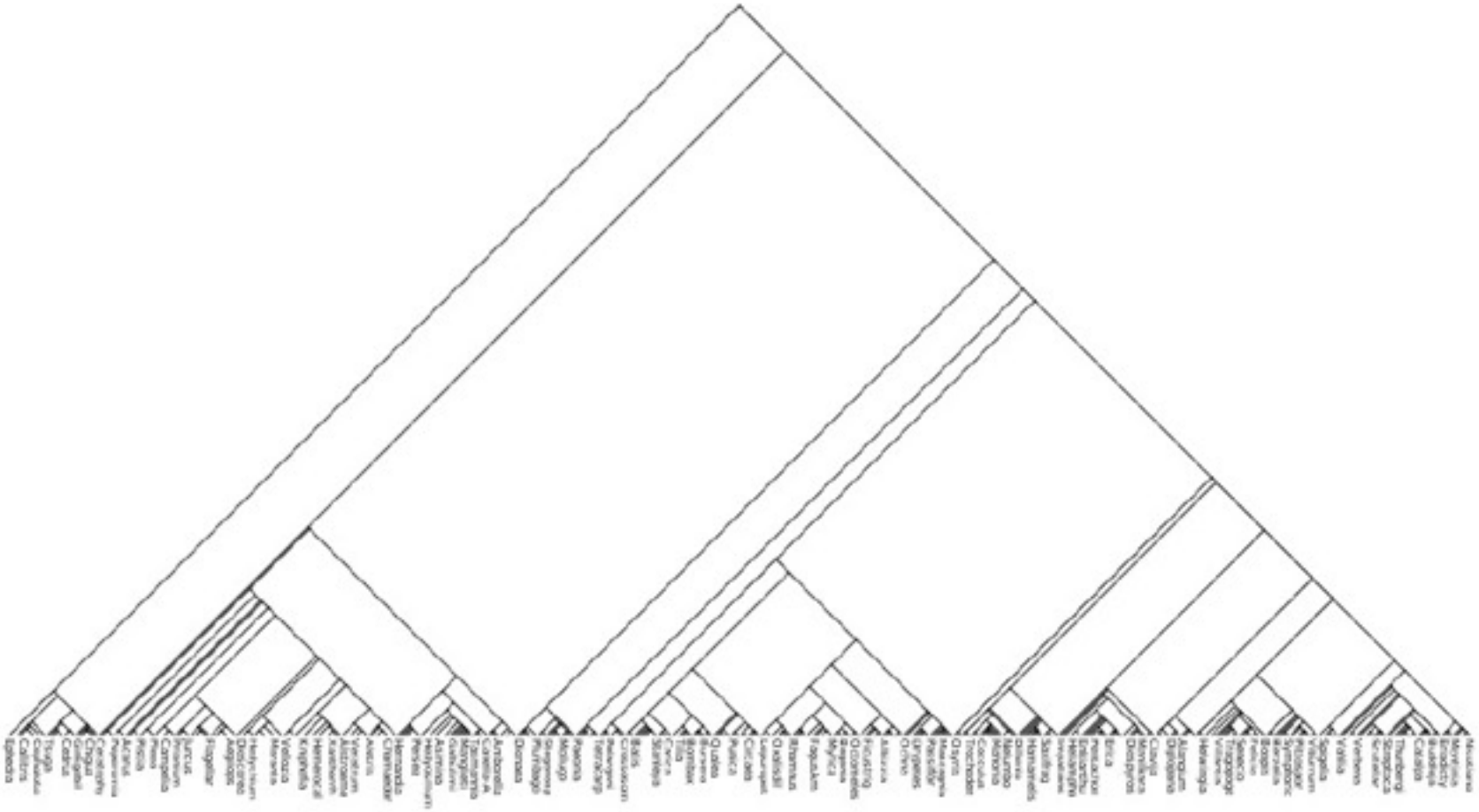
http://www.zo.utexas.edu/faculty/antisense/DownloadfilesToL.html

PhyloWidget



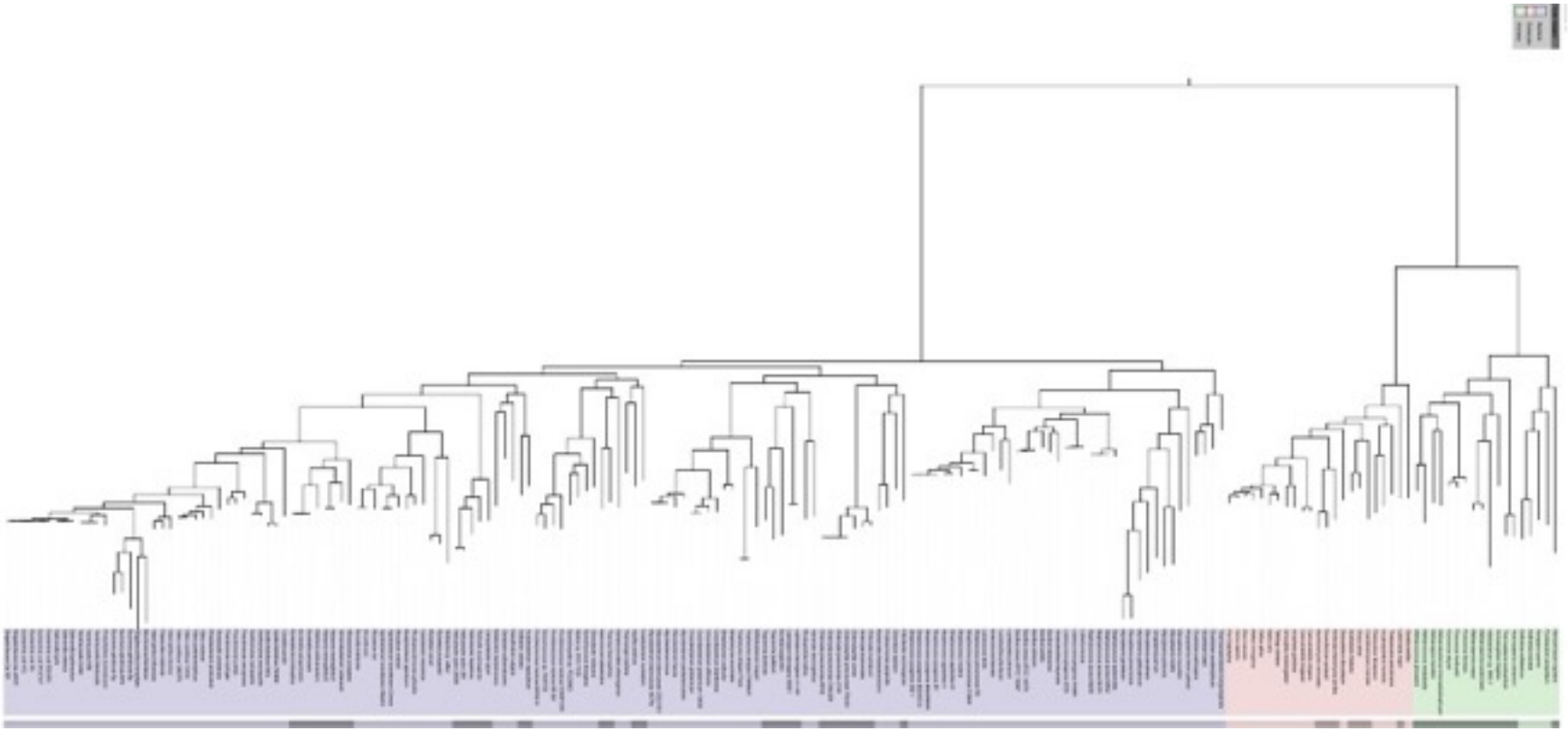
http://www.phylowidget.org/

PhyloWidget



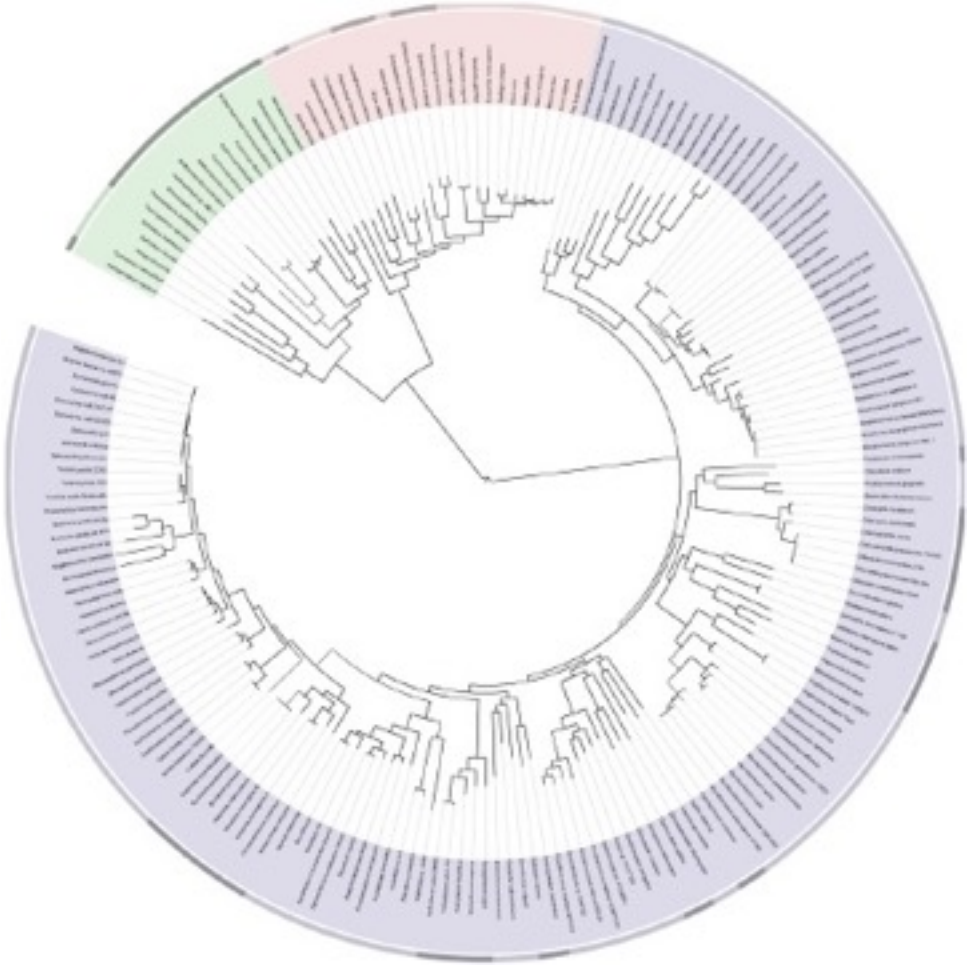
http://www.phylowidget.org/

Interative ToL



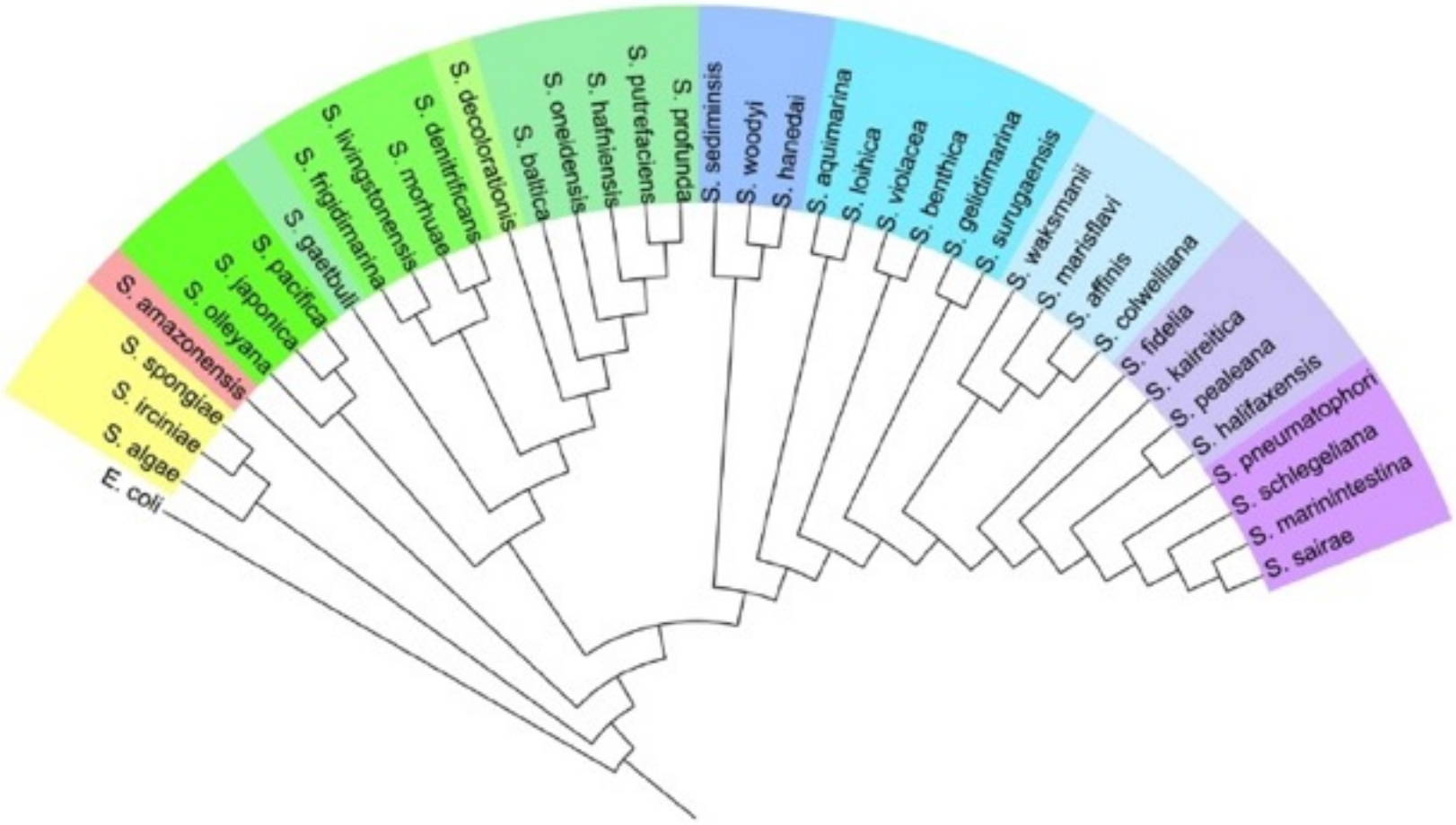
http://itol.embl.de/

Interative ToL



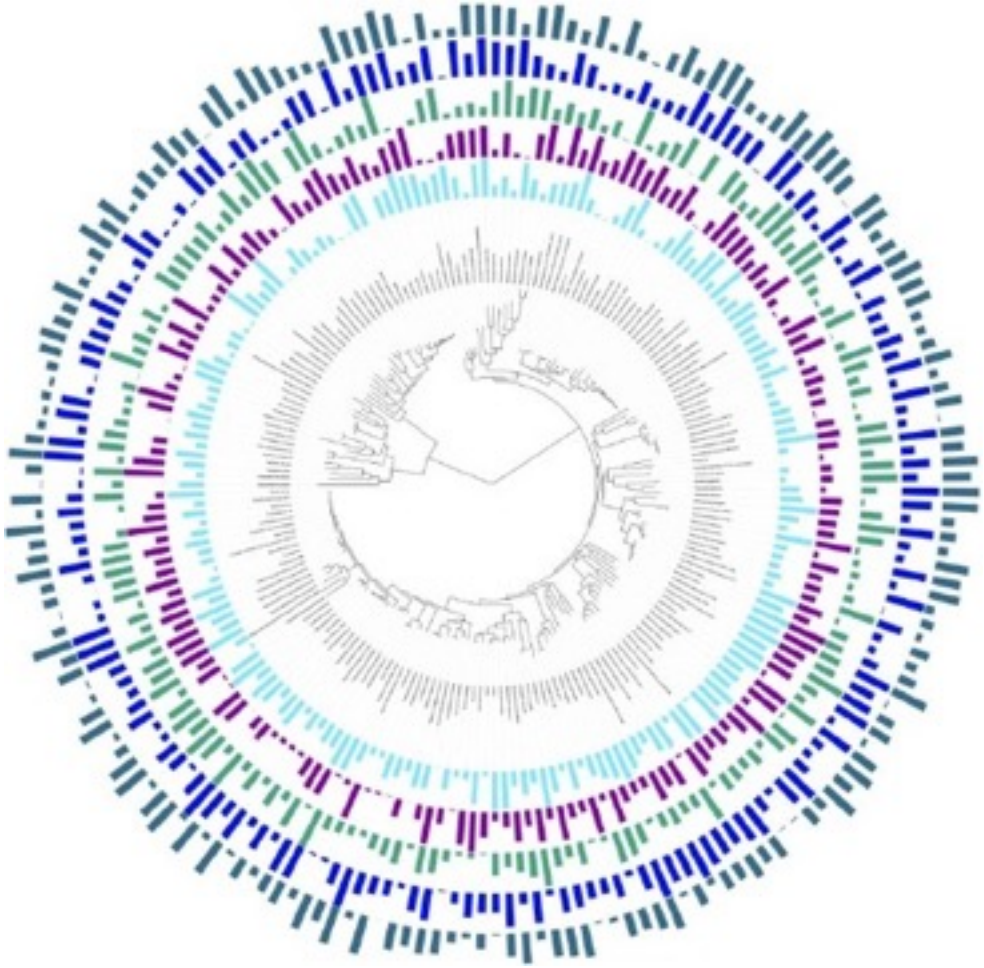
http://itol.embl.de/

Interative ToL



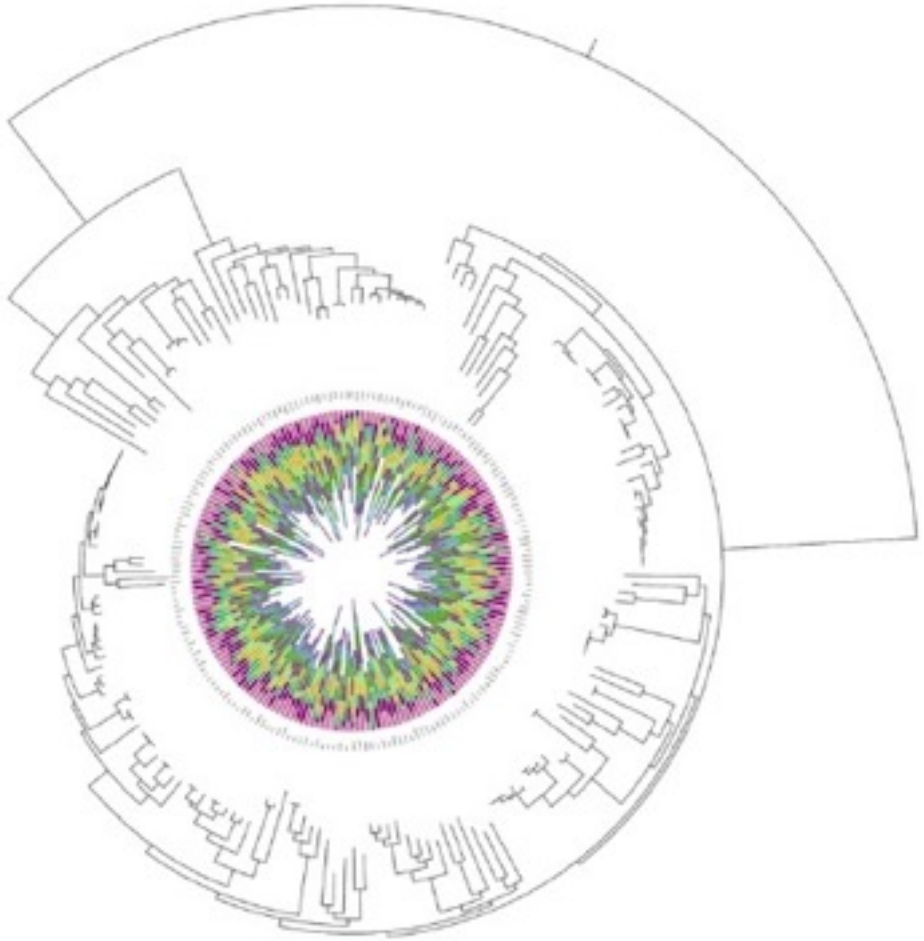
http://itol.embl.de/

Interative ToL



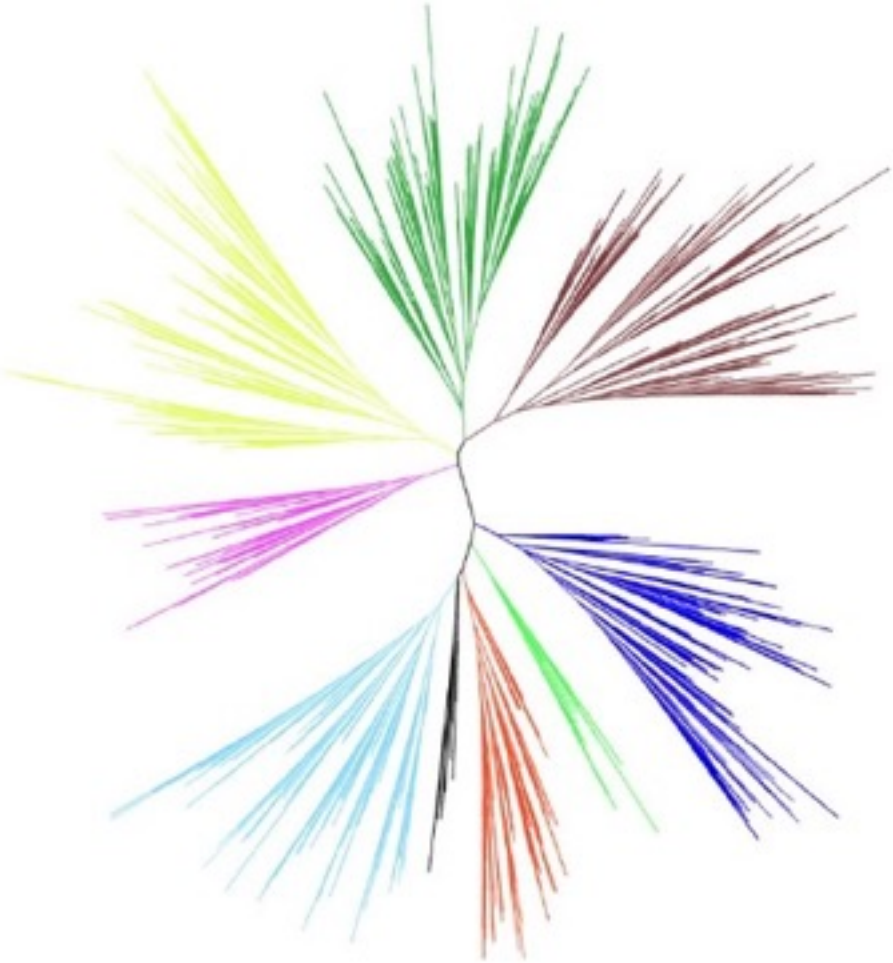
http://itol.embl.de/

Interative ToL



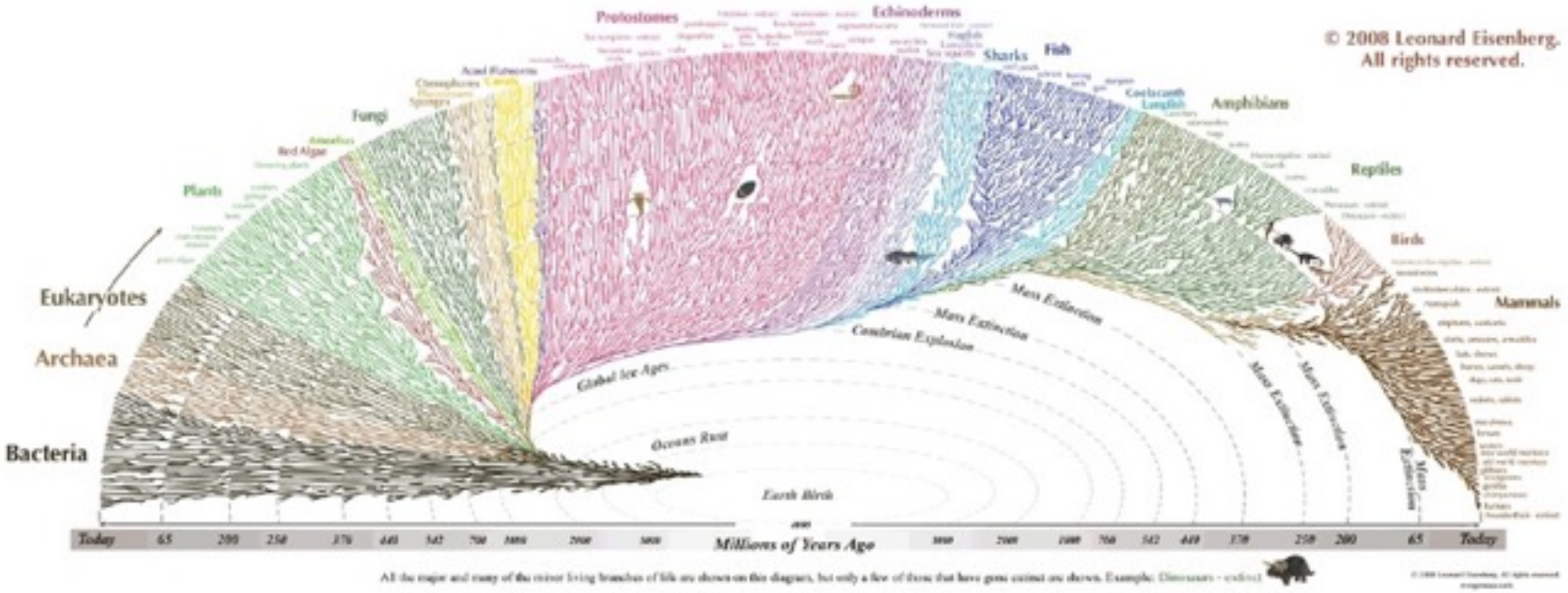
http://itol.embl.de/

Interactive ToL



http://itol.embl.de/

Illustration

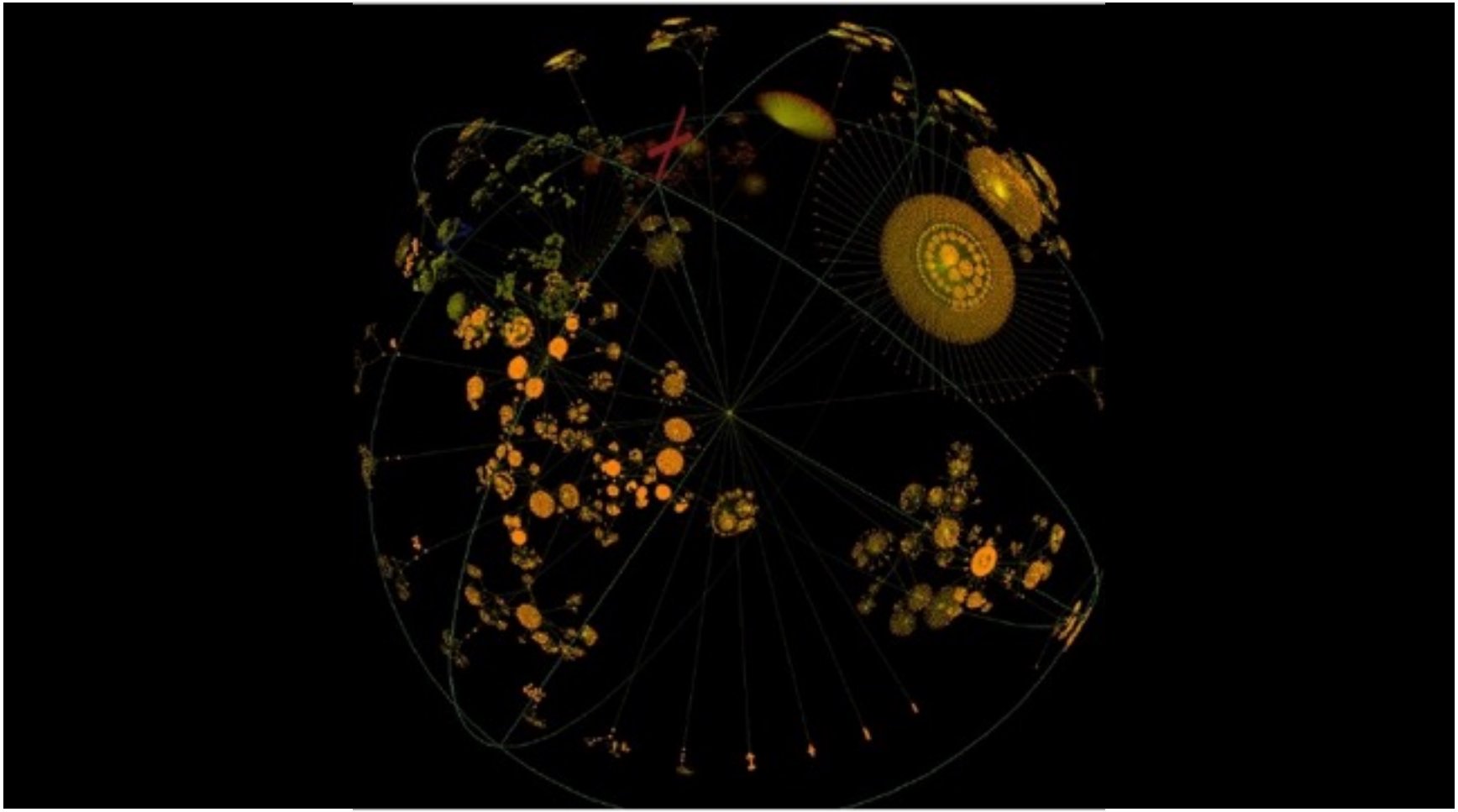


http://www.evogeneao.com/

Interactive ToL (2)

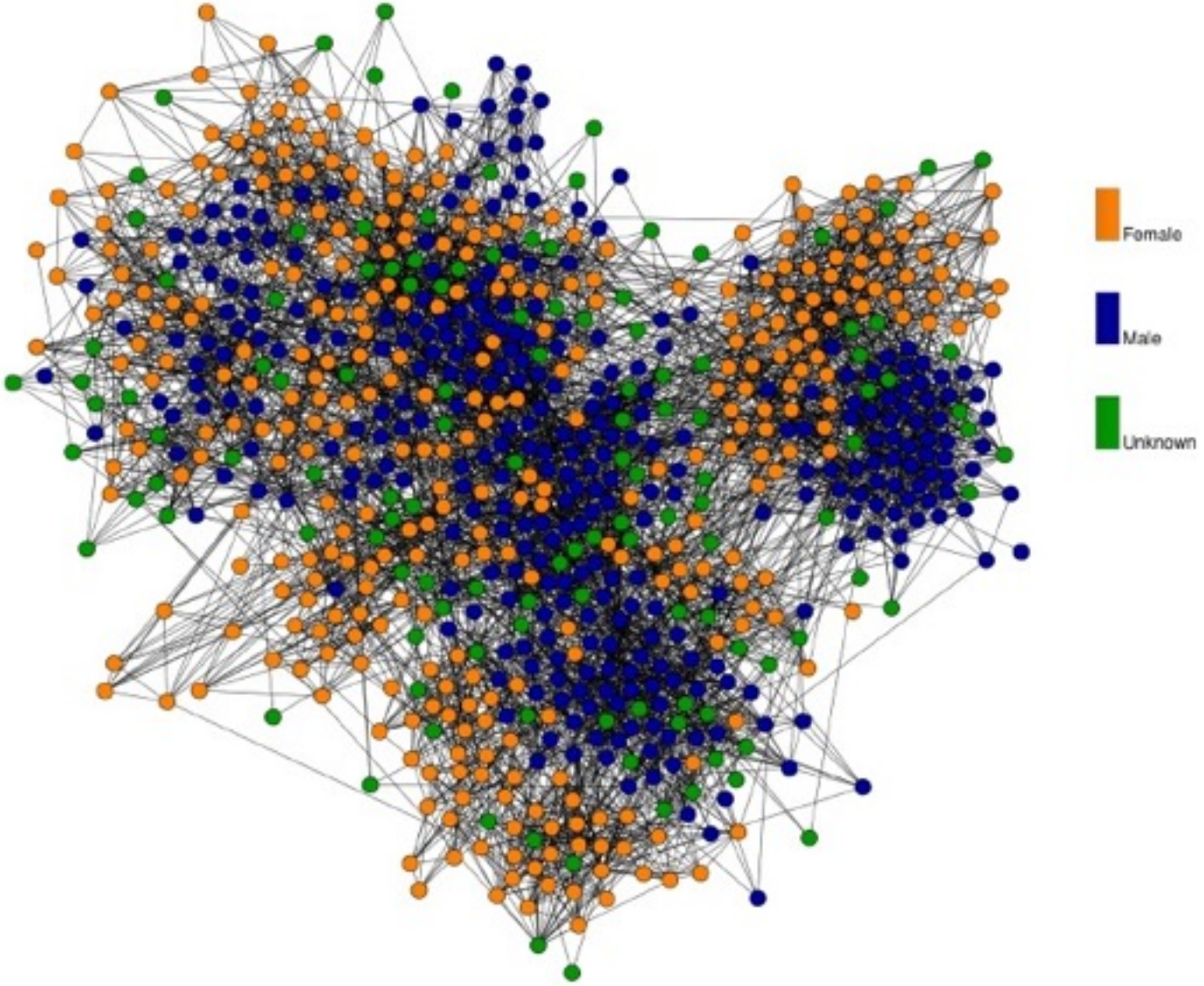
http://www2.research.att.com/~yifanhu/TOL/

ToL Using Walrus

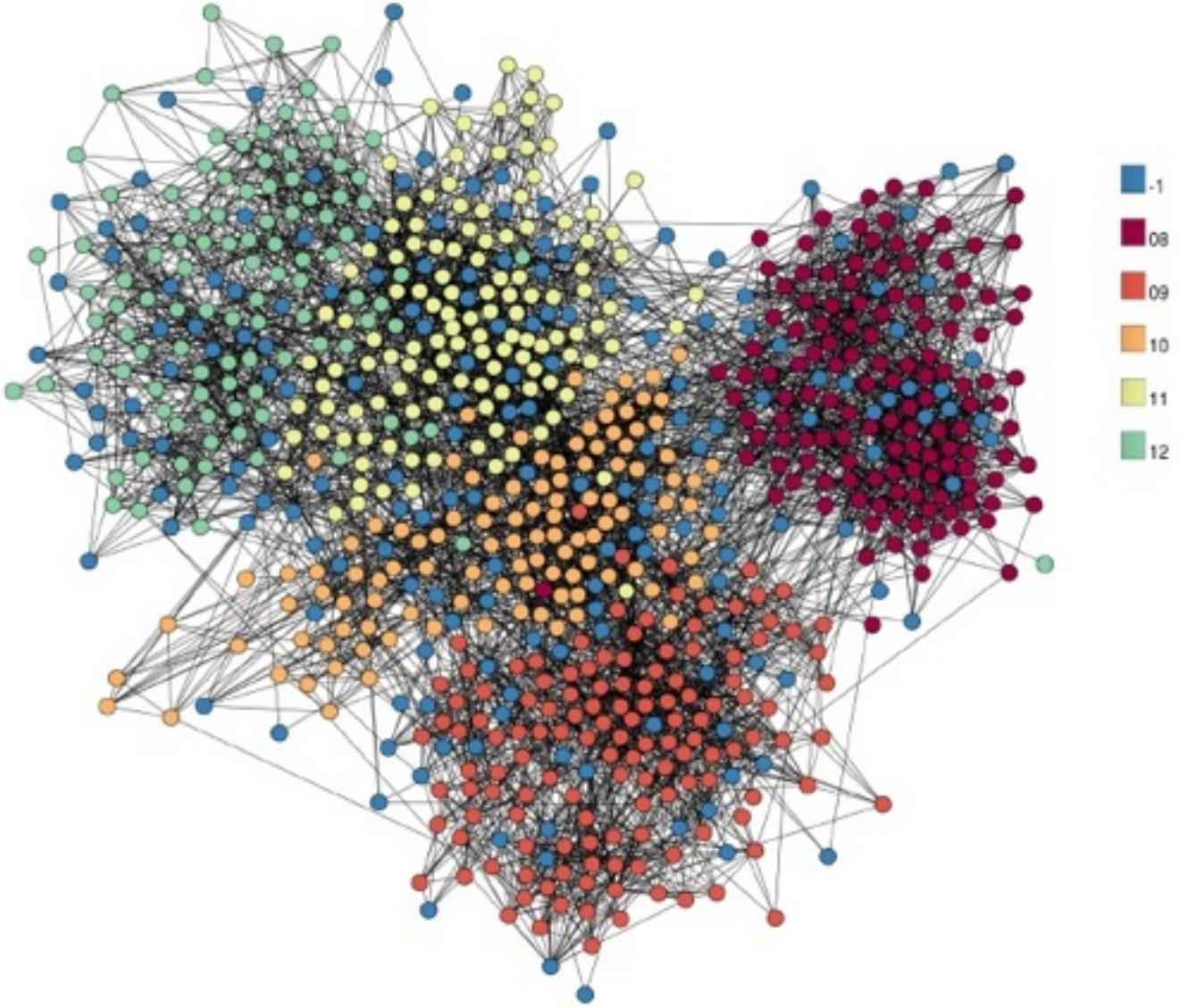


http://digitised.info/content/view/20/51/

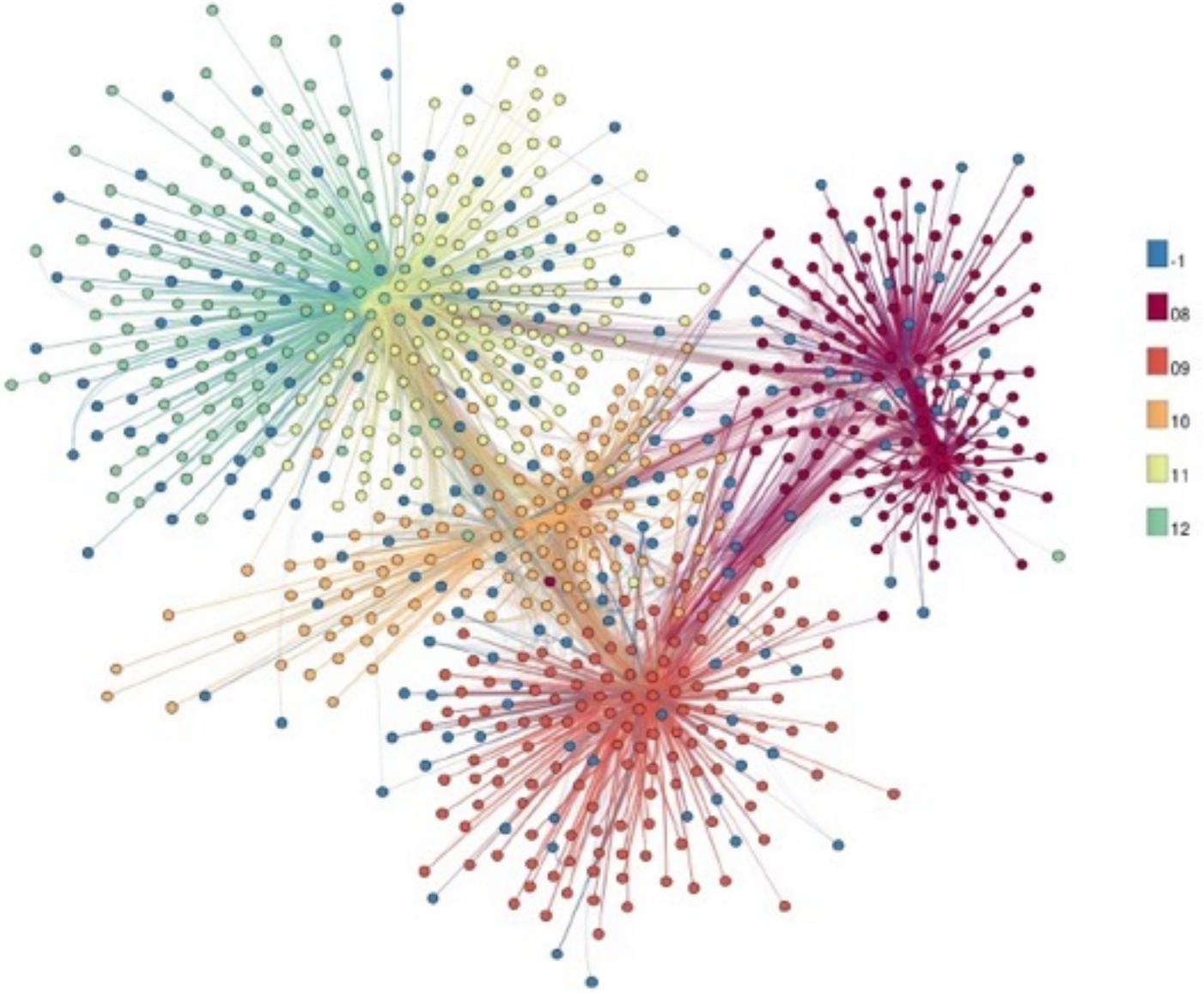
GRAPH VISUALIZATION MOTIVATION



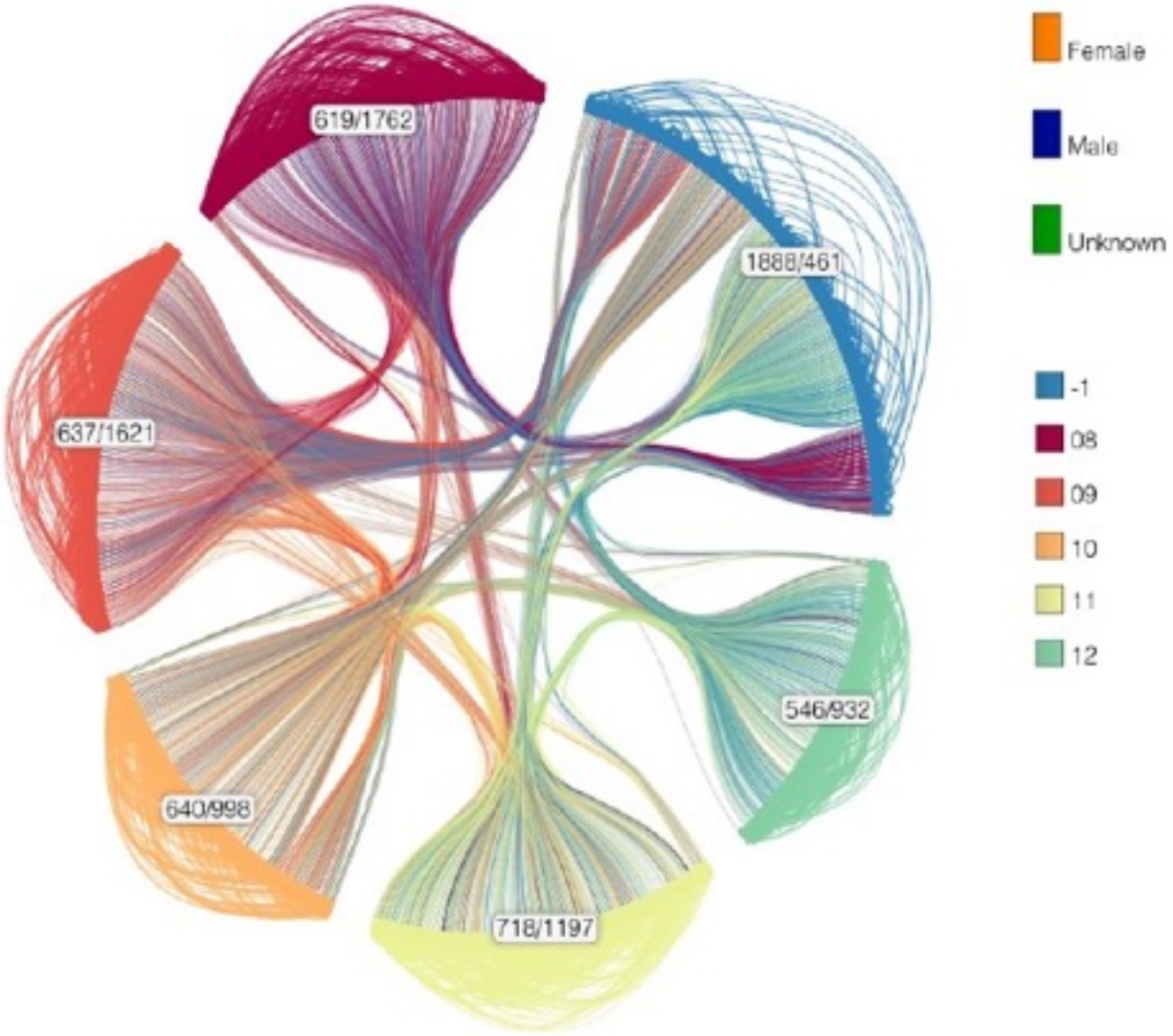
http://vidi.cs.ucdavis.edu/projects/AggressionNetworks/



http://vidi.cs.ucdavis.edu/projects/AggressionNetworks/



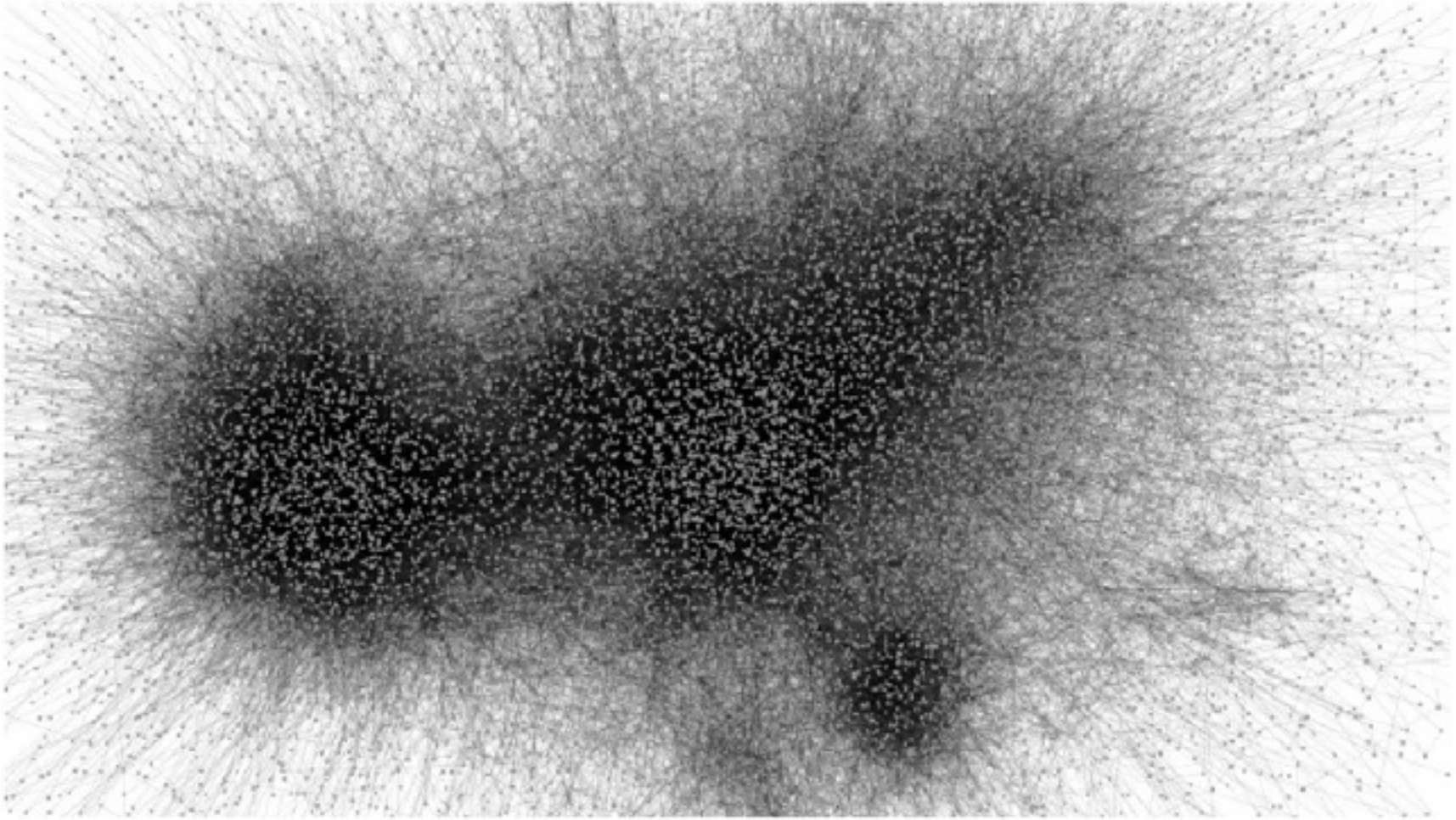
http://vidi.cs.ucdavis.edu/projects/AggressionNetworks/



http://vidi.cs.ucdavis.edu/projects/AggressionNetworks/

What considerations should we make when visualizing graphs?

Hairballs



http://www.michelecoscia.com/?p=171

Hairballs

http://www.nytimes.com/imagepages/2008/11/20/science/20mammoth.ready.html

Considerations

- Node Layout
  - Place randomly?
  - Place on grid?
  - Place by metric?
  - Place using physics?
- Node Attributes
  - Color?
  - Size?
  - Shape?
- Edge Layout
  - Straight edges?
  - Curved edges?
  - Edge crossings?
  - Edge bundling?
- Edge Attributes
  - Color?
  - Width?
  - Arrows?

Considerations

- Non overlapping nodes?
- Visible labels?
- Minimize edge crossings?
- Minimize distance between nodes?
- View overall structure?
- View connections and connectivity?
- View detailed subgraphs?

MATRIX DIAGRAMS

Matrix Diagrams

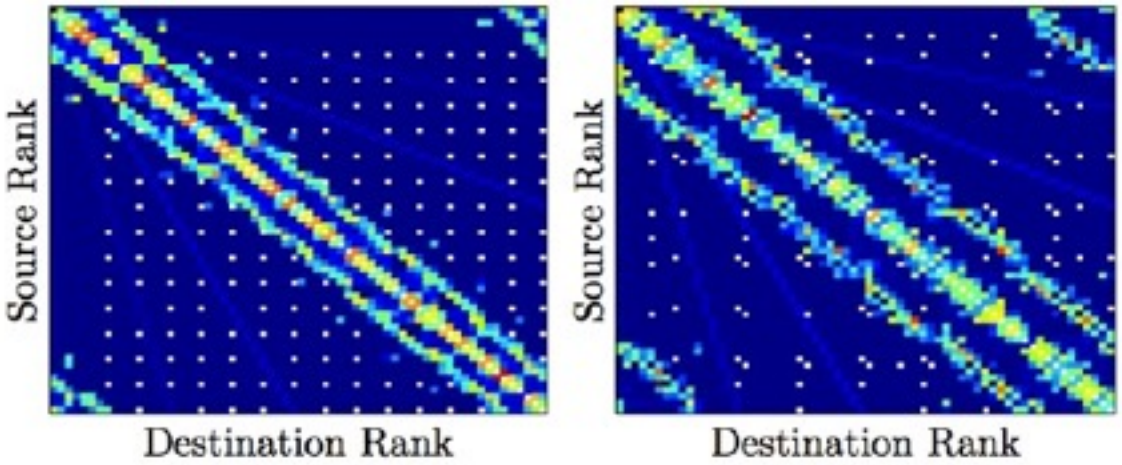
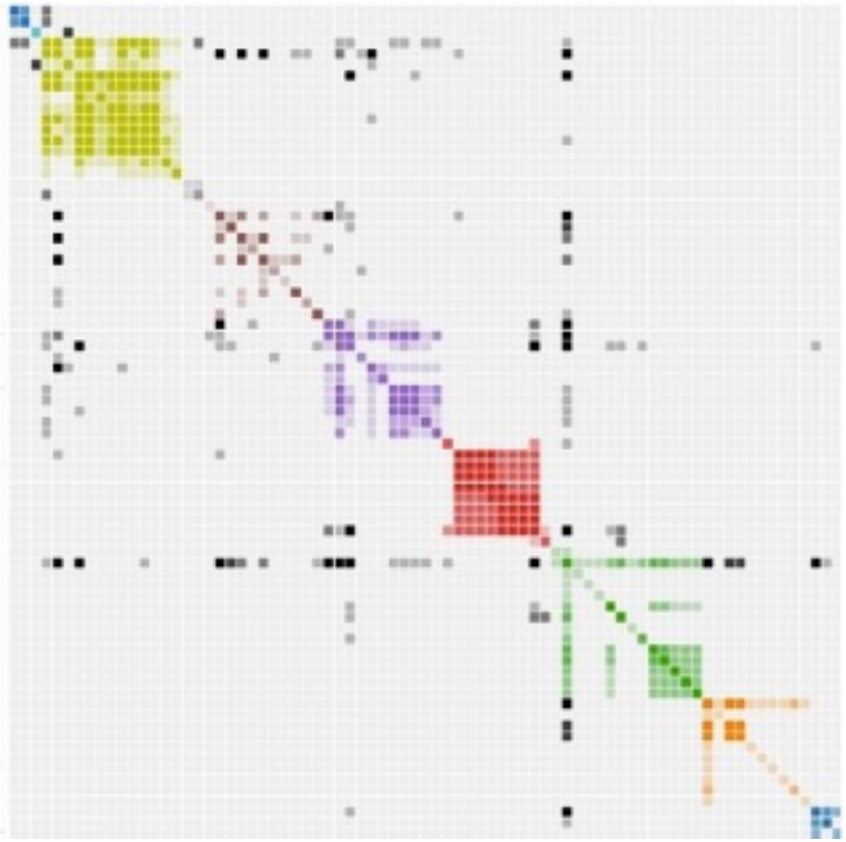


Figure 3: Data dependent topology demonstrated by molecular dynamics simulator NAMD under different molecular arrangements. The number of bytes sent between ranks is linearly mapped from dark blue (lowest) to red (highest), with white indicating an absence of communication.

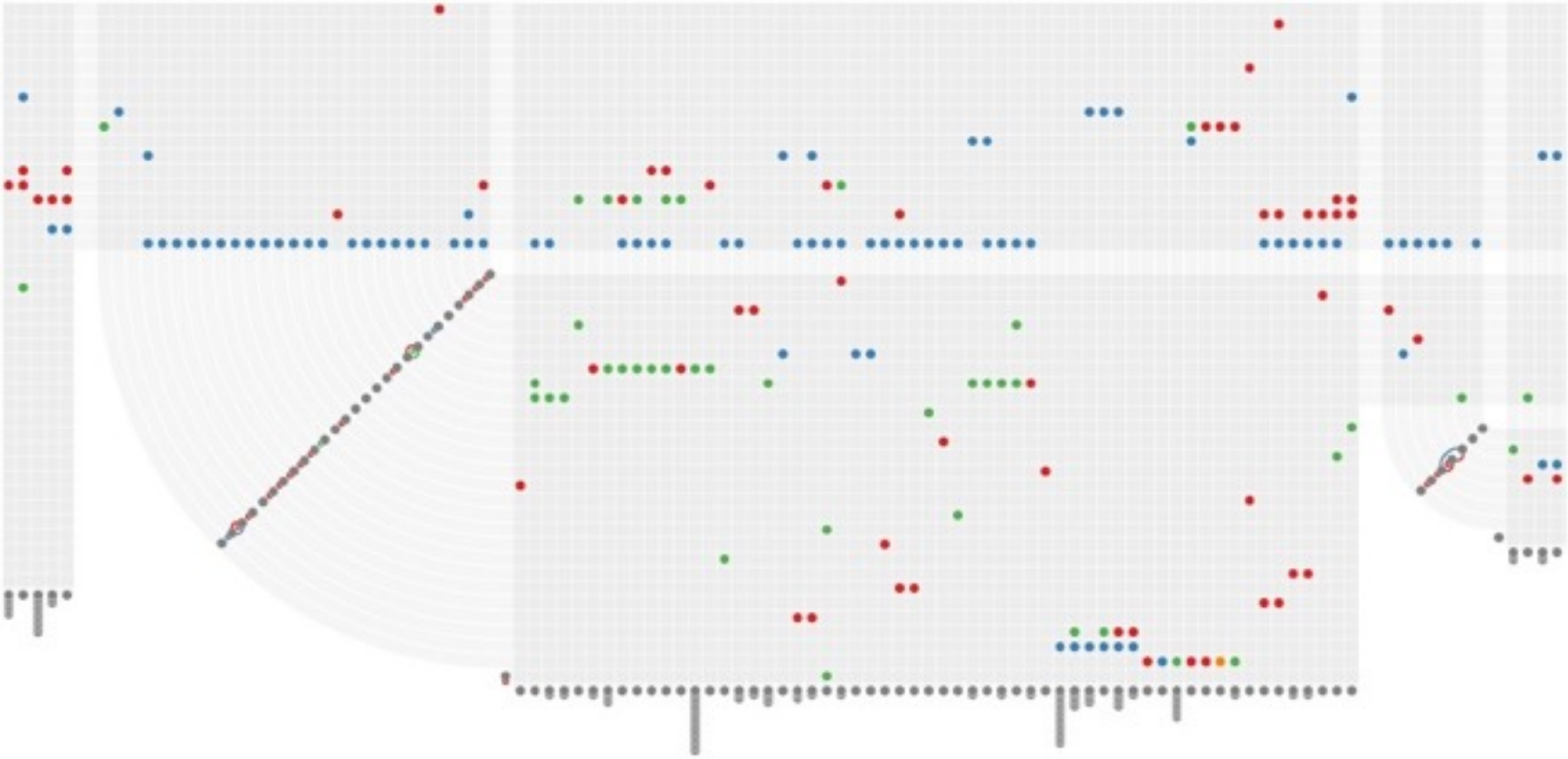
http://node99.org/papers/ntc-journal.pdf

Les Misérables Co-Occurrence



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

Compressed Adjacency Matrix



http://www.computer.org/csdl/trans/tg/2012/12/ttg2012122457-abs.html

NODE LAYOUT

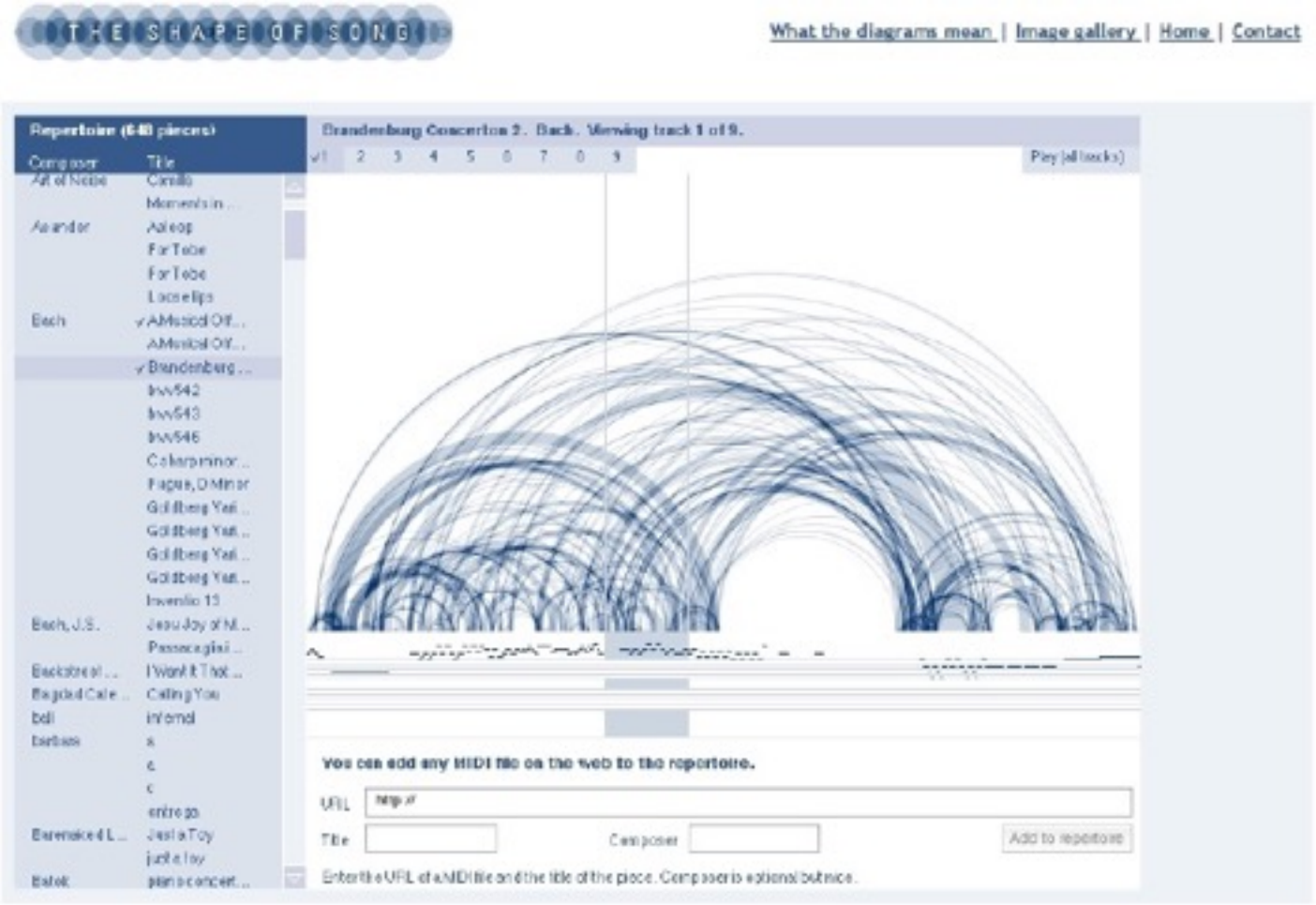
Common Graph Layouts

- Arc Diagrams
- Circle Layout
- Spring and Force-Directed Layouts
- Self-Organizing Map Layout
- Fruchterman Reingold Layout
- Kamada Kawai Layout
- Hive Plots
- Multi-Level Layouts

Arc Diagram

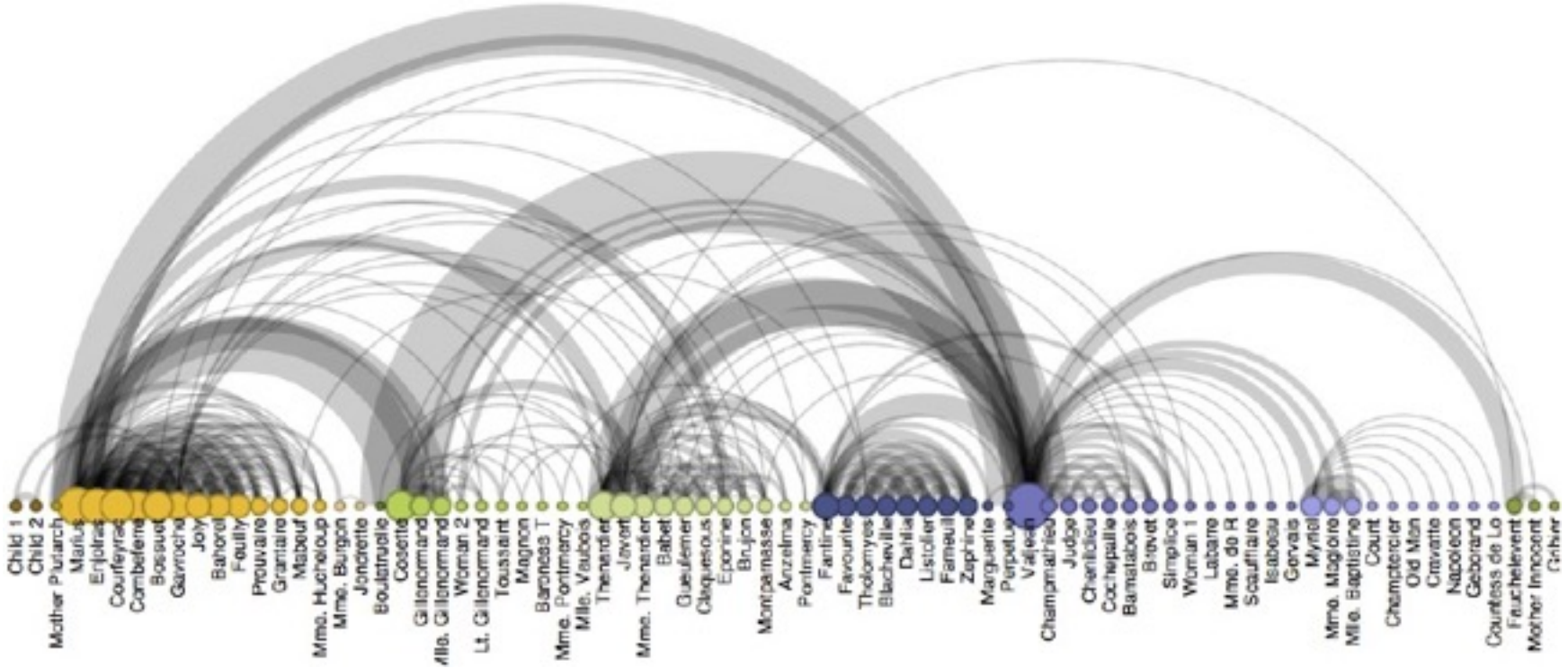
http://www.turbulence.org/Works/song/method/method.html

Arc Diagram



http://www.turbulence.org/Works/song/mono.html

Arc Diagram in Protovis

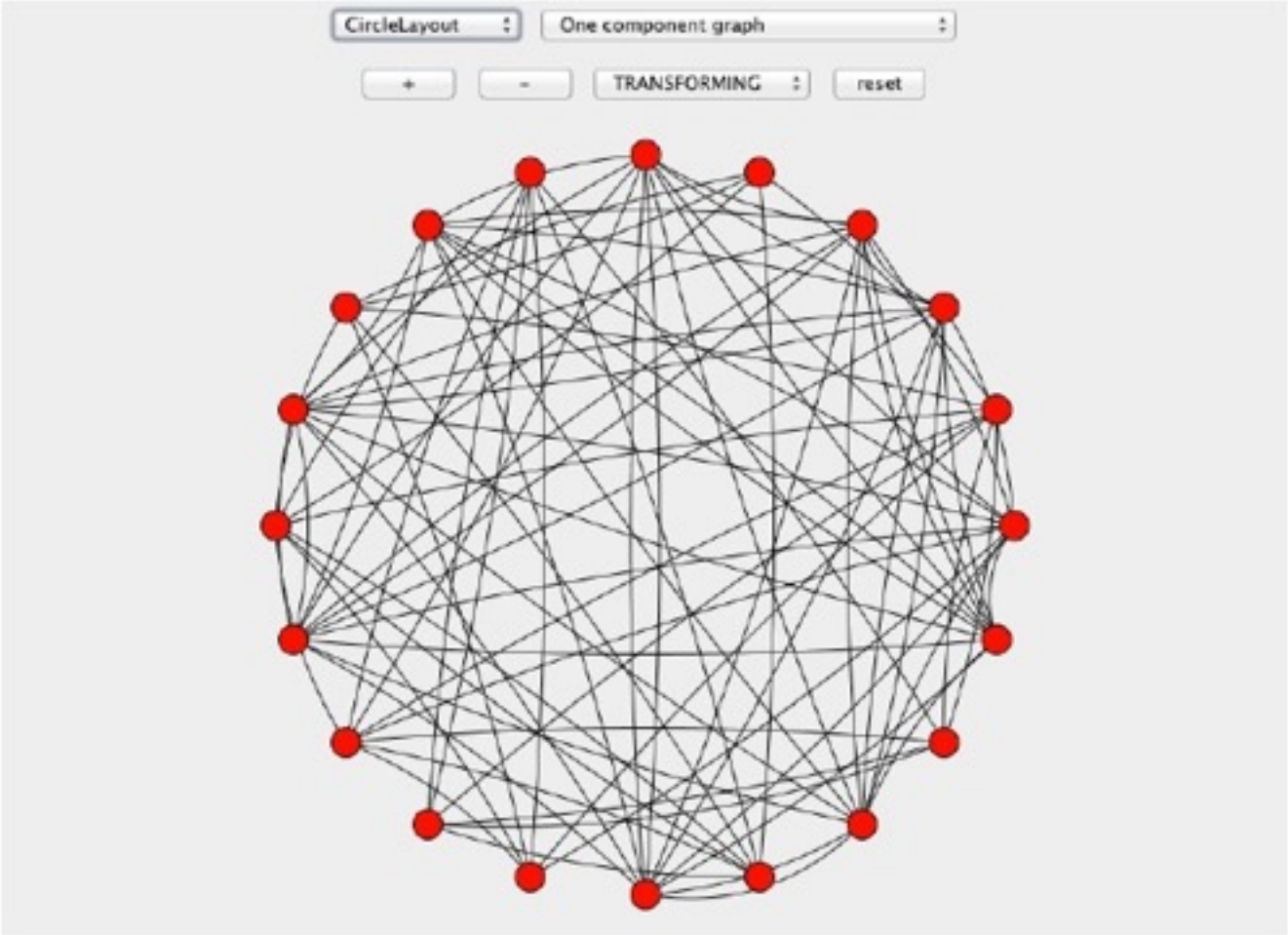


http://mbostock.github.io/protovis/ex/arc.html

Similar Diversity

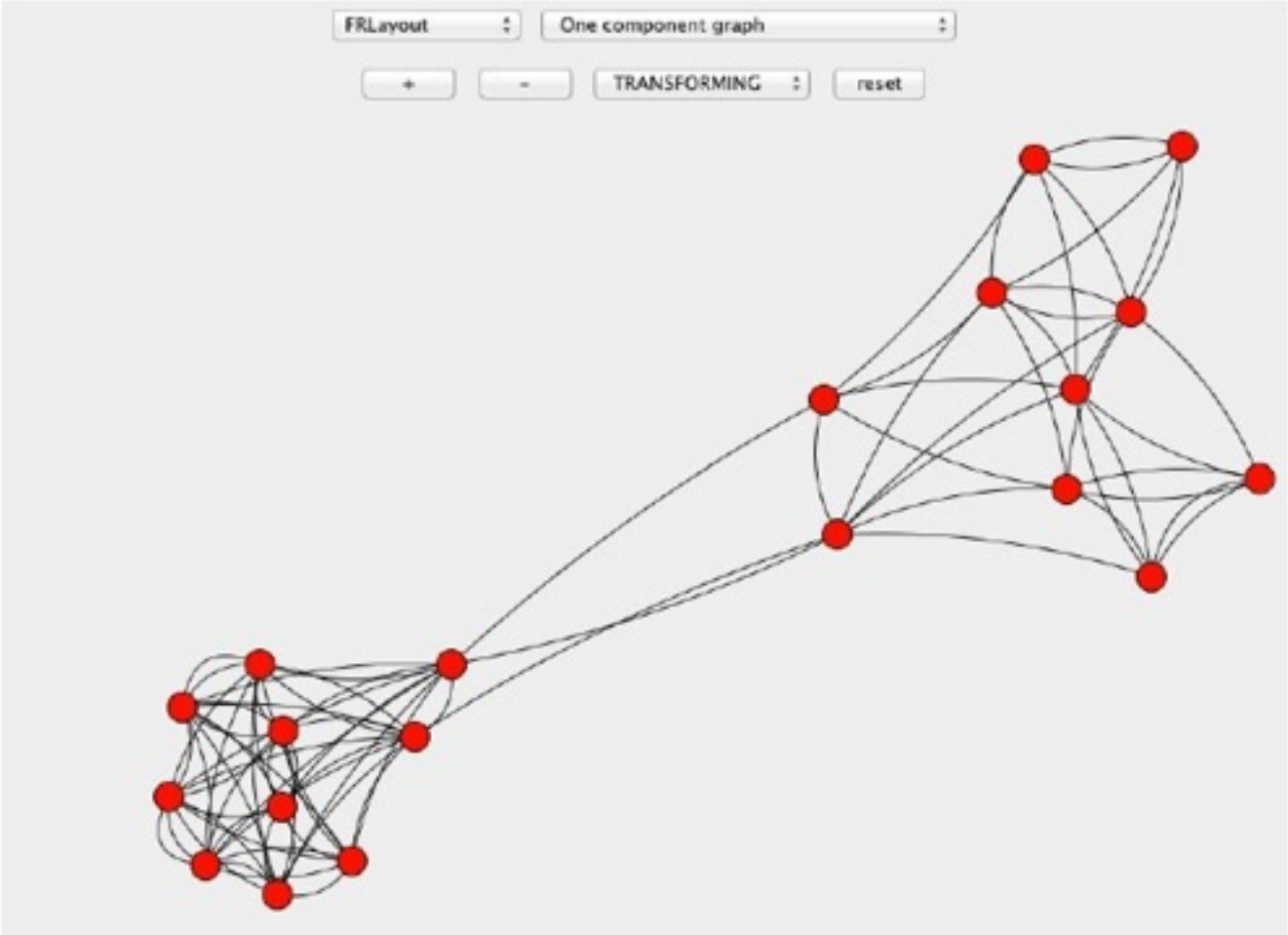
http://similardiversity.net/about/

JUNG Layouts



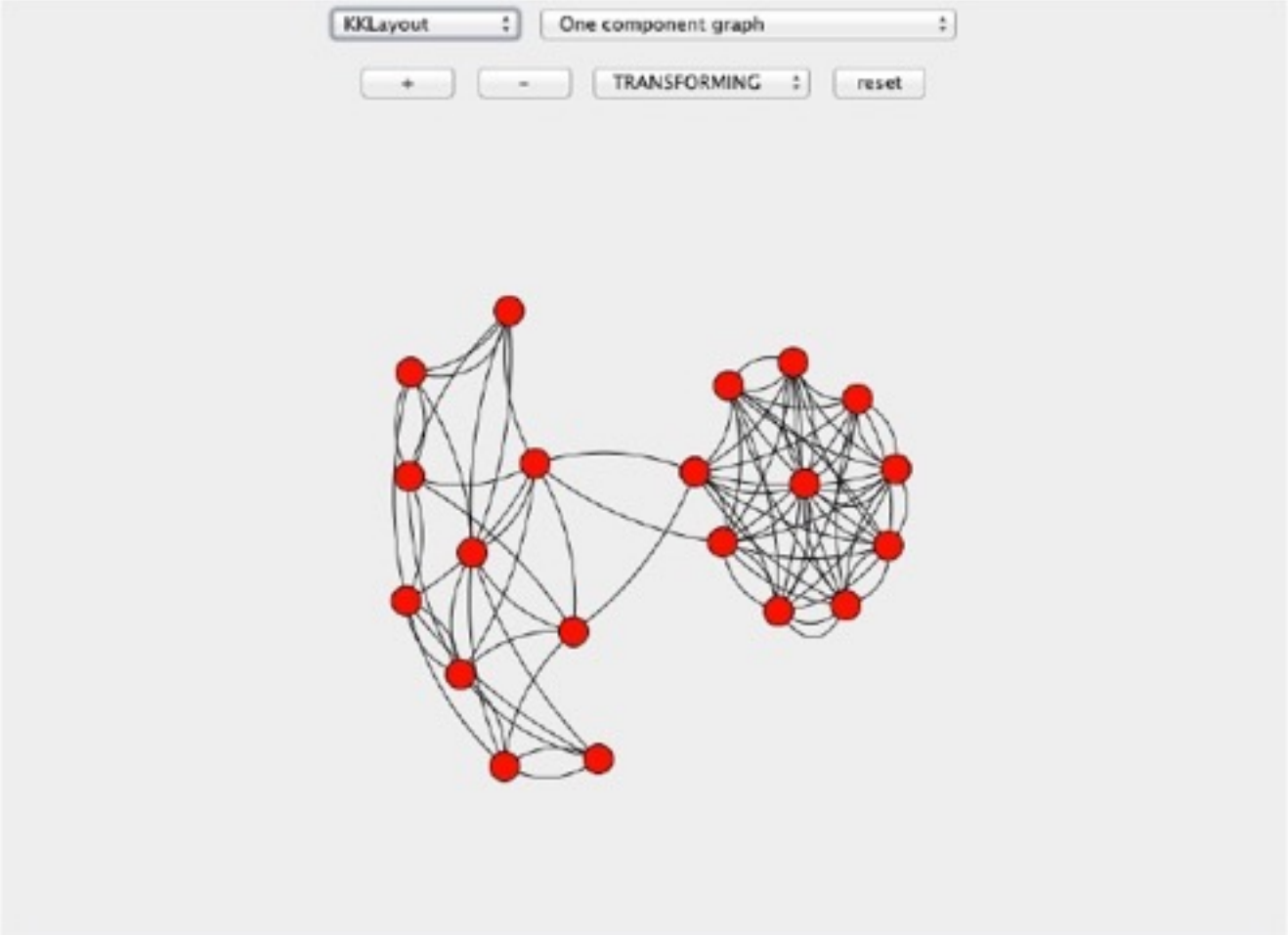
http://jung.sourceforge.net/applet/showlayouts2.html

JUNG Layouts



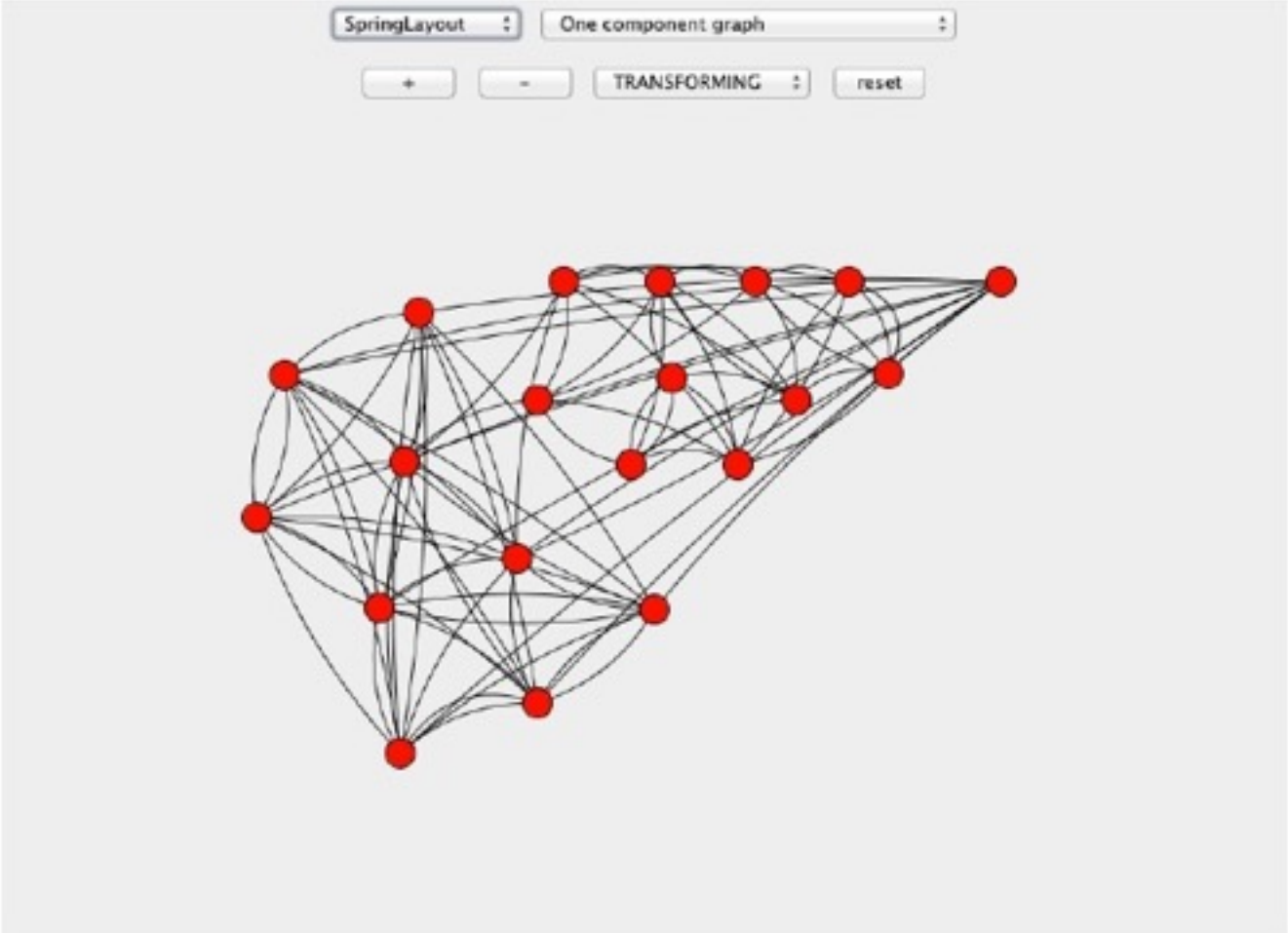
http://jung.sourceforge.net/applet/showlayouts2.html

JUNG Layouts



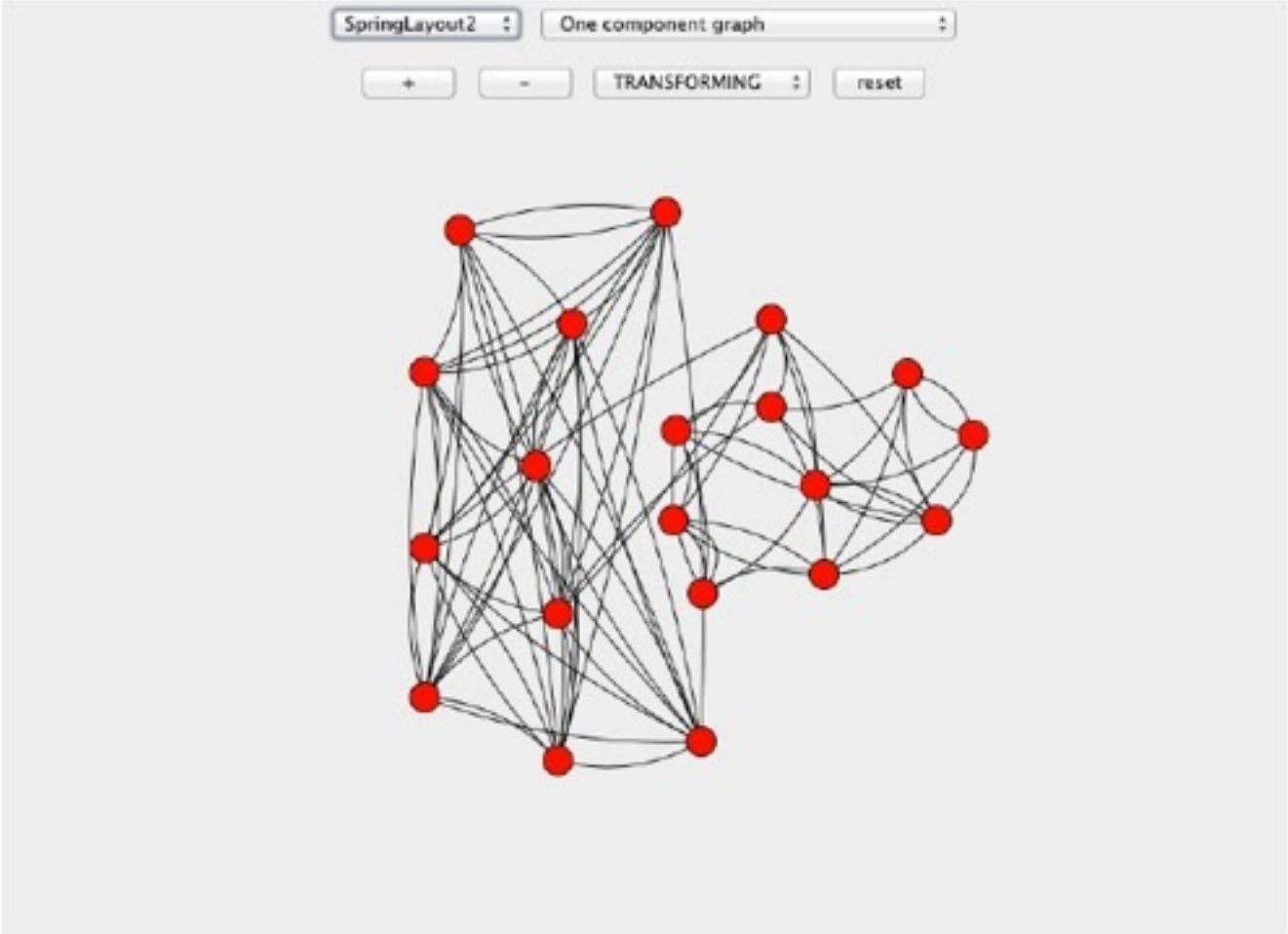
http://jung.sourceforge.net/applet/showlayouts2.html

JUNG Layouts



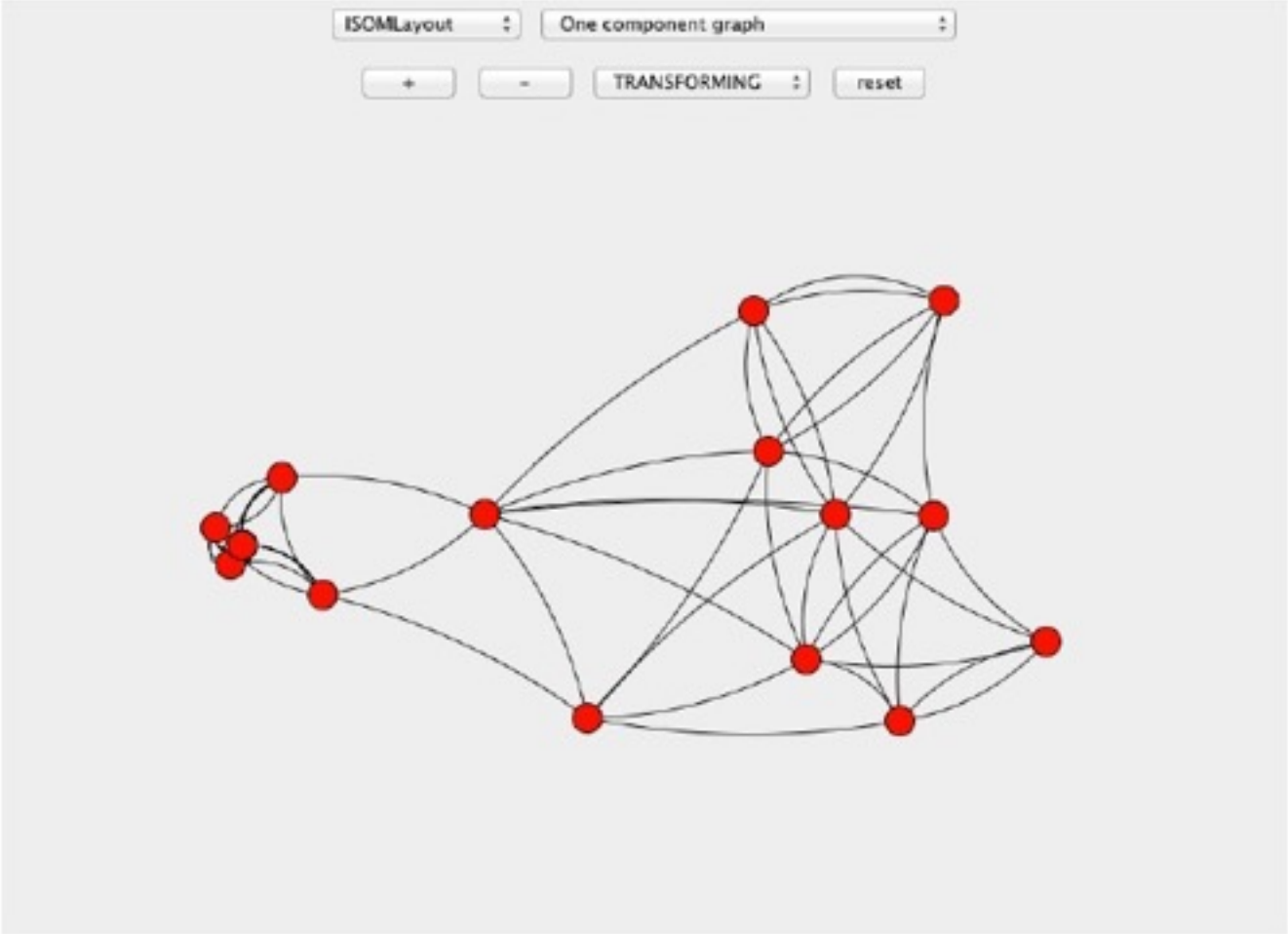
http://jung.sourceforge.net/applet/showlayouts2.html

JUNG Layouts



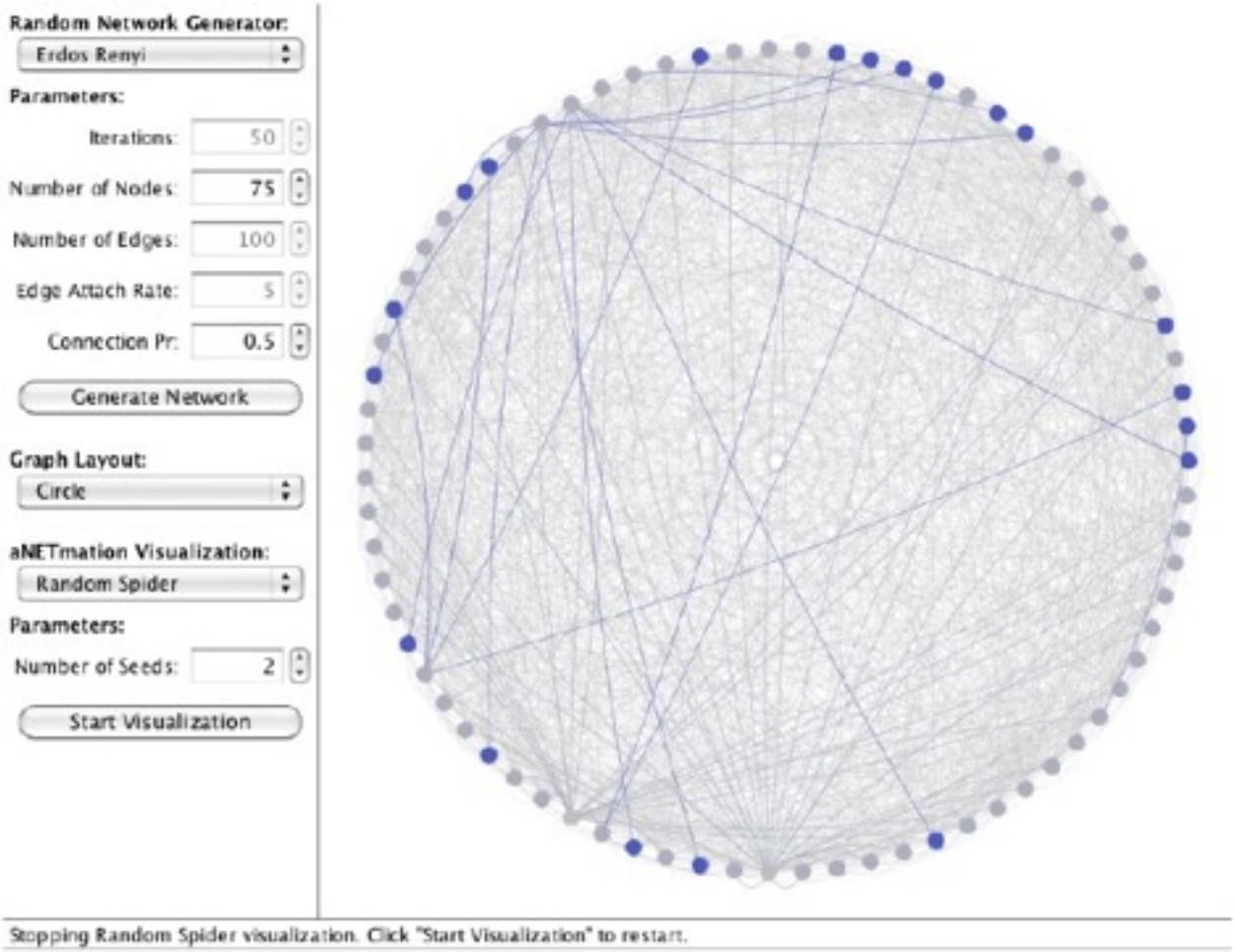
http://jung.sourceforge.net/applet/showlayouts2.html

JUNG Layouts



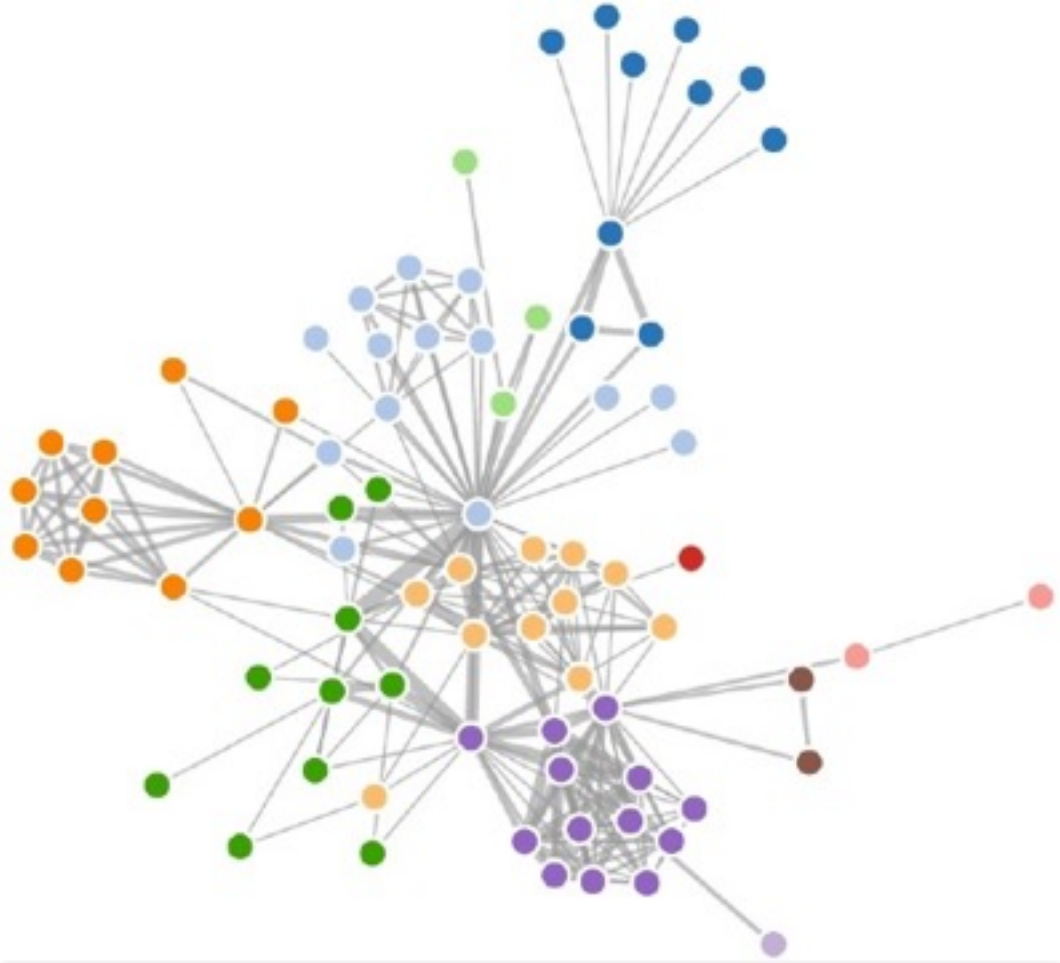
http://jung.sourceforge.net/applet/showlayouts2.html

aNETmation



http://www.phien.org/ucdavis/grad/projects/anetmation/

Force Directed Layout in D3



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

HIVE PLOTS

Hive Plots

- What are hive plots?
  - Network layout algorithm using per-node network properties for no deplacement
  - A radially-arranged parallel coordinate plot
- Why use hive plots?
  - Repeatable, comparable network layouts
  - Shows network properties with topology

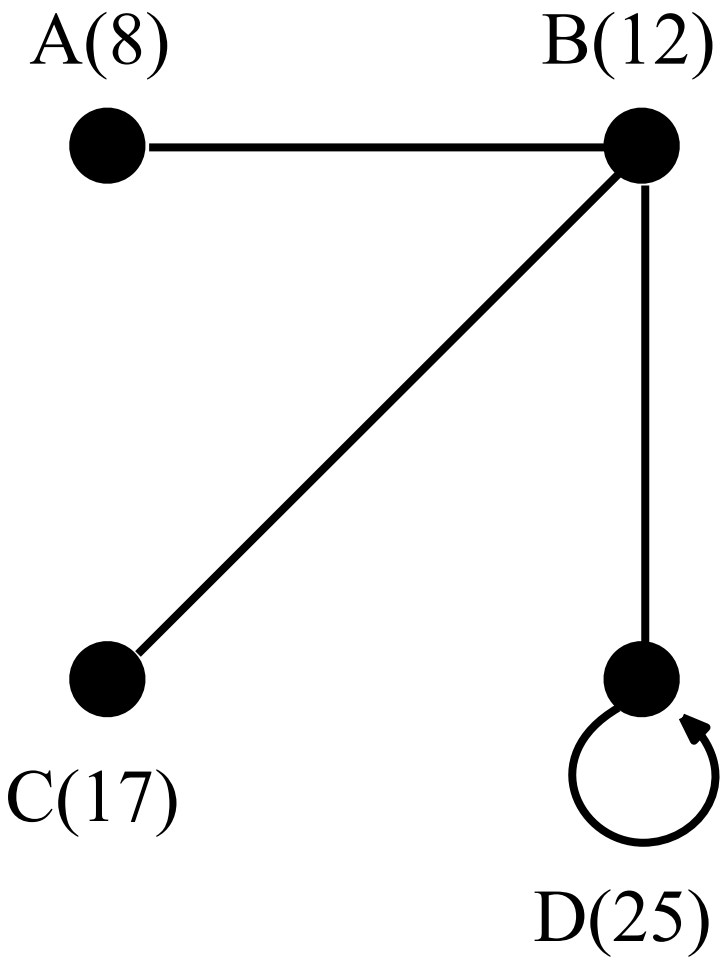
http://www.hiveplot.net/

Motivation

Subset of the human protein-protein interaction network rendered by Cytoscape. Each visualization uses the same layout (spring embedded), using the previous as a starting point.
Rual et al., *Nature* **437**(7062):1173-8.

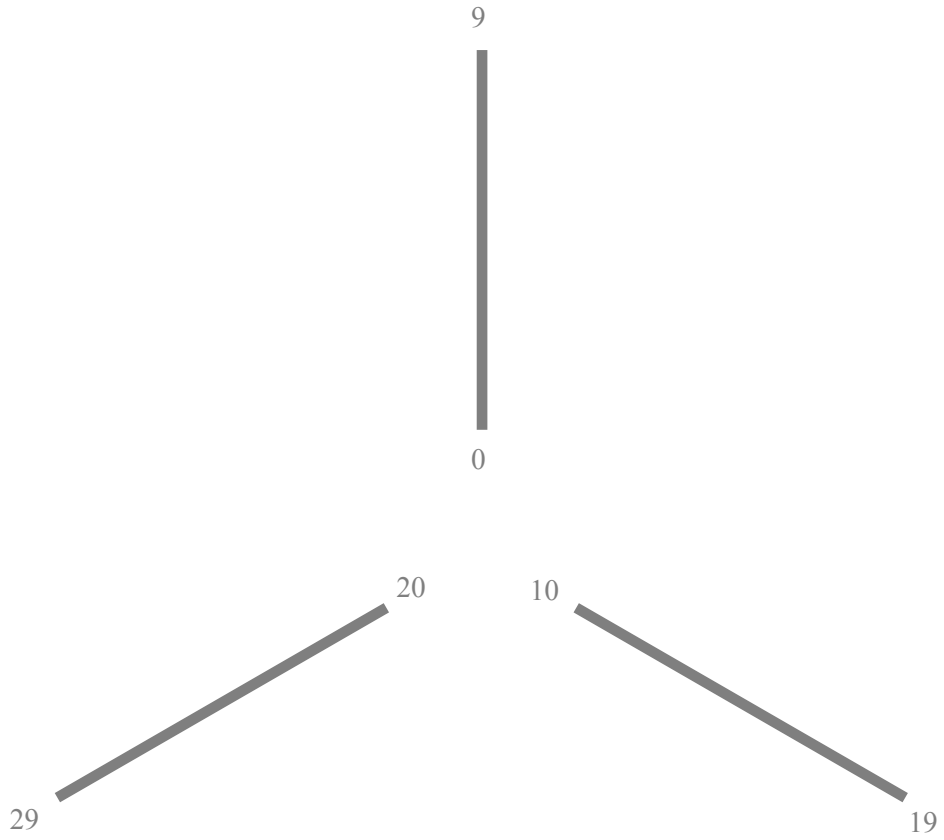
http://www.hiveplot.net/talks/hive-plot.pdf

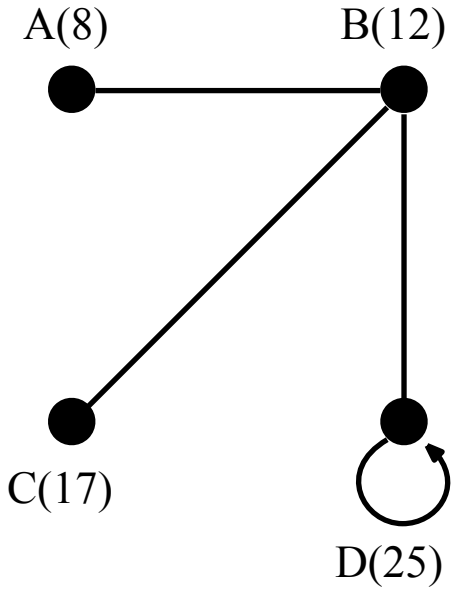
Initial Network



Simple network with node weights and a self-loop.

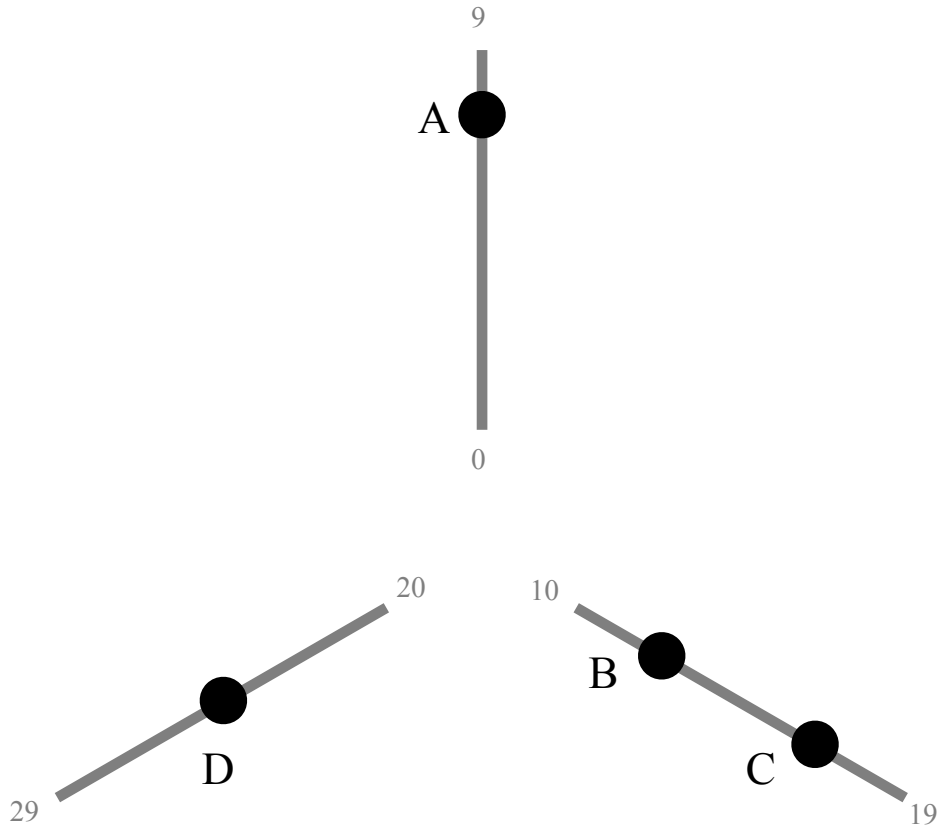
Axis Layout

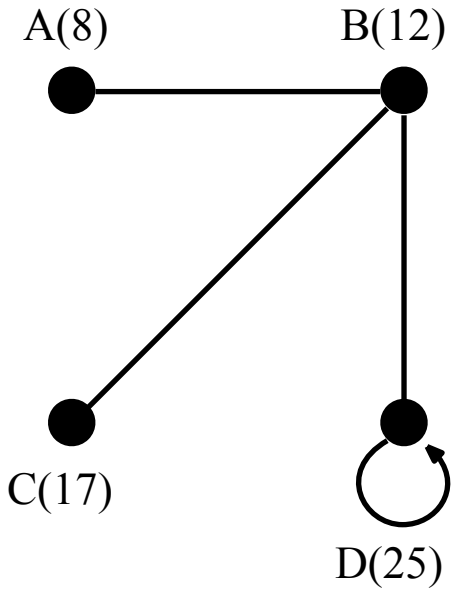




Three axis bars guarantee no edge crossings across axes. Divide node weight range between axes.

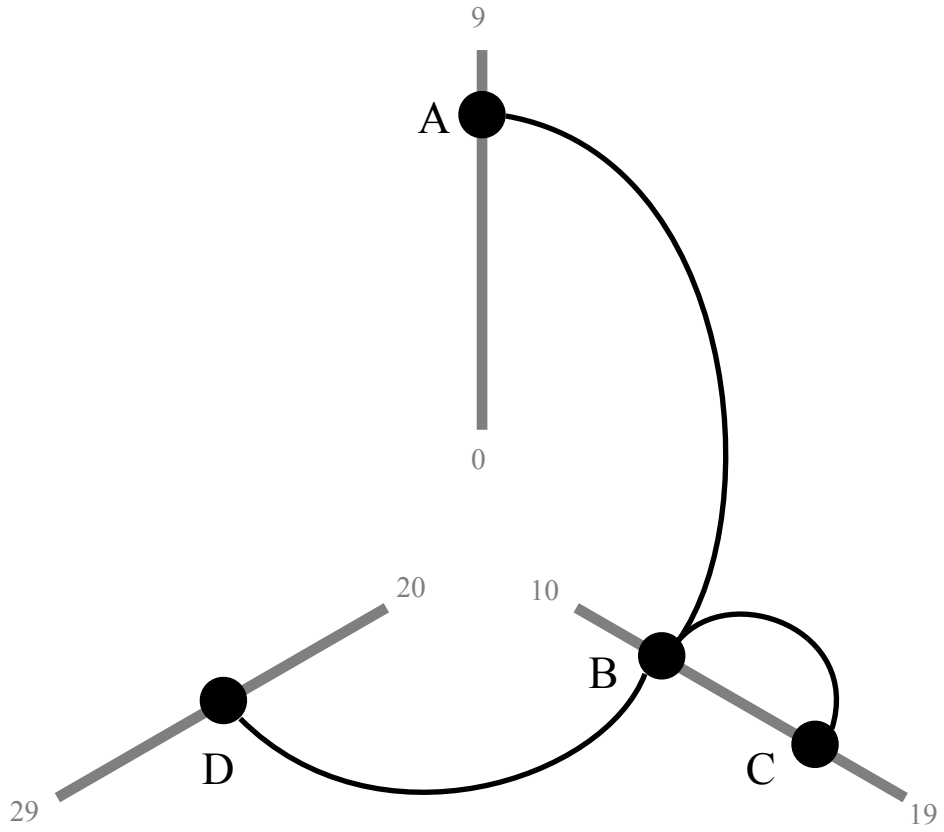
Node Layout

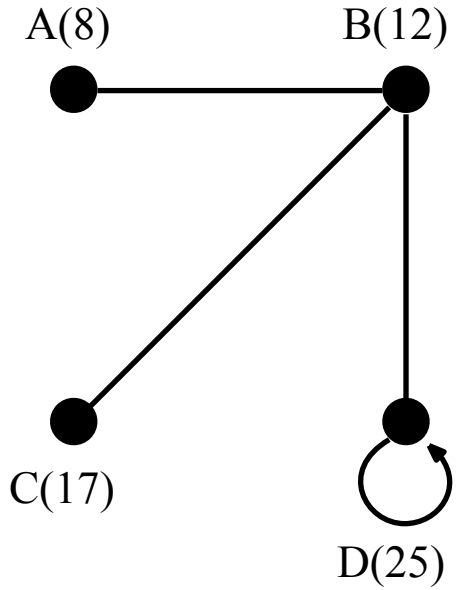




Place nodes on axis lines according to weight.

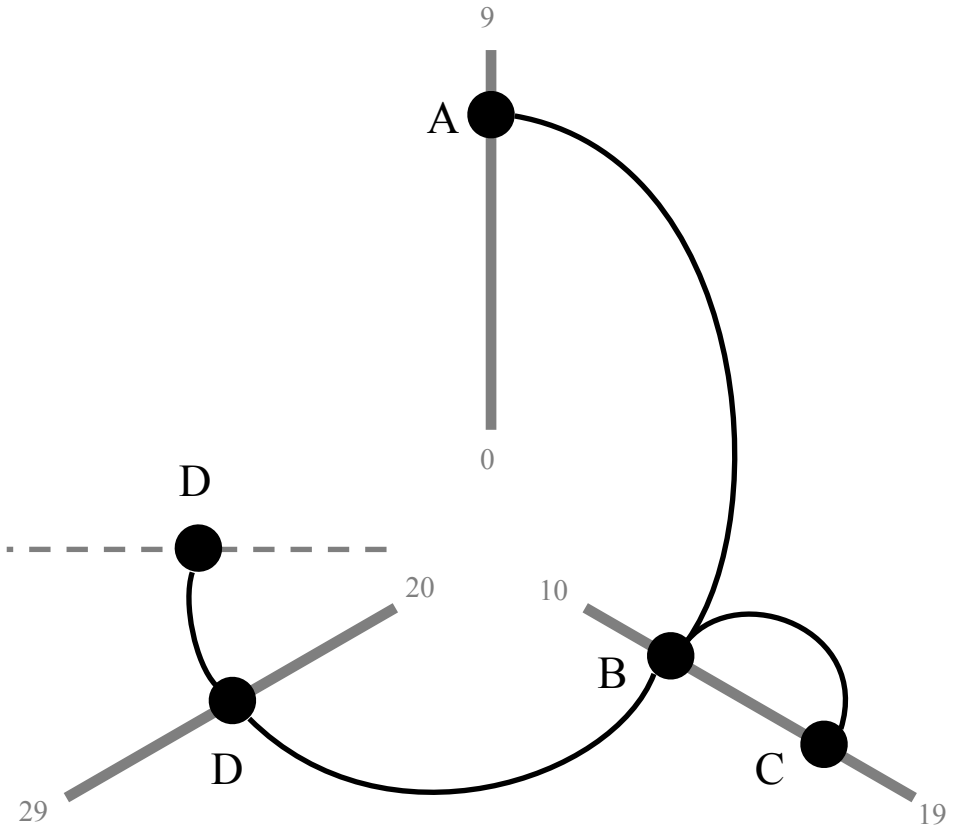
Edge Layout

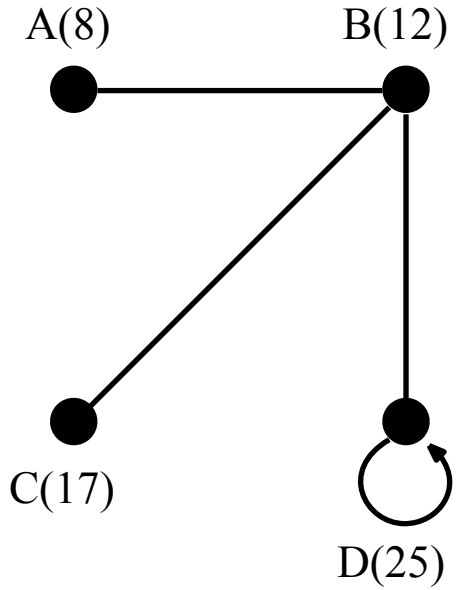




Connect nodes together accordingly.

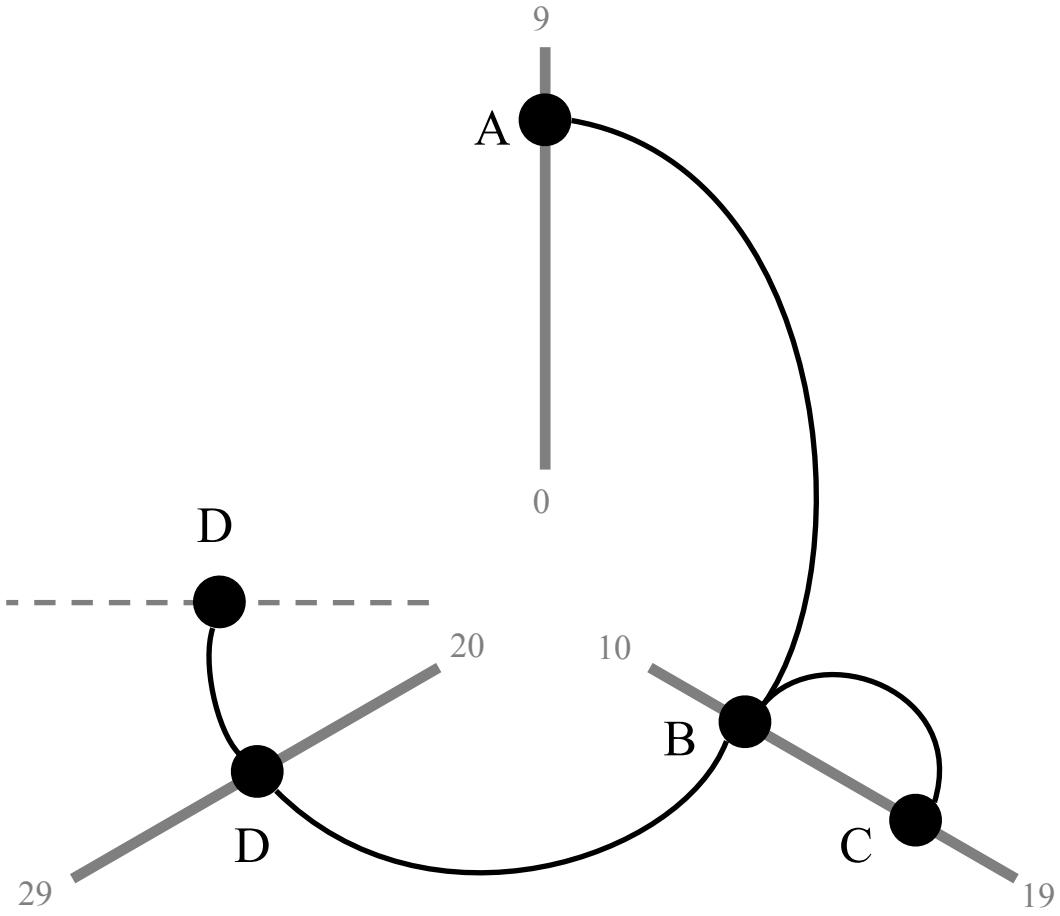
Self Loops



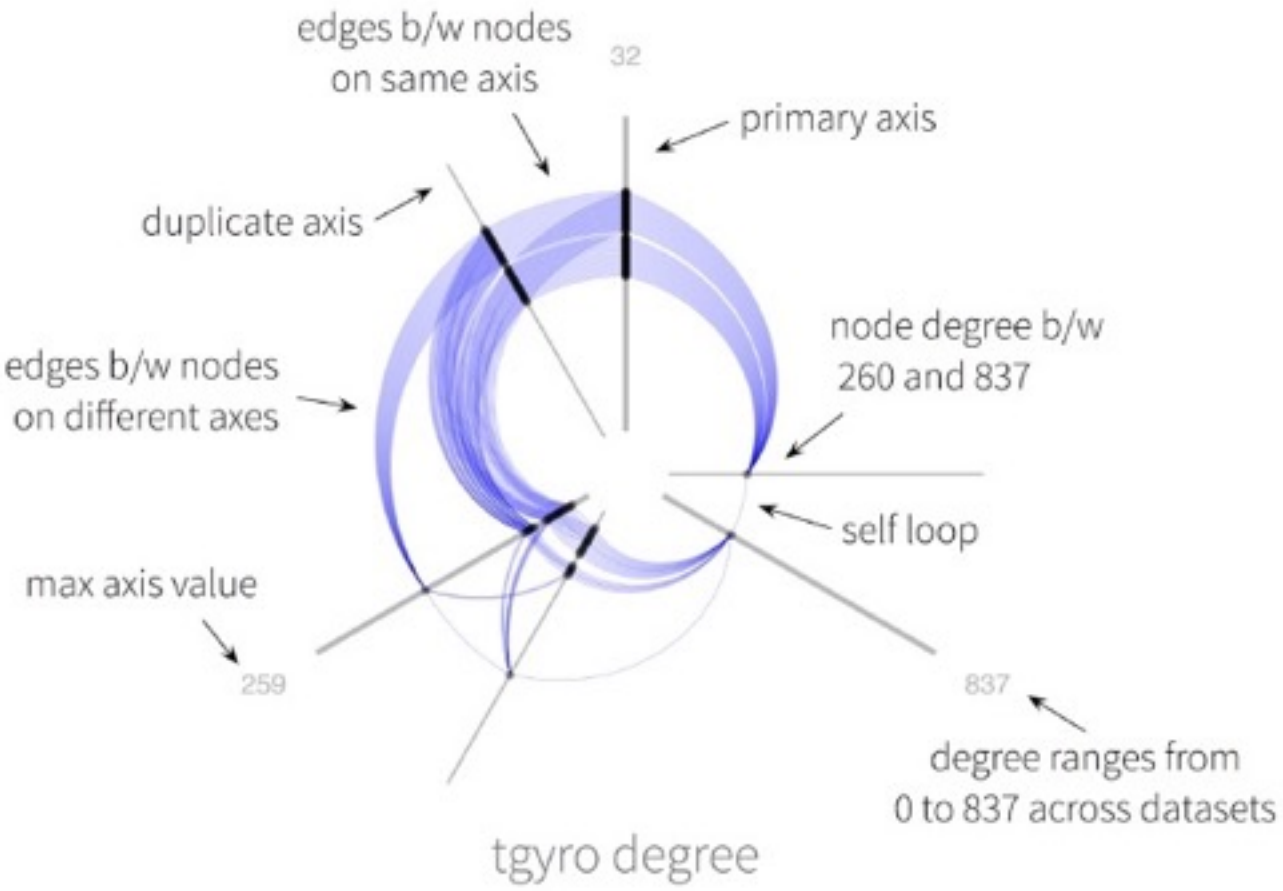


Clone axis lines to show self-loops in network.

Final Layout

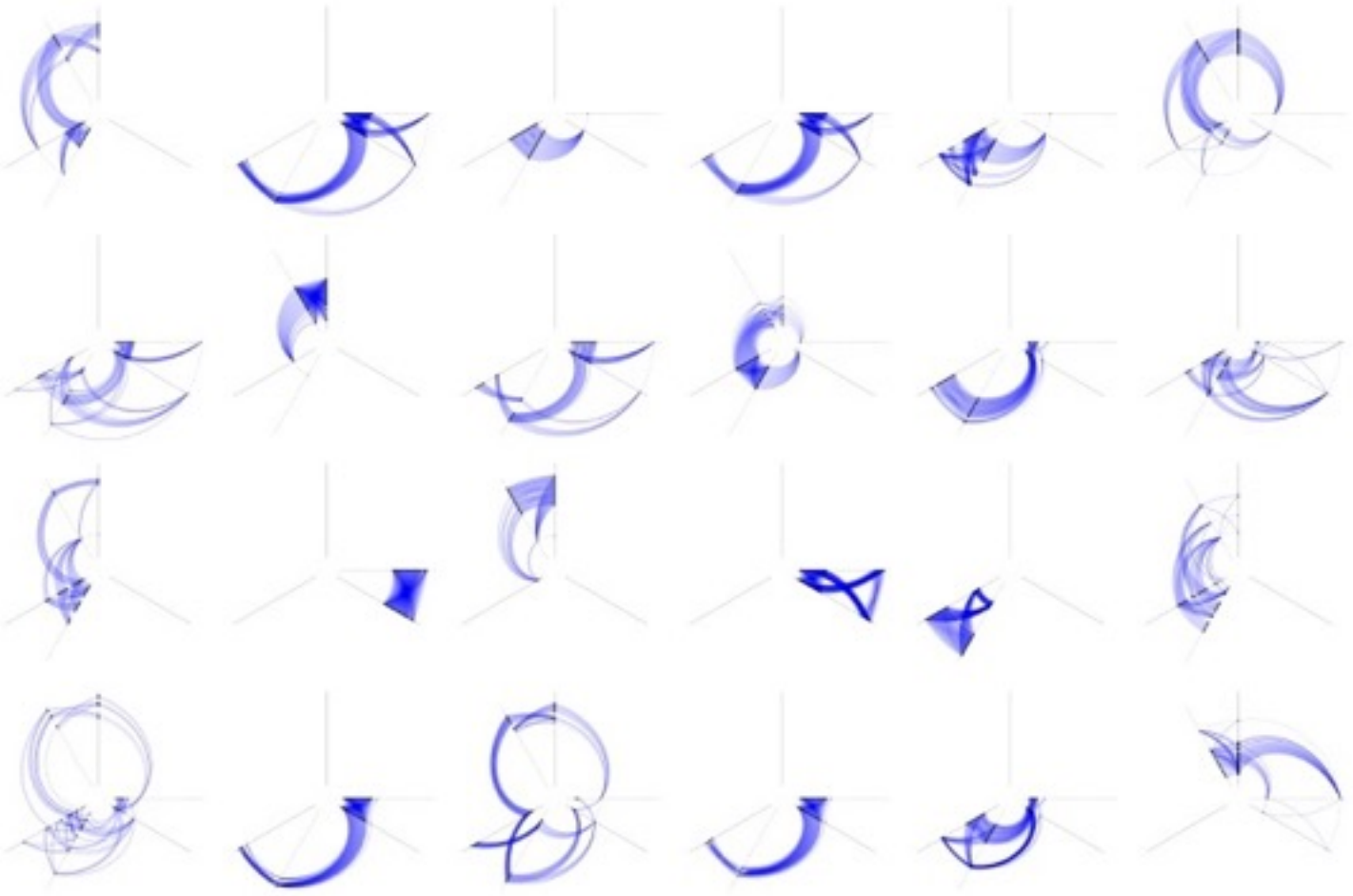


Hive Plots



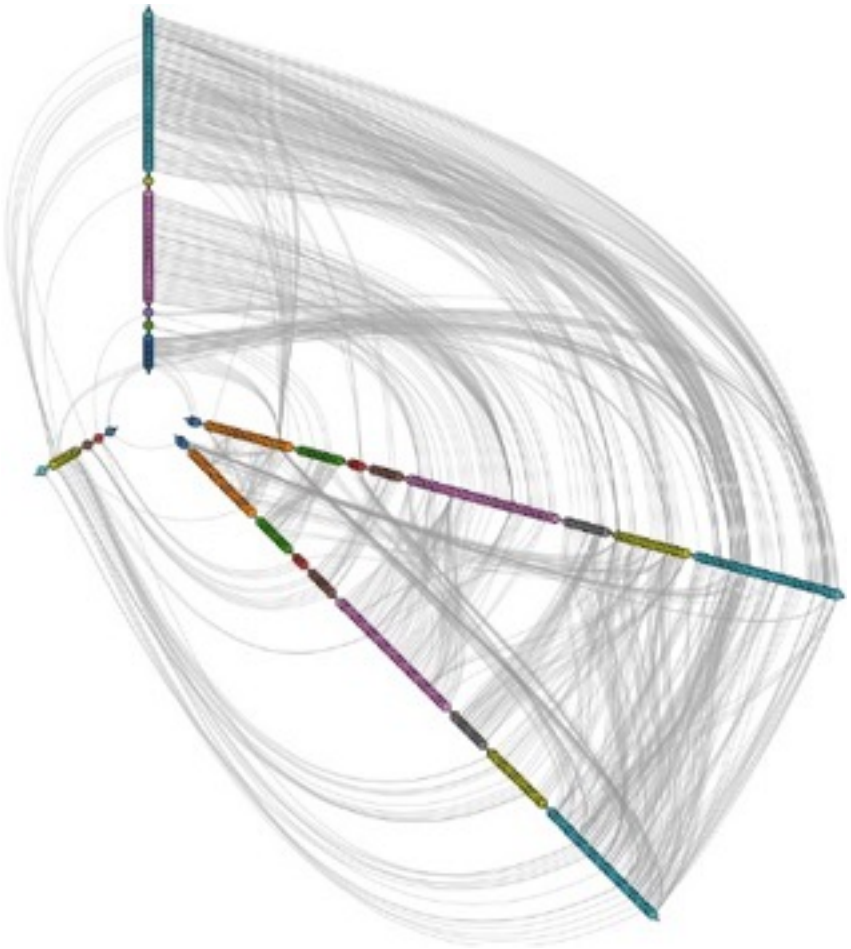
http://dl.acm.org/citation.cfm?id=2379698

Hive Panels



http://dl.acm.org/citation.cfm?id=2379698

Hive Plots in D3

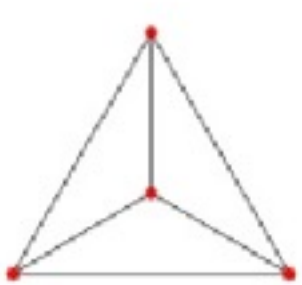


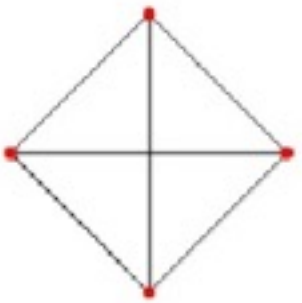
http://bost.ocks.org/mike/hive/

EDGE LAYOUT

Edge Crossings

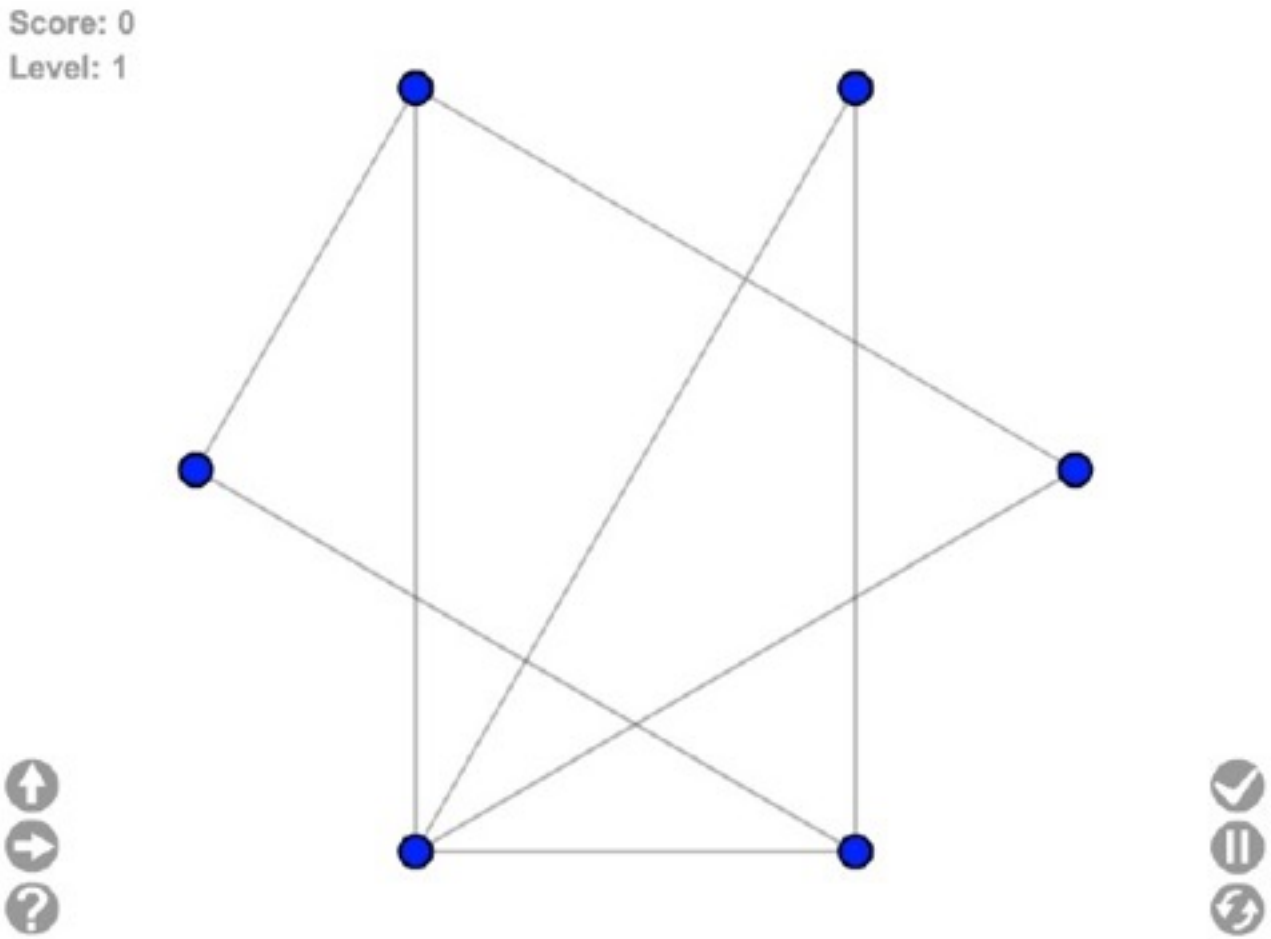
- Planar Graph
  - "A graph is planar if it can be drawn in a plane without graph edges crossing."
- If the graph is not planar, it is impossible to draw without edge crossings.
- Trees are planar graphs.





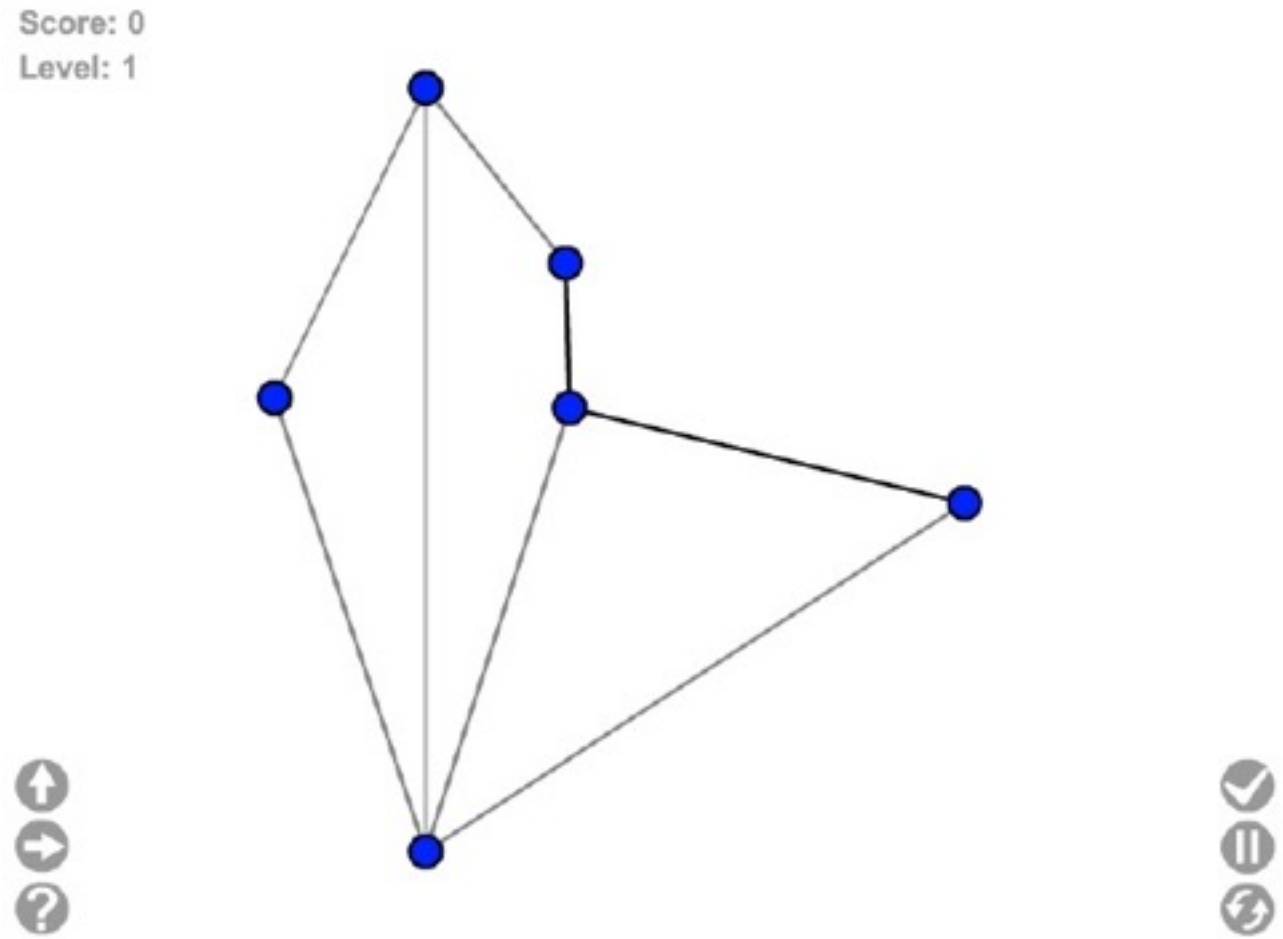
http://mathworld.wolfram.com/PlanarGraph.html

Planarity Game



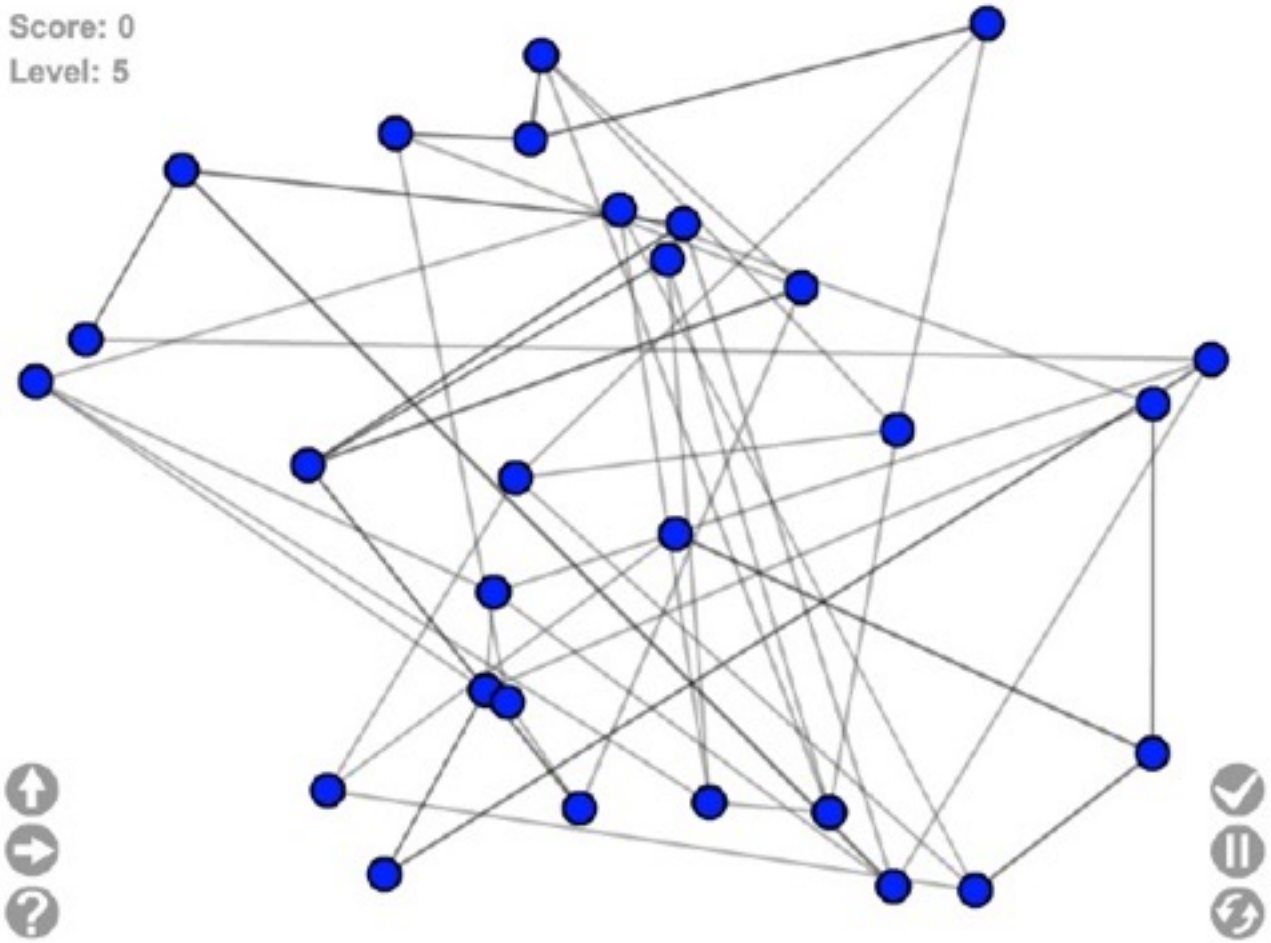
http://www.planarity.net/

Planarity Game



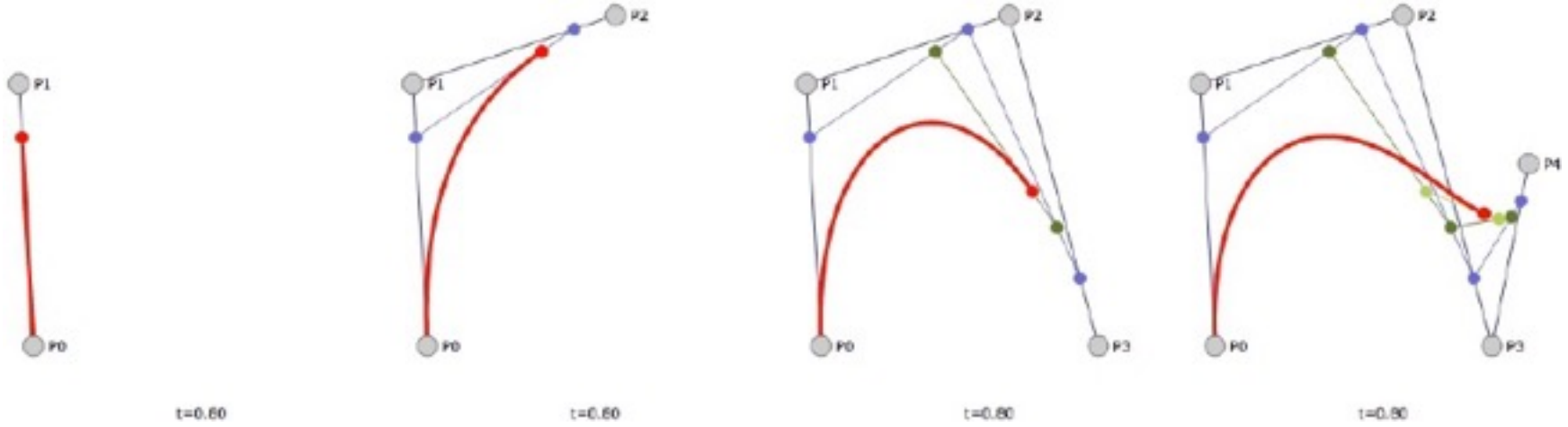
http://www.planarity.net/

Planarity Game



http://www.planarity.net/

Curved Edges



http://www.jasondavies.com/animated-bezier/

Edge Bundling

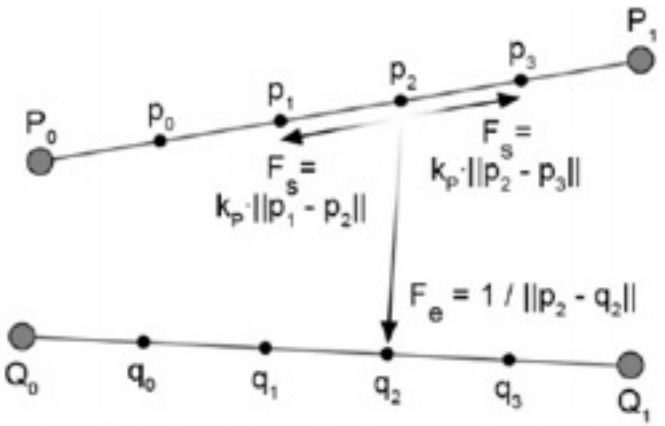


Figure 1: *Two interacting edges P and Q. The spring forces* $\mathbf{F_s}$ *and the electrostatic force* $\mathbf{F_e}$ *that are exerted on subdivision point* p_2 *by* p_1, p_3, *and* q_2 *are shown.*

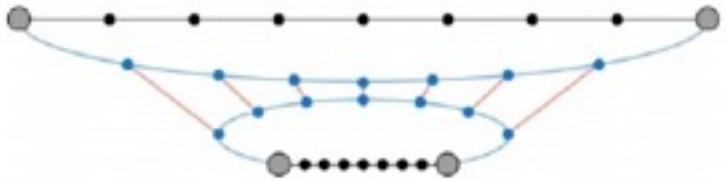


Figure 4: *Bundling edges that differ considerably in length can result in noticeable stretching and curving of short edges. Original edges, curved edges and attracting forces are shown in black, blue, and red, respectively.*

https://www.win.tue.nl/vis1/home/dholten/papers/forcebundles_eurovis.pdf

Edge Bundling

Danny Holten & Jarke J. van Wijk / Force-Directed Edge Bundling for Graph Visualization

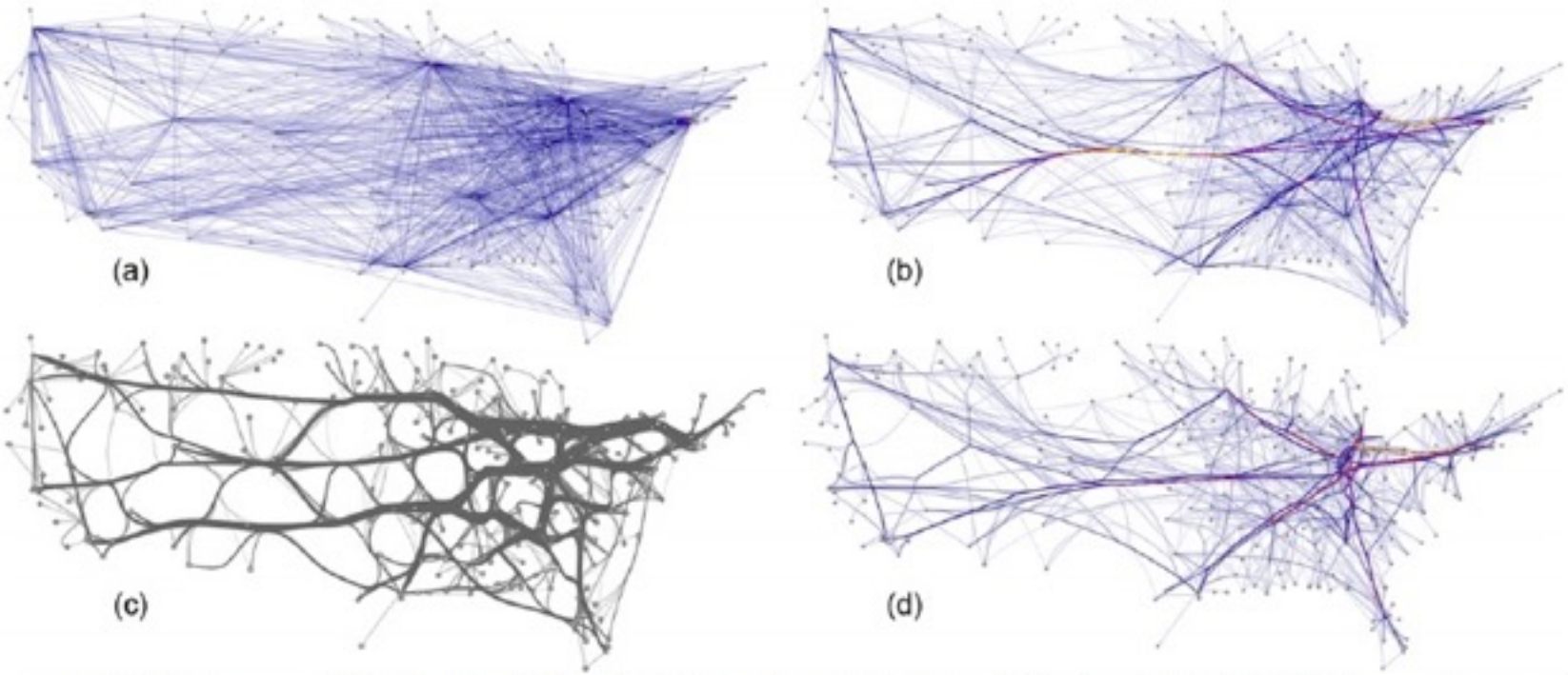
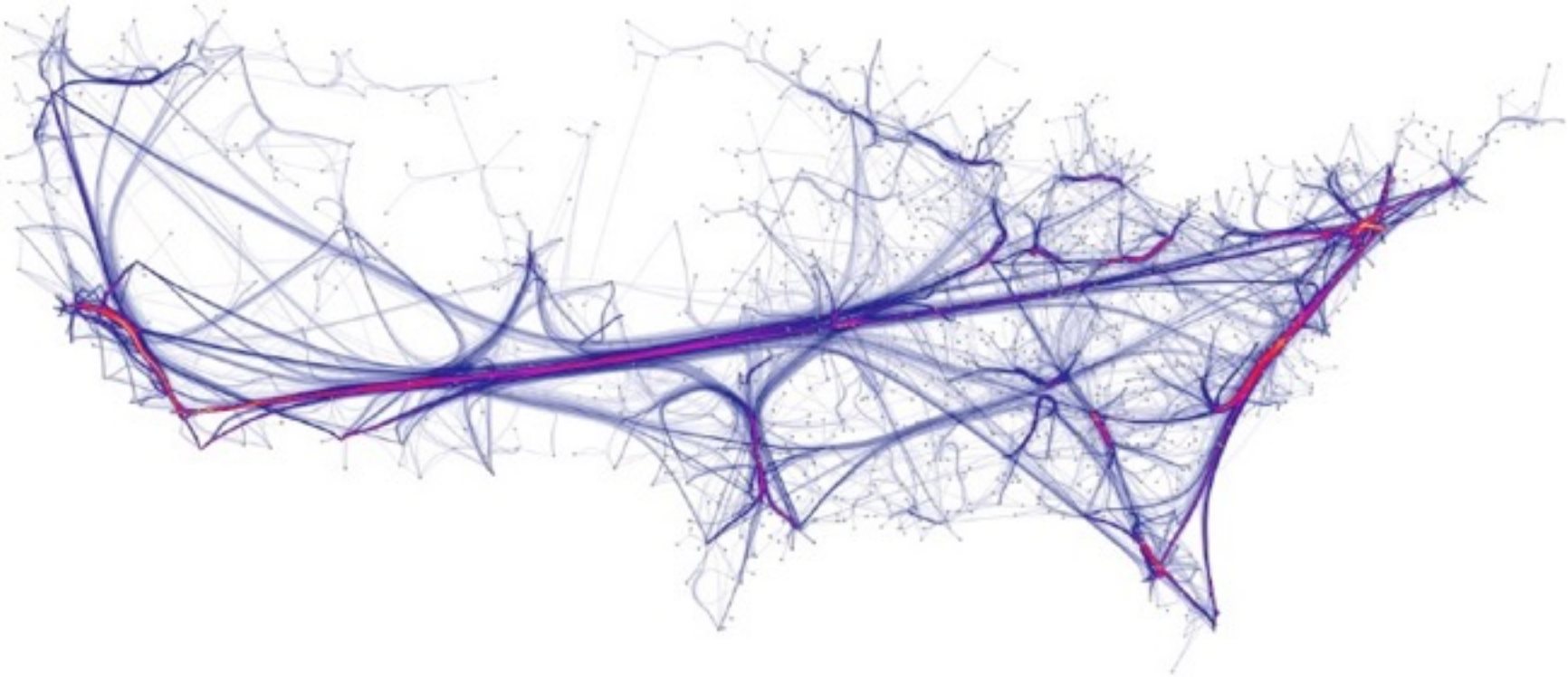


Figure 7: *US airlines graph (235 nodes, 2101 edges) (a) not bundled and bundled using (b) FDEB with inverse-linear model, (c) GBEB, and (d) FDEB with inverse-quadratic model.*

https://www.win.tue.nl/vis1/home/dholten/papers/forcebundles_eurovis.pdf

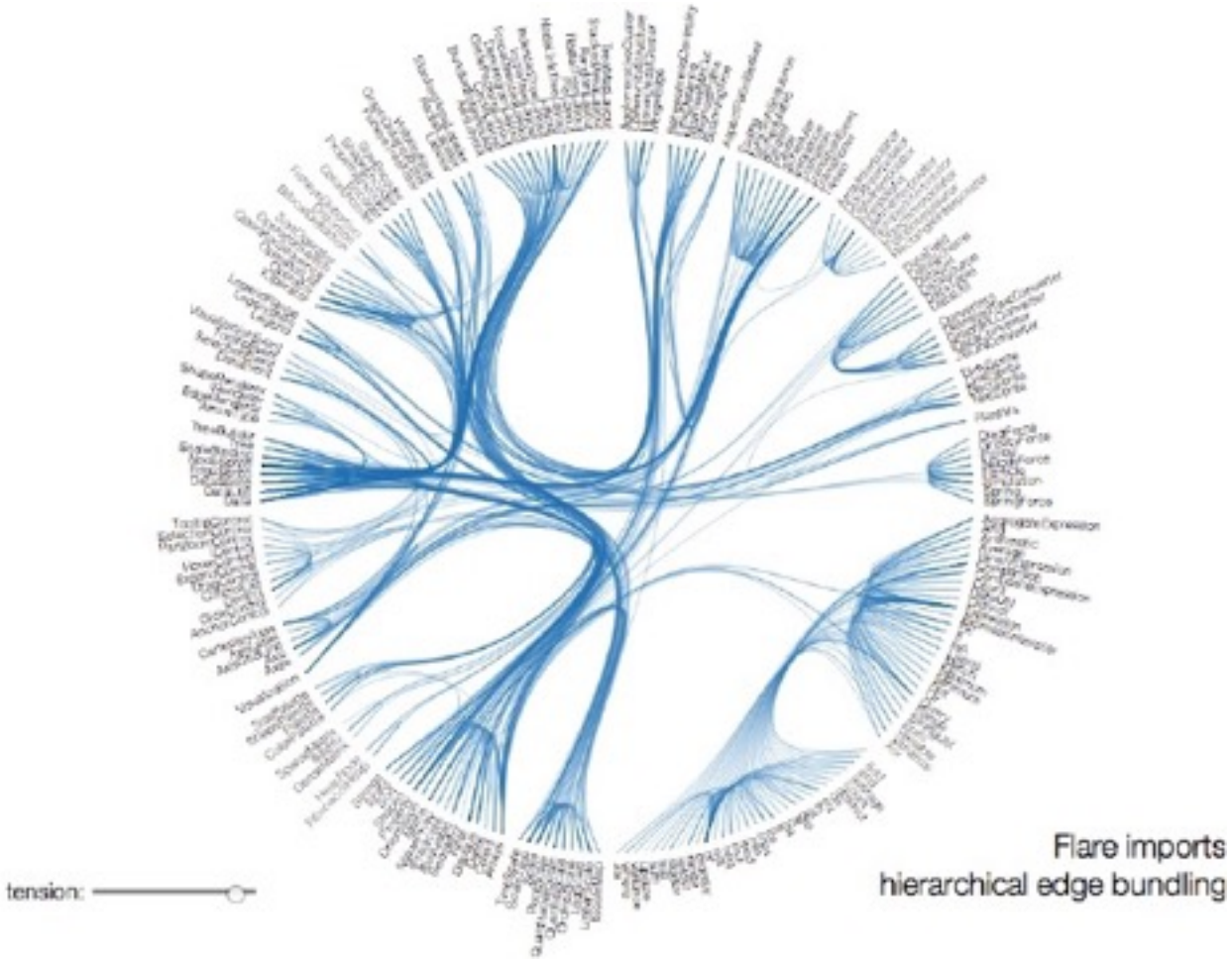
Edge Bundling



Edge Bundling

http://mbostock.github.io/d3/talk/20111116/bundle.html

Edge Bundling



http://mbostock.github.io/d3/talk/20111116/bundle.html

QUESTIONS?

Thanks to
Sophie J. Engle
San Francisco University
for ideas, suggestions, slides, links, and much other stuff