

ARC²S Group

Applied Research on Computational Complex Systems

Hierarchical Data and Graph Visualization

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“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

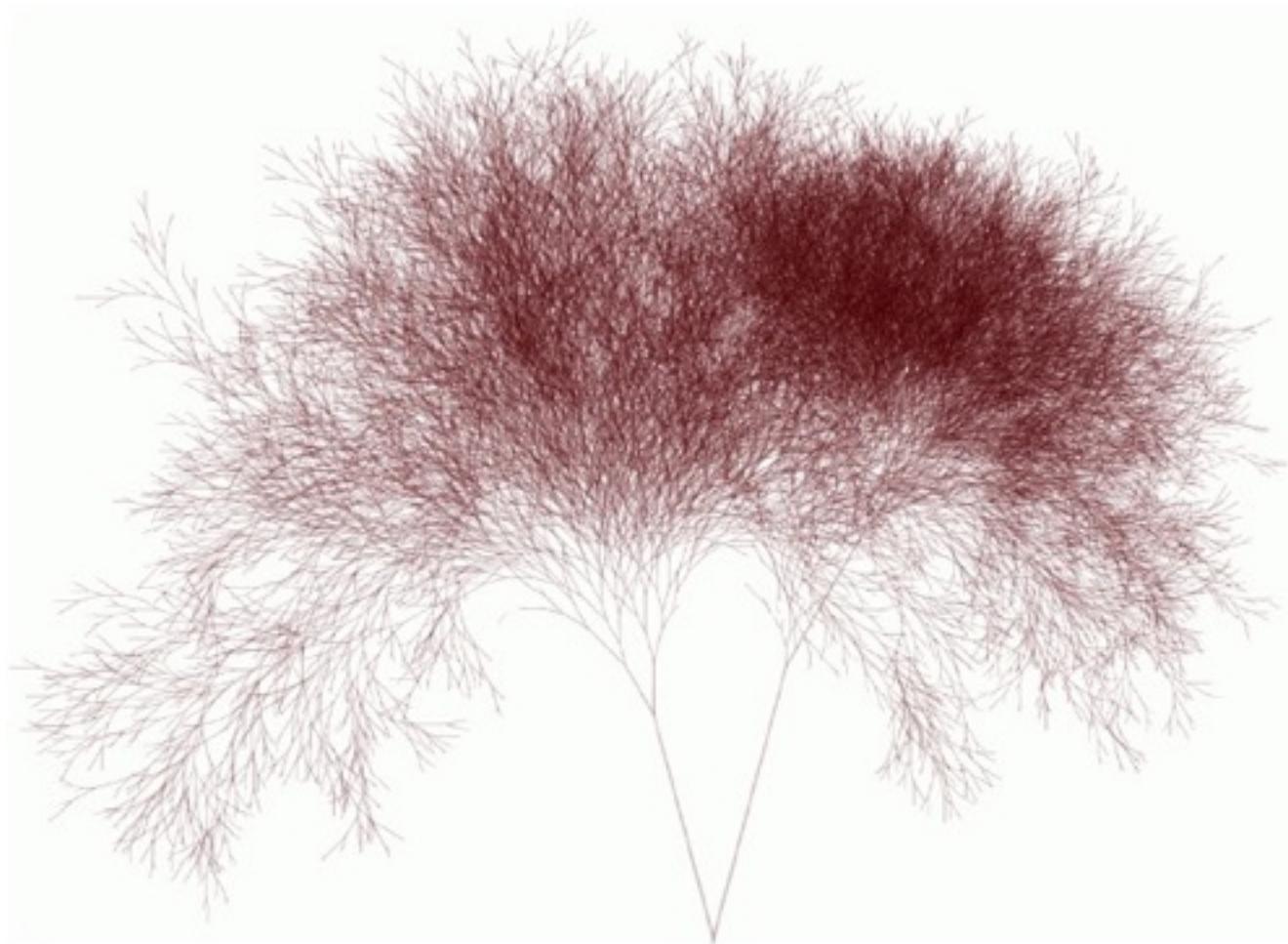
Hierarchical Data

- 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

Examples of Hierarchical Data

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

Tree Structures



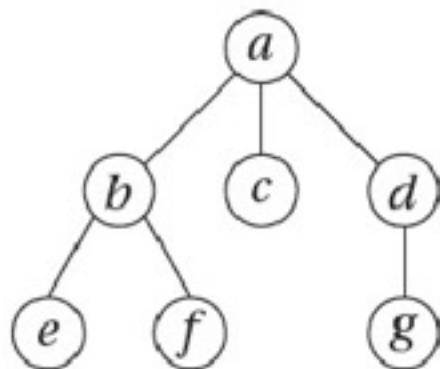
<http://drunkmenworkhere.org/219>

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**)

Tree Terminology

FIGURE 2.8: TREE TERMINOLOGY AND NOTATION



$G = (N, E)$ where

$$\begin{aligned} N &= \{ a, b, c, d, e, f, g \} \\ E &= \{ (a, b), (a, c), (a, d) \\ &\quad (b, e), (b, f), (d, g) \} \end{aligned}$$

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

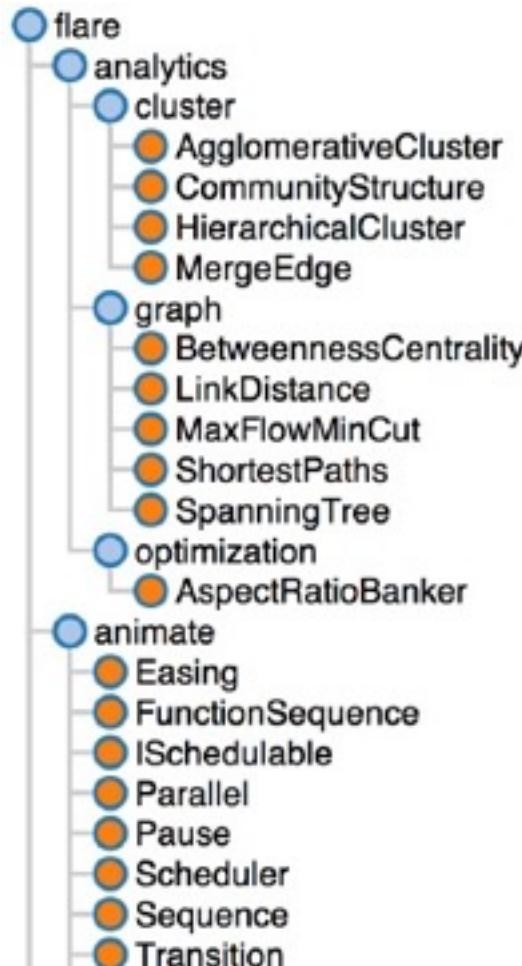
NODE-LINK DIAGRAMS

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

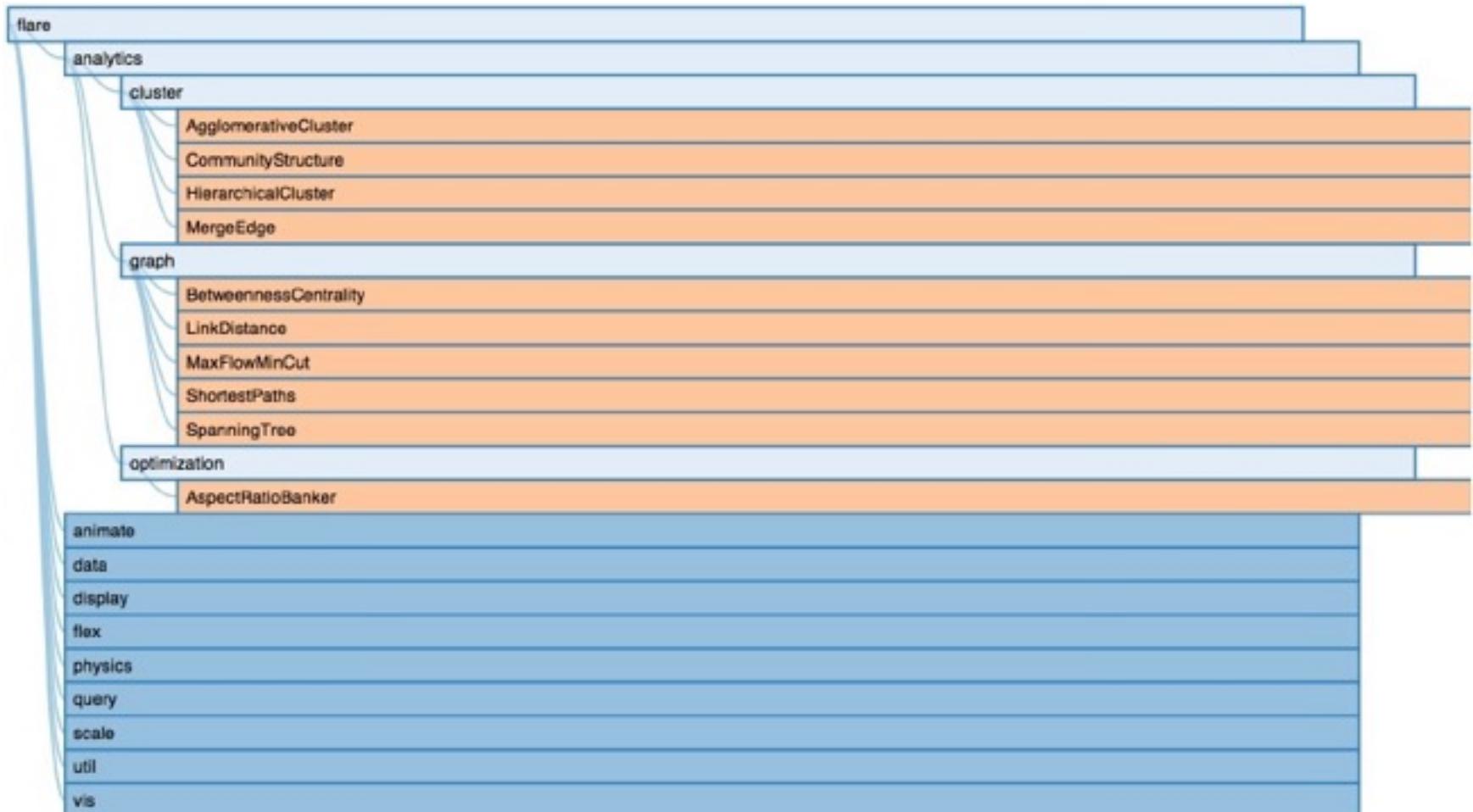
Indented Layout



933KB	►	Archived Resources
47KB	►	CS 107 App Inventor
14KB	►	CS 110 Intro to CS I
3KB	►	CS 112 Intro to CS II
3KB	►	CS 212 Software Development
6KB	►	2012 Fall
0KB	►	2012 Spring
25KB	►	2013 Spring
5KB	►	Lectures
7KB	►	00 Eclipse Setup.pdf
5KB	►	00 Eclipse SVN Setup.pdf
3KB	►	01 Java Basics.pdf
6KB	►	02 Data Structures.pdf
6KB	►	03 Classes and Objects.pdf
97KB	►	04 Software Testing.pdf
16KB	►	05 Inheritance, Part 1.pdf
5KB	►	05 Inheritance, Part 2.pdf
1KB		
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<http://mbostock.github.io/protovis/ex/indent.html>

Indented Layout

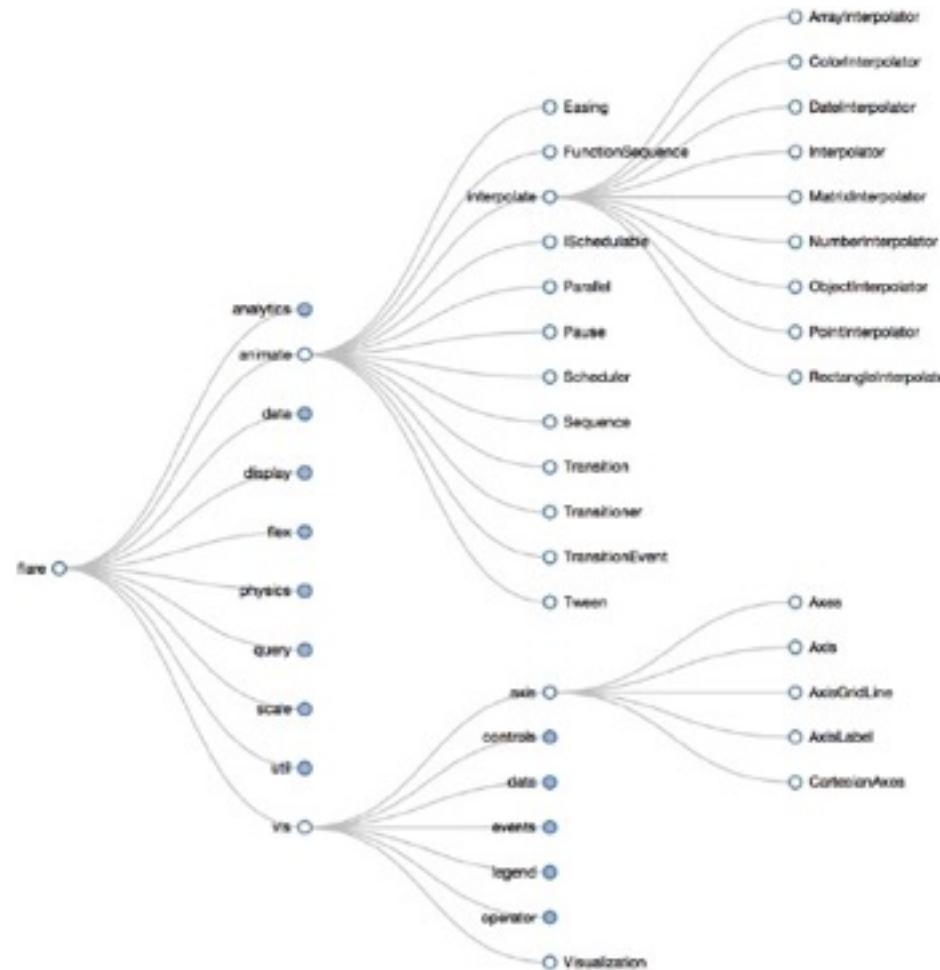


<http://bl.ocks.org/mbostock/1093025>

Node-Link Diagrams

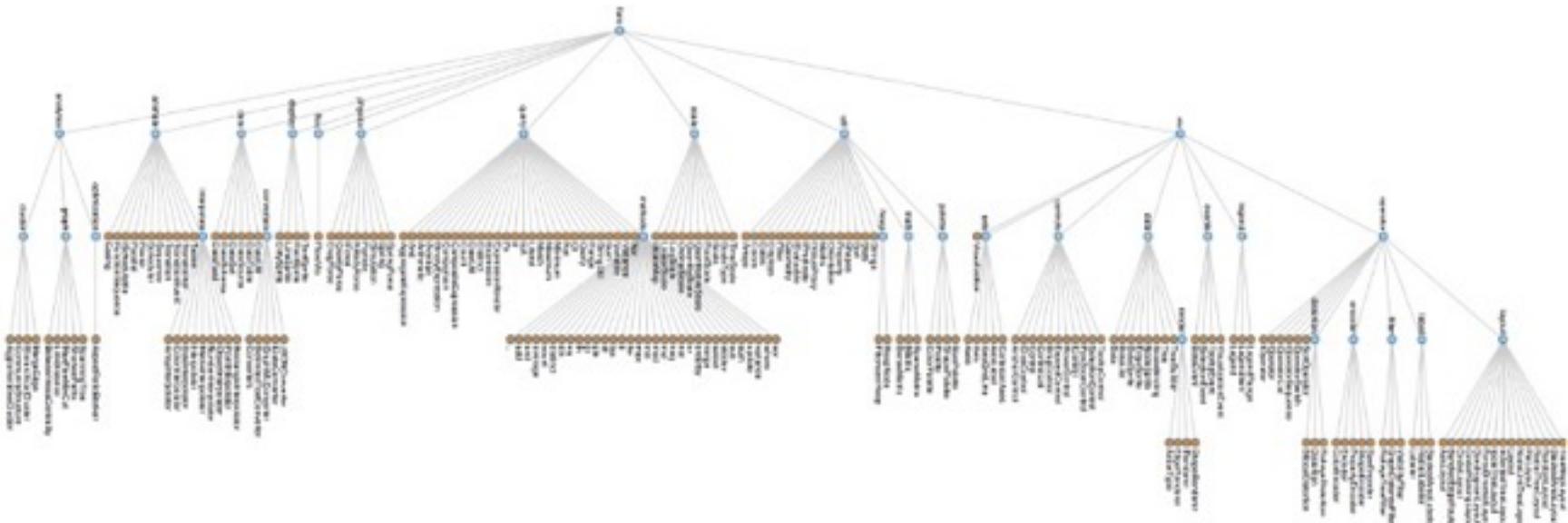
- Traditional Layout
 - Nodes laid out by level, root at top
 - Edges connect adjacent nodes
- Dendrogram
 - All leaves at bottom of diagram
 - Edges usually drawn with sharp corners
 - Often used to show clusters
(sometimes called cluster layout)

Traditional Layout



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

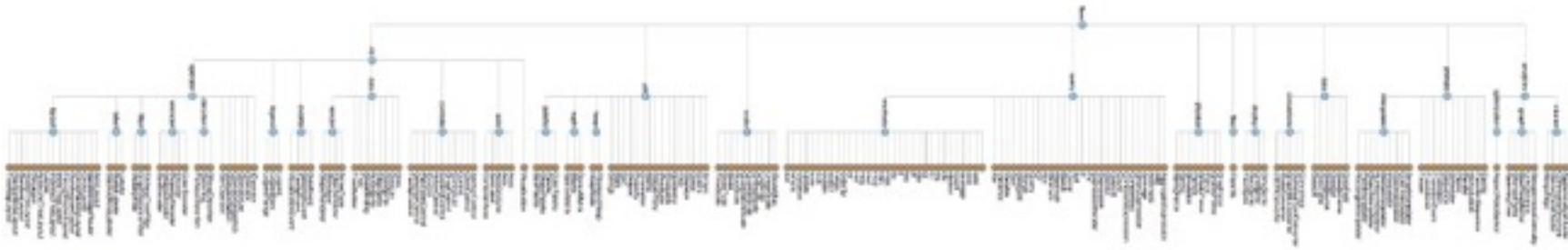
Traditional Layout



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

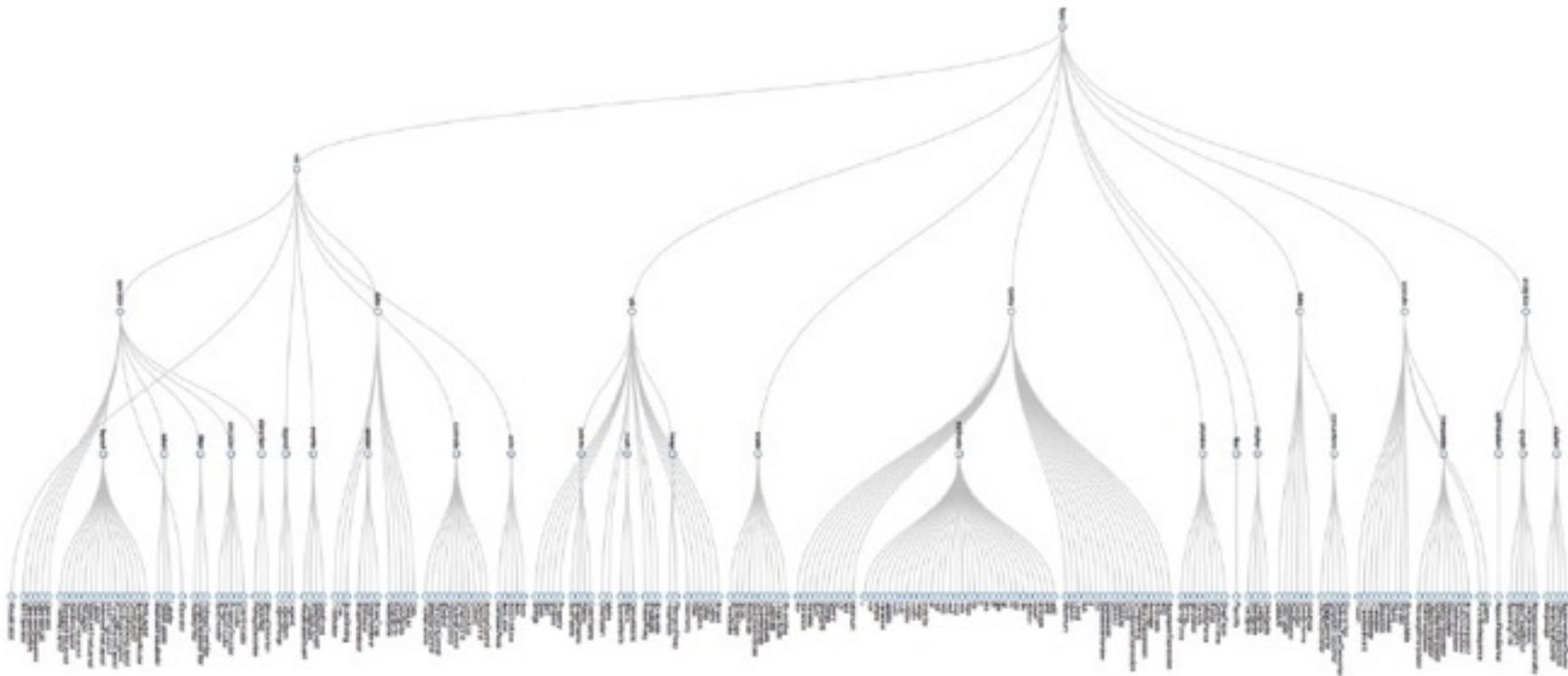
See [here](#) for more visualization tools!

Dendrogram



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

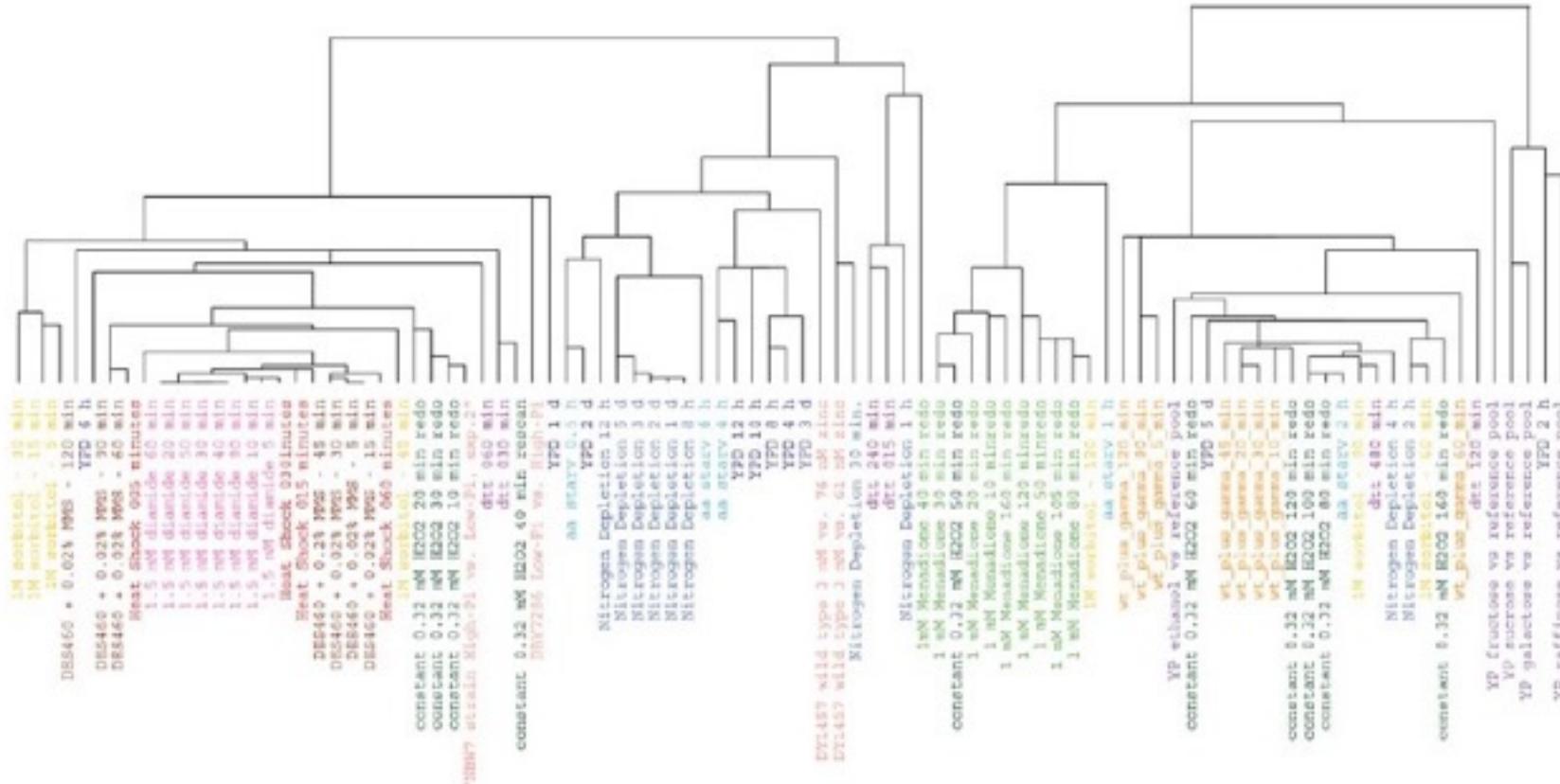
Dendrogram



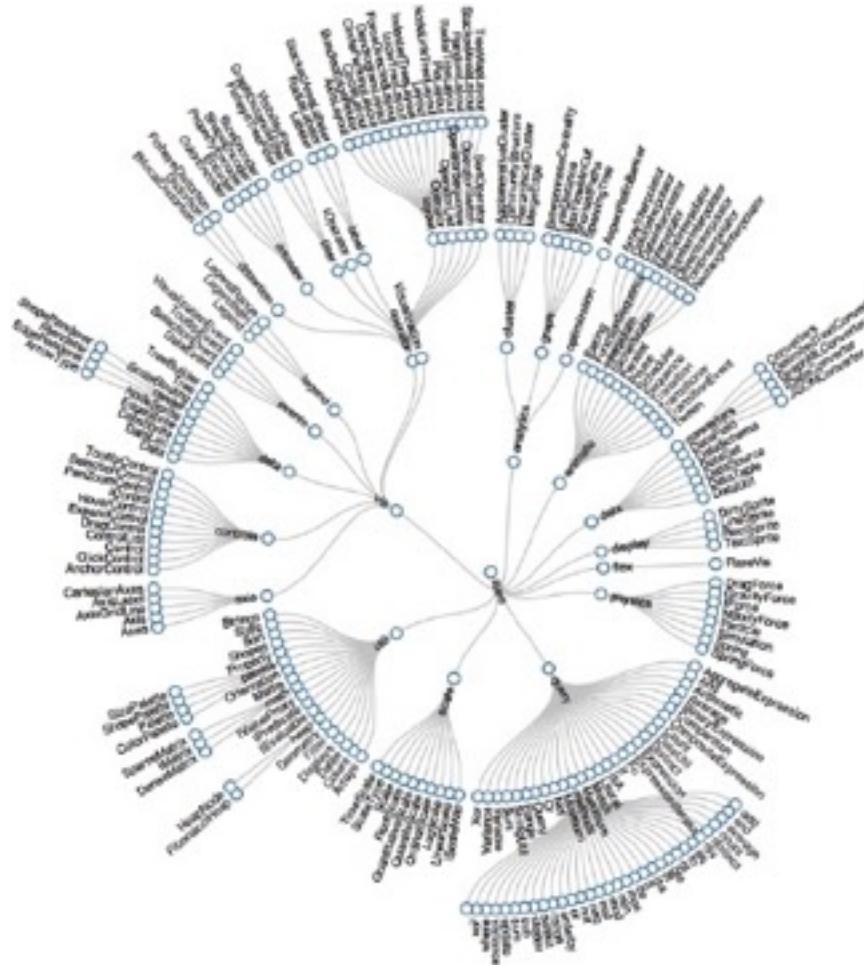
<http://mbostock.github.io/protovis/ex/dendrogram.html>

Dendrogram

Cluster 11: protein folding chaperones

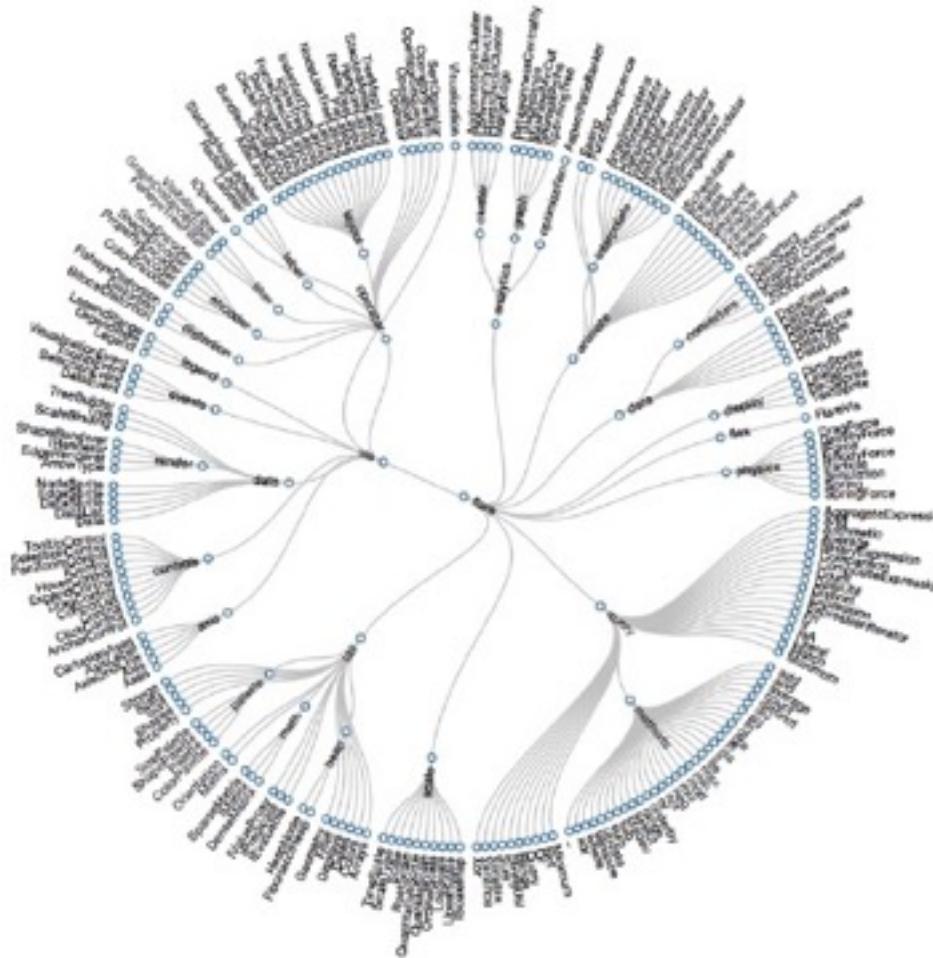


Circular Layout



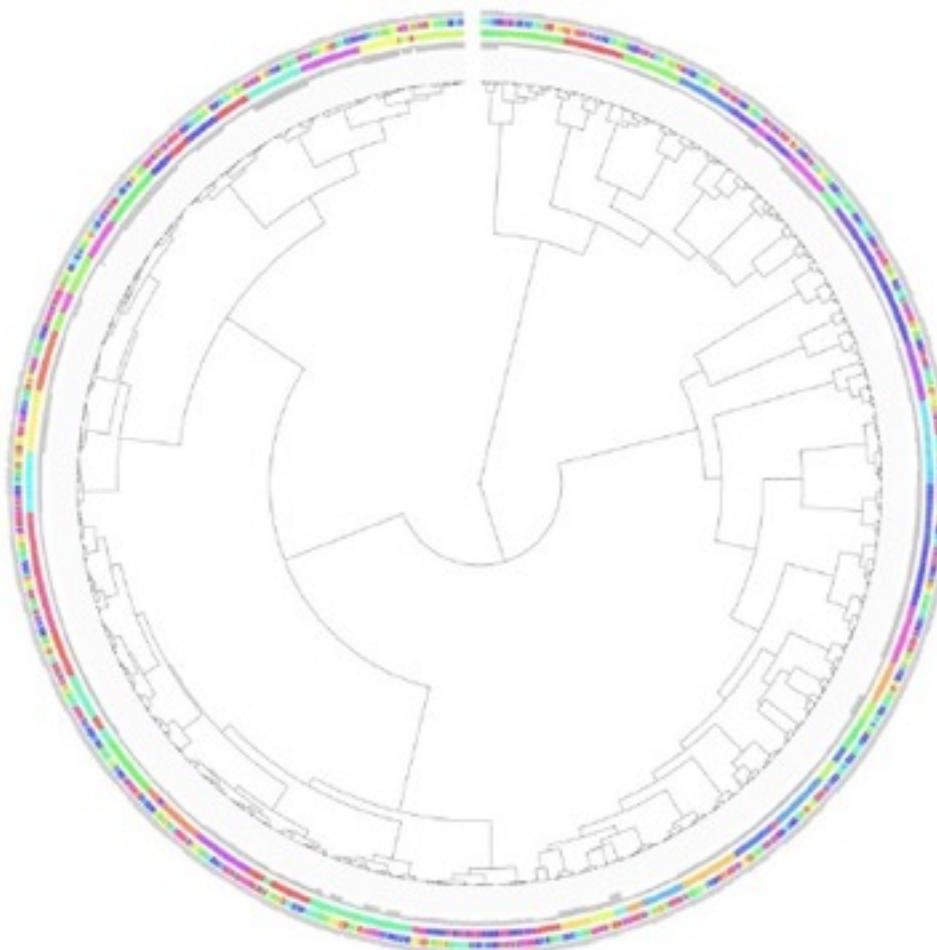
<http://bl.ocks.org/mbostock/4063550>

Circular Dendrogram



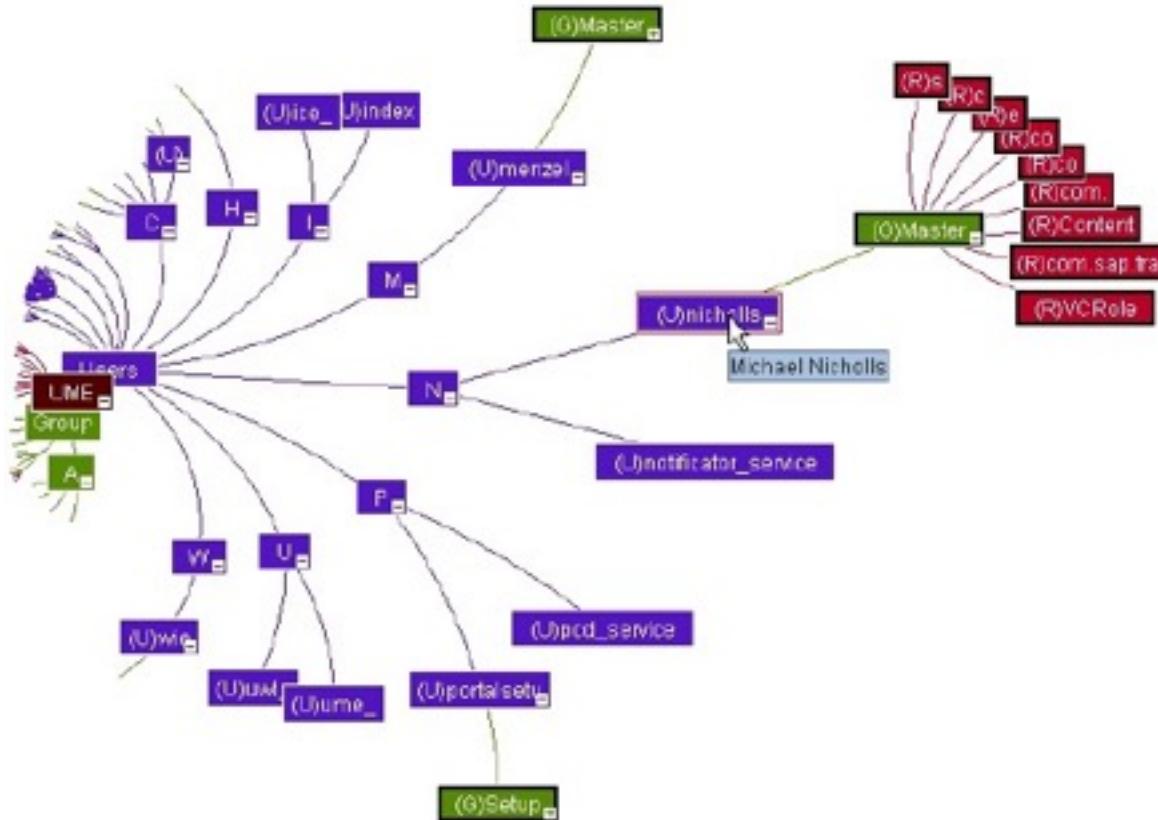
<http://mbostock.github.io/d3/talk/20111018/cluster.html>

Circular Dendrogram



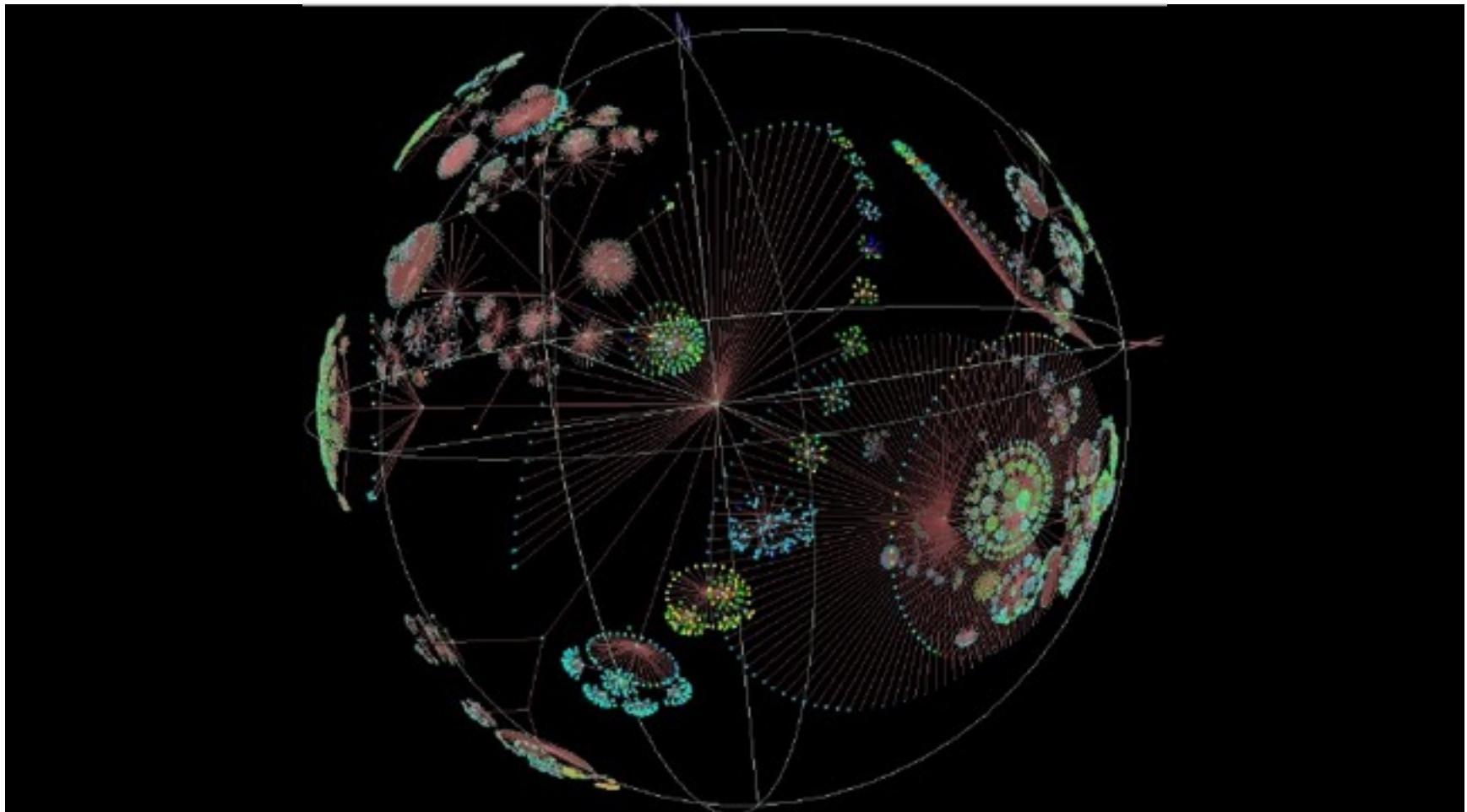
<http://cs.jhu.edu/~razvanm/fs-expedition/2.6.x.html>

Hyperbolic Tree



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

Hyperbolic Tree (3D)

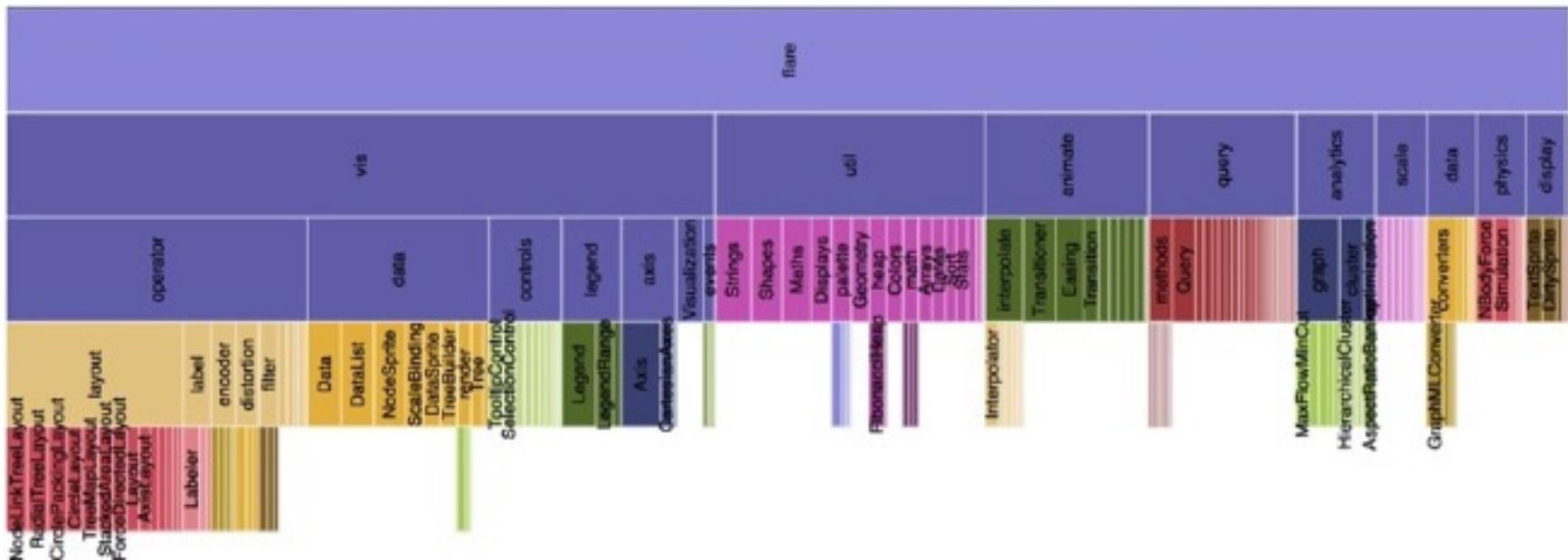


<http://www.caida.org/tools/visualization/walrus/>

SPACE-FILLING DIAGRAMS

Tree Visualization

Icicle Diagram



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

Icicle Diagram



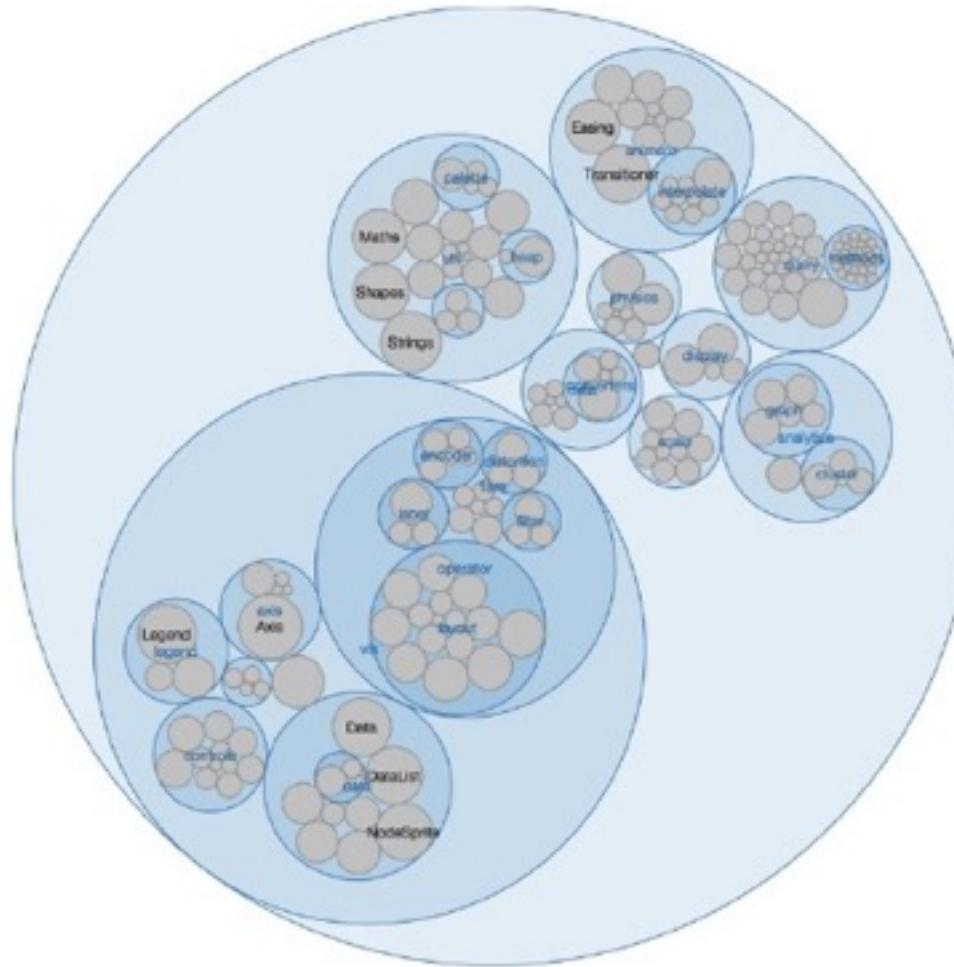
<http://mbostock.github.io/d3/talk/20111018/partition.html>

Sunburst Diagram



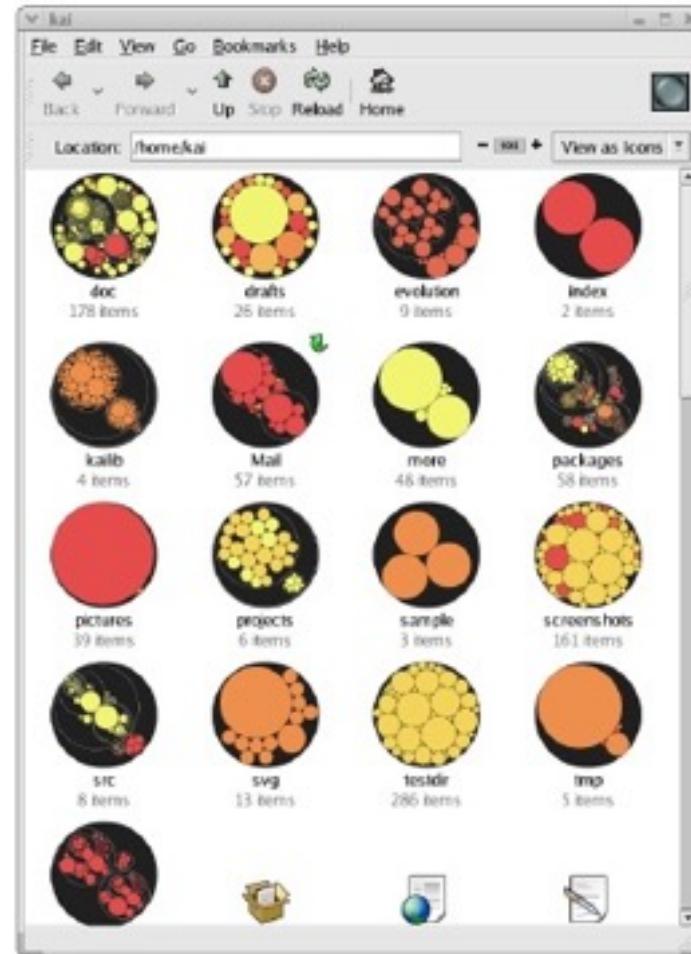
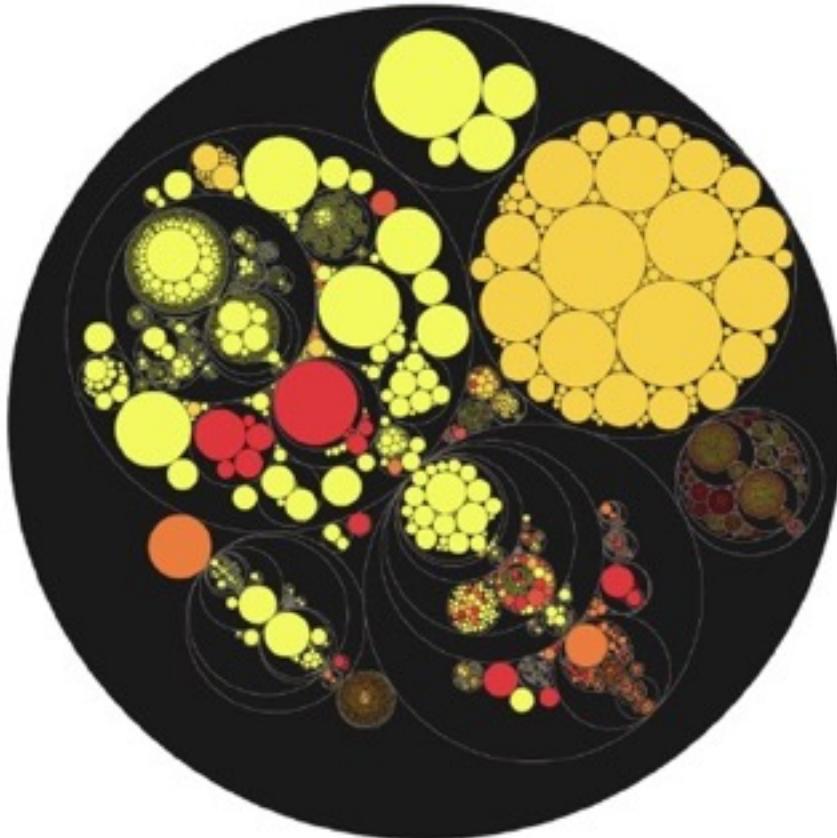
<http://bl.ocks.org/mbostock/4063423>

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://blocks.org/mbostock/4063582>

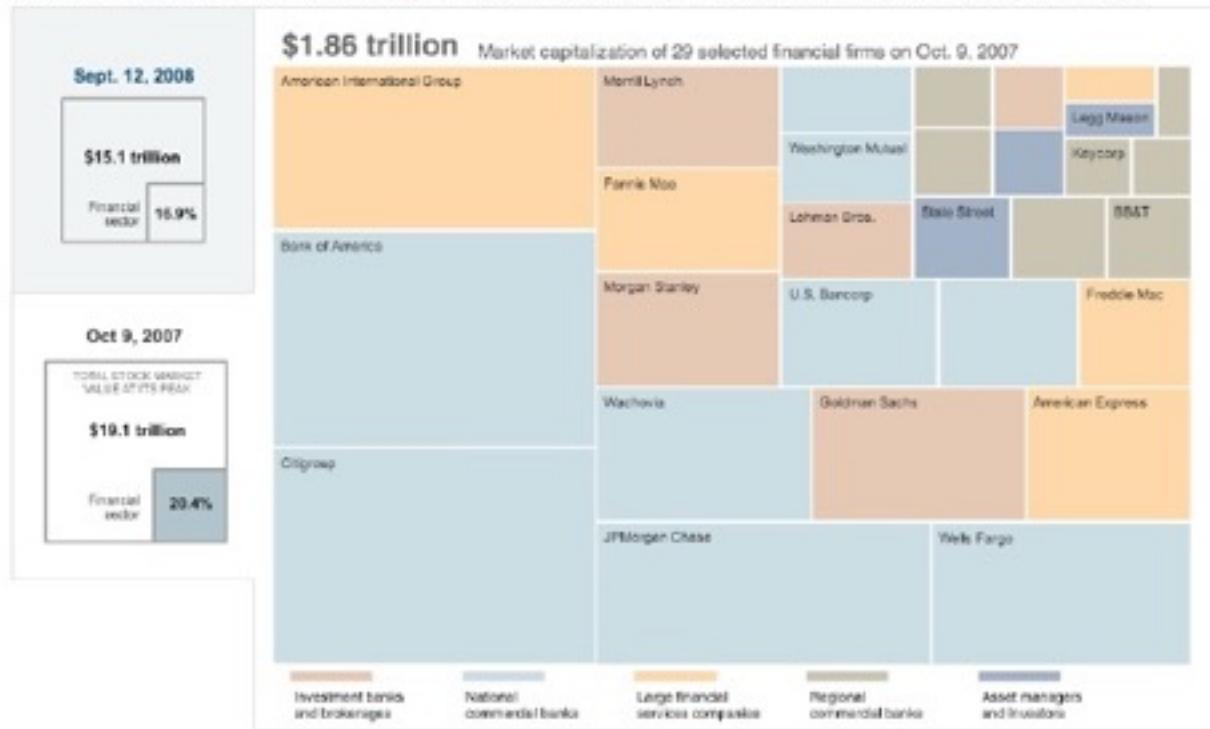
A Year of Heavy Losses

September 15, 2008

SIGN INTO EMAIL OR SAVE THIS | FEEDBACK

A Year of Heavy Losses

A year ago, financial companies were flying high. But as problems in the mortgage and credit markets have grown, the stocks of many Wall Street firms have been hard hit. Some of the biggest companies have been bought out, taken over by the government or gone bankrupt.



These two snapshots of the U.S. stock market and the financial sector are based on the Dow Jones Wilshire 5000 index, the market's broadest measure. Each box represents the market value of one company, which is found by multiplying the number of a company's shares outstanding by its stock price.

Source: Wilshire Associates

Kevin Quigley and Dylan Loeb McClain / The New York Times

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

How the Giants of Finance Shrunk

Published: September 12, 2009

How the Giants of Finance Shrunk, Then Grew, Under the Financial Crisis



<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

The screenshot shows a news aggregator interface with a grid of news items. The main article on the left is titled "Masters 2013: Rory McIlroy primed for Augusta and shot at third major". Other prominent titles include "Student charged after 14 wounded in mass stabbing at Texas college", "GOP Senators Signal Possible Breakthrough in Gun Debate", and "Brad Paisley Goes on Twitter to Defend 'Accidental Racist'". The grid also includes stories about a Champions League game, NBA, NFL, and various international and entertainment news.

Category / Headline	Summary	Image / Link
Masters 2013: Rory McIlroy primed for Augusta and shot at third major	Rory McIlroy is favored to win the Masters Tournament at Augusta National Golf Club. He has won two majors and has been involved in a controversial photo shoot.	Full Story
Student charged after 14 wounded in mass stabbing at Texas college	A student was charged with 14 counts of aggravated assault after stabbing multiple people at a college campus.	Full Story
GOP Senators Signal Possible Breakthrough in Gun Debate	Senators from both parties are discussing potential legislation to regulate guns.	Full Story
Brad Paisley Goes on Twitter to Defend 'Accidental Racist'	Brad Paisley responded to critics of his 'Elysium' trailer by posting a defense on Twitter.	Full Story
Drama drips in Dortmund as favorites advance in Champions League	Real Madrid and Bayern Munich advanced in the UEFA Champions League.	Full Story
Miami Heat ties franchise record with win over Milwaukee Bucks	The Miami Heat won their 10th straight game, tying a franchise record.	Full Story
Michigan's Spike Albrecht tweets at Kate Upton after loss to Louisville	Spike Albrecht, a Michigan basketball player, tweeted at Kate Upton, a Louisville Cardinals player.	Full Story
Bump in Ratings for Men's College Basketball Final	The ratings for the 2013 NCAA Men's Basketball Final increased.	Full Story
The Blue Jays are off to a slow start, and their road is getting tougher	The Toronto Blue Jays are performing poorly at the start of the season.	Full Story
Fireworks by Knicks, Followed by a Title	The New York Knicks won the NBA championship.	Full Story
Nabokov backstop Islanders to win against Flyers	The New York Islanders won an NHL game despite being short-handed.	Full Story
McNamee may have left KU after one season, but his journey has just begun	Mike McNamee, a former Kansas basketball player, has signed with the Chicago Bulls.	Full Story
Michigan Not Desired to Throw, Might Need Surgery	A Michigan football coach is considering surgery for a shoulder injury.	Full Story
Smith Leaving for NBA, Father Says	Tony Smith, a former NBA player, is leaving to play in the Chinese Basketball Association.	Full Story
Nettie Clark, Tomato Plant's Living a Picture Without Jay Z	A woman named Nettie Clark has created a tomato plant that looks like Jay-Z's face.	Full Story
Illinois black ministers split on same-sex marriage legislation	Black ministers in Illinois are divided on whether to support same-sex marriage legislation.	Full Story
Democrats pressure Republicans for a vote on guns	Democrats are pushing for a vote on gun control bills in Congress.	Full Story
Heavy snow expected from Colorado to Minnesota	Severe winter weather is expected across several US states.	Full Story
Scott London: Tipping Began at Golf Club	Scott London, a golfer, has admitted to tipping on the golf course.	Full Story
Low calls on Germany to focus on growth to spur European economy	Germany is being urged to prioritize economic growth over debt reduction.	Full Story
Chris Brown Goes to Rihanna's Concert Amid Breakup Reports	Chris Brown attended a Rihanna concert despite rumors of a breakup.	Full Story
Dancing With the Stars Elimination: A Cut Weeks in the Making	The latest elimination on 'Dancing with the Stars'.	Full Story
Matt Damon's 'Elysium' Trailer: Watch Now!	The trailer for Matt Damon's new movie 'Elysium' is available online.	Full Story
Death toll in Iran's 6.1-magnitude quake rises to 32	A major earthquake in Iran has killed 32 people.	Full Story
Top admiral: US can intercept a North Korean missile	A US admiral says the US can intercept a North Korean missile.	Full Story
G8 foreign ministers to meet to address Syria	G8 foreign ministers will discuss the situation in Syria.	Full Story
Cuba to turn over Florida couple who allegedly kidnapped children	A Cuban court has ordered the return of two American parents held captive in Cuba.	Full Story
Malta: French Forces Begin New Offensive	French forces are launching a new offensive in Libya.	Full Story
Japan readies defenses for possible missile test by North Korea	Japan is preparing for a possible missile launch from North Korea.	Full Story
North Korea closes China border to tourists	The North Korean government has closed its border with China.	Full Story
Saudi Arabia Says Prisoner Sentence is Valid	A Saudi Arabian court has upheld the death sentence of a prisoner.	Full Story
Al Gore's Message and Tipper Rock Back Up After Rue Mein Outage	Al Gore and Tipper Gore have responded to a power outage.	Full Story
Senate Confirms to Assign Top Posts in Defense Department	Senate Republicans have confirmed several top posts in the Defense Department.	Full Story
Senate OKs Financial Regulation Bill	A Senate committee has approved a bill to regulate financial derivatives.	Full Story
Marilyn Tavenner soars through Senate Finance hearing	Marilyn Tavenner has passed a Senate confirmation hearing.	Full Story
Lindsey Lohan Finds Herself In The Hot Seat On 'Letterman'	Lindsay Lohan appeared on 'The Late Show with David Letterman'.	Full Story
April Is Planning Surprise for Her Fiancé on Their Wedding Day	April is preparing a surprise wedding day for her fiancé.	Full Story
Justin Timberlake, Mary Staples and more bring sounds of soul to the White ...	Singers including Justin Timberlake and Mary Staples performed at the White House.	Full Story
U.S. donates billion-dollar collection to Met	The United States is donating a significant collection of artifacts to the Metropolitan Museum of Art.	Full Story
APK: Security Concerns Surrounding 'Dark Knight' Film Reveal	Security concerns have arisen regarding the filming of 'The Dark Knight Rises'.	Full Story
Nick Fornio's Skills From That Game	Nick Fornio is showcasing his skills from a video game.	Full Story
Justine Timberlake, Mary Staples and more bring sounds of soul to the White ...	Singers including Justine Timberlake and Mary Staples performed at the White House.	Full Story
April Is Planning Surprise for Her Fiancé on Their Wedding Day	April is preparing a surprise wedding day for her fiancé.	Full Story
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<http://newsmap.jp/>

Cushion Treemap

Cushion TreeMaps

In this example a static JSON tree is loaded into a Cushion Treemap.

Left click to set a node as root for the visualization.

Right click to set the parent node as root for the visualization.

You can choose a different tiling algorithm below:

Squarified

Strip

SliceAndDice

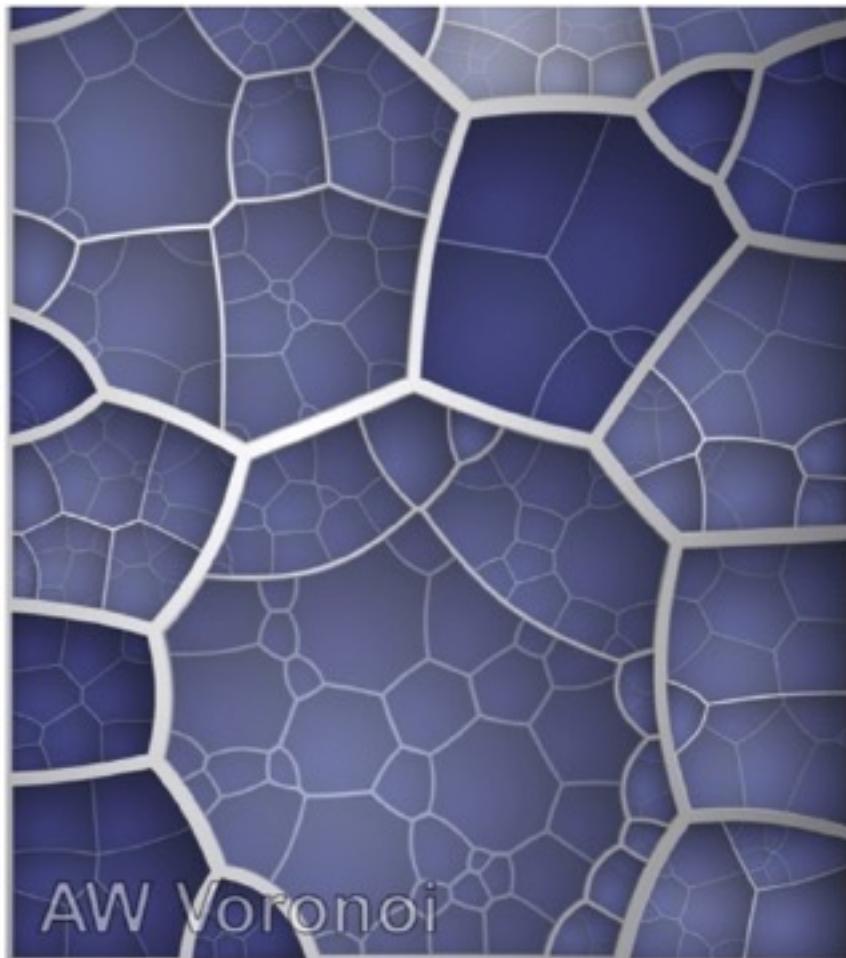
[Go to Parent](#)

[See the Example Code](#)

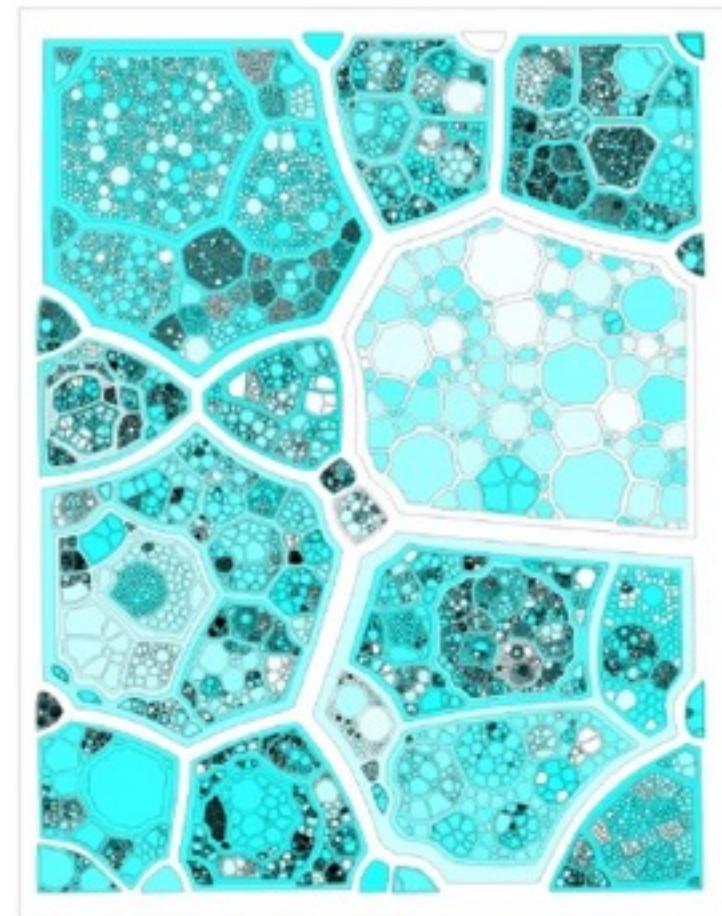
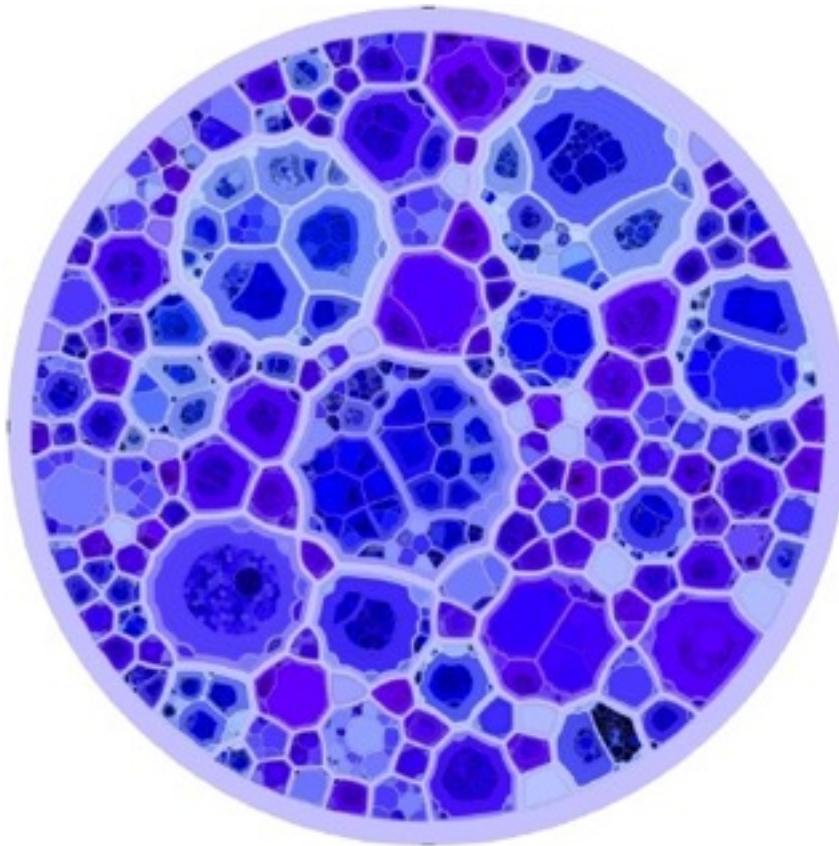


<http://philogb.github.io/jit/static/v20/Jit/Examples/Treemap/example3.html>

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

ZOOM IN ZOOM OUT

Food and beverages 15%

The high price of oil is a factor that has made food prices rise quickly.

Miscellaneous 3%

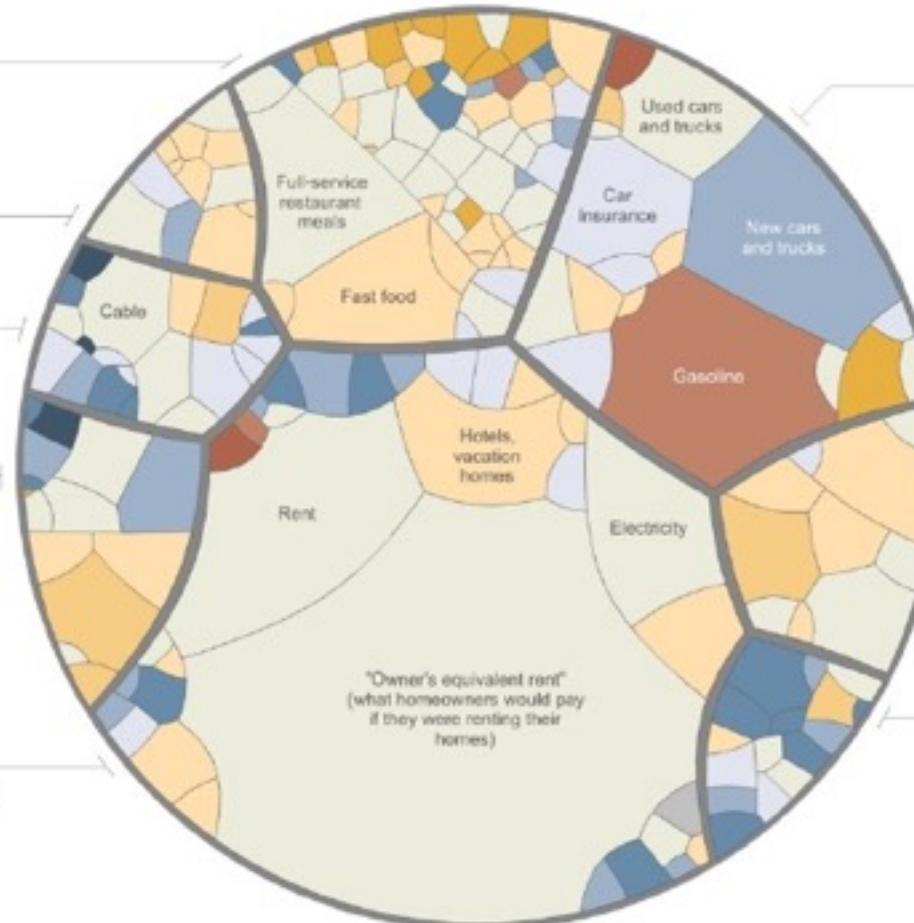
Recreation 6%

Education/Communication 6%

Cellphones were added to the index in 1997. Because the Consumer Price Index can be slow to add new goods, which are often cheaper, it may overstate parts of inflation.

Housing 42%

In the C.P.I., home ownership costs track rent prices more closely than housing prices. This means inflation may have been understated when home prices were rising faster than rents.



Transportation 18%

Gas is 5.2 percent of spending nationwide, but only 3.8 percent in the New York area.

Health care 6%

As a group, the elderly spend about twice as much of their budget on medical care.

Apparel 4%

The ratio of spending on women's clothes to that on men's clothes is about 2 to 1.

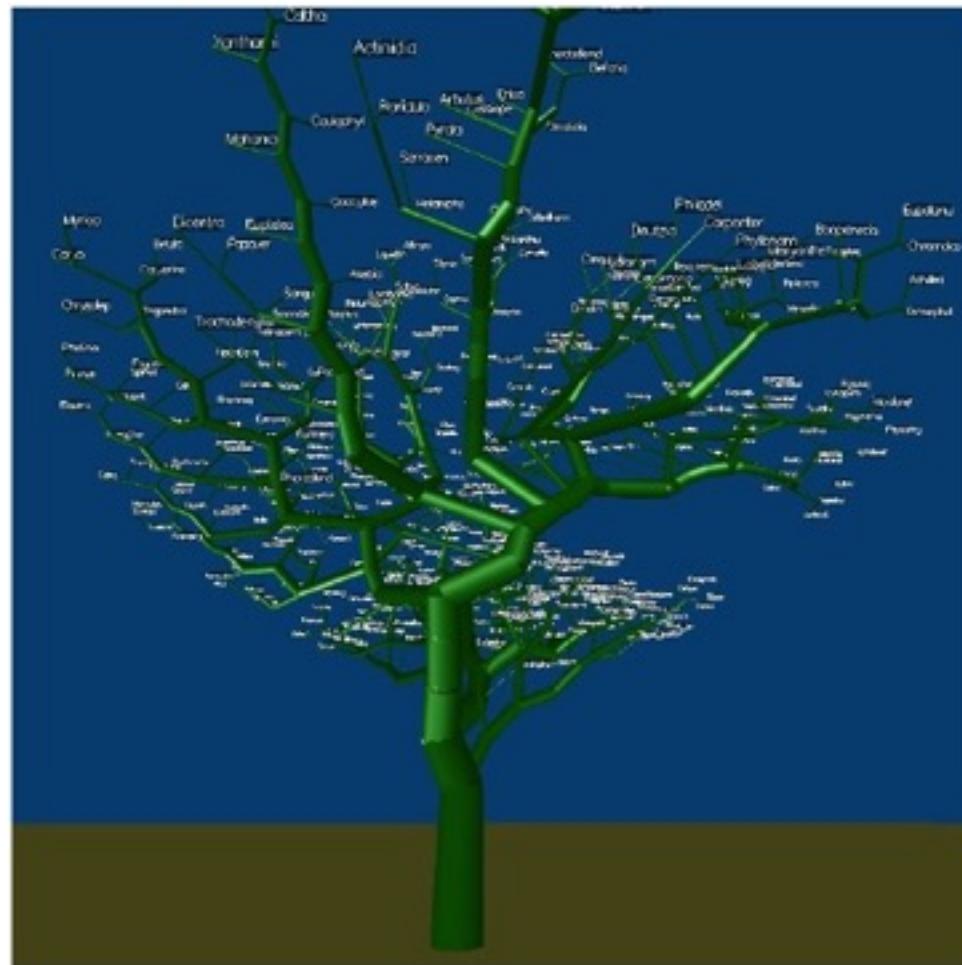
TREE OF LIFE

Case Study

Tree of Life

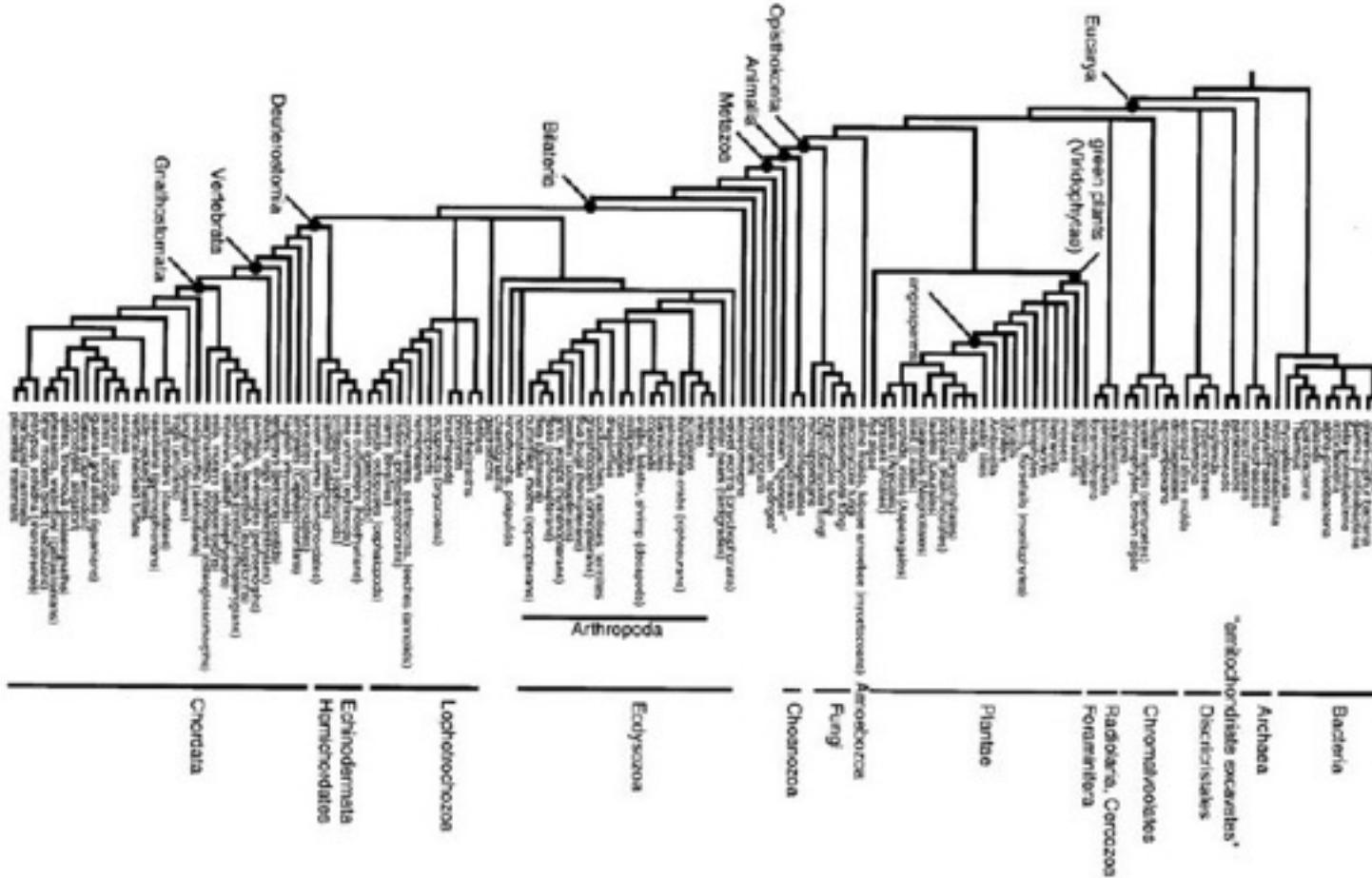
- Specifically phylogenetic tree of life
 - Evolutionary tree, showing where species branch
- Can be thousands to tens of thousands of nodes
- Many tools for the ToL exist using different visualization techniques
- See <http://tolweb.org/tree/phylogeny.html>

Paloverde



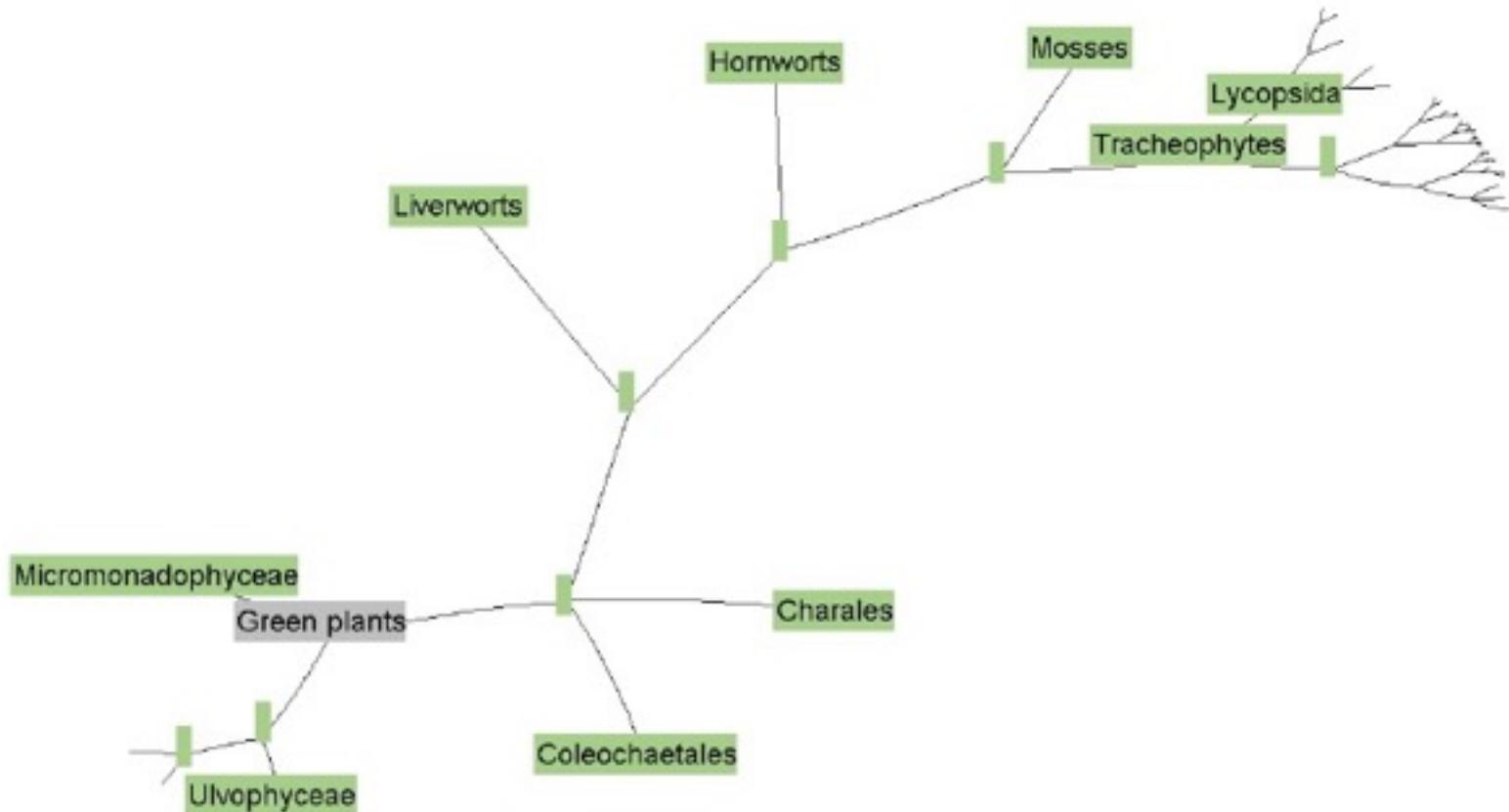
<http://loco.biosci.arizona.edu/paloverde/paloverde.html>

Teachable ToL



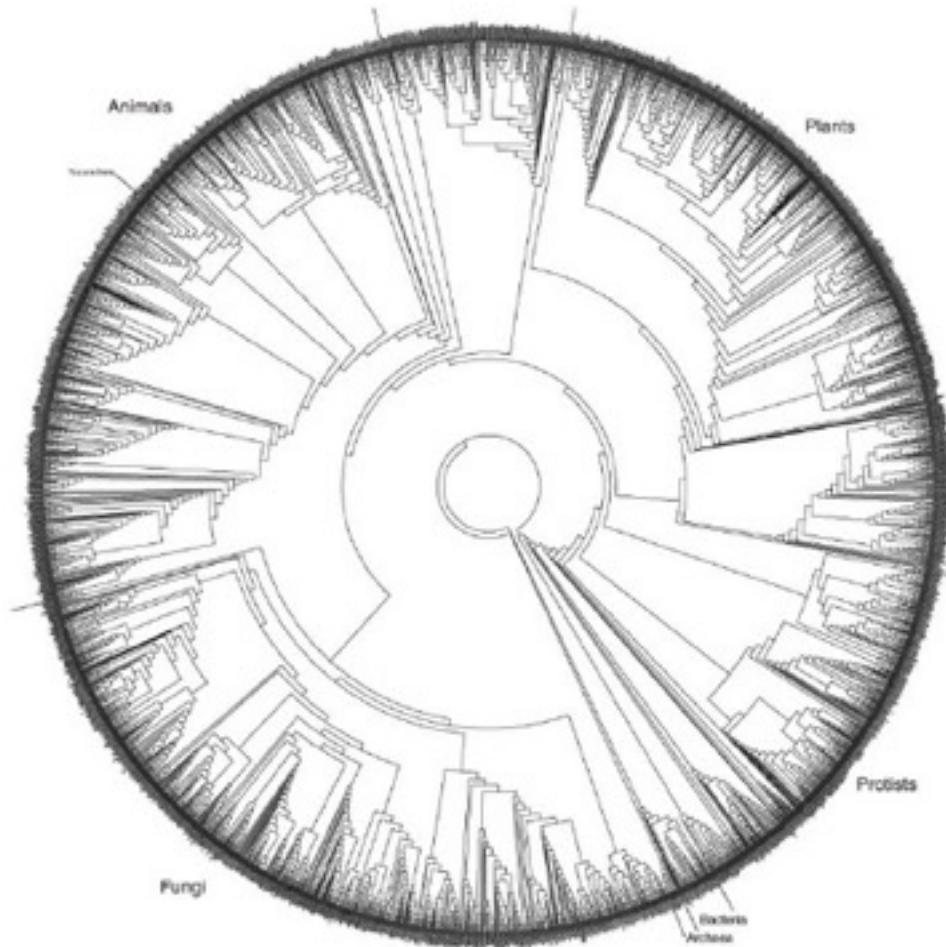
<http://www.rebeccashapley.com/cipres/telescoping.htm>

Hyperbolic ToL (Plants Only)



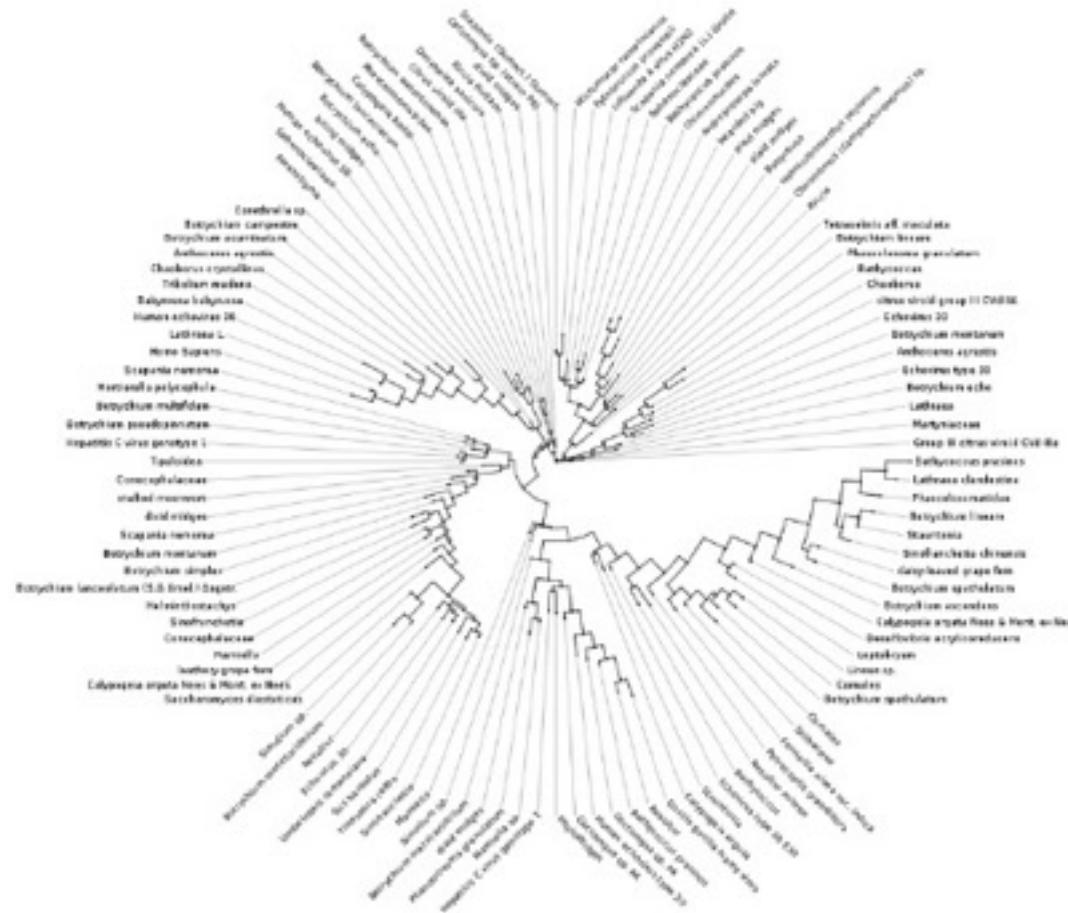
<http://ucjeps.berkeley.edu/TreeofLife/hyperbolic.php>

Subset of 3,000 Species



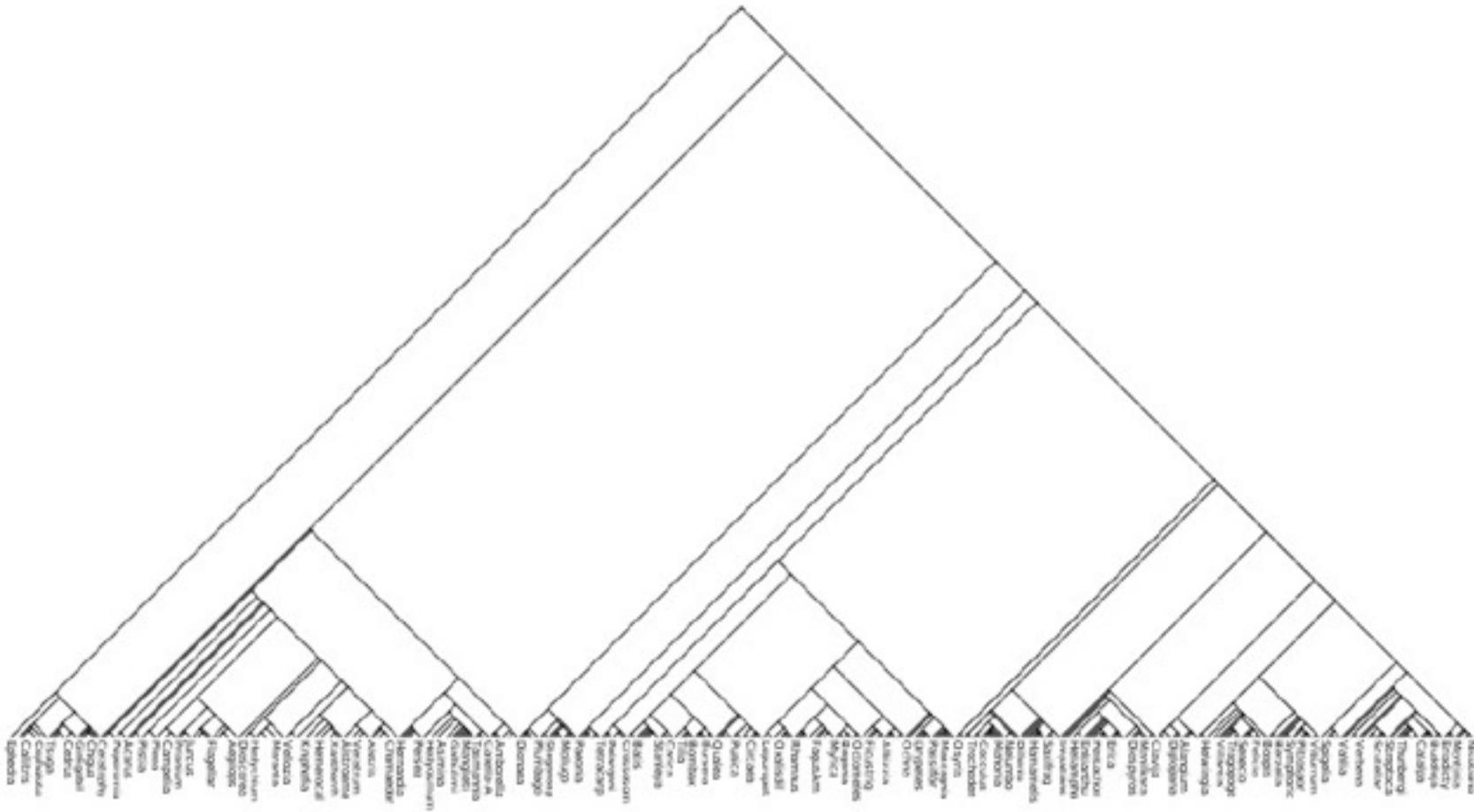
<http://www.zo.utexas.edu/faculty/antisense/DownloadfilesToL.html>

PhyloWidget



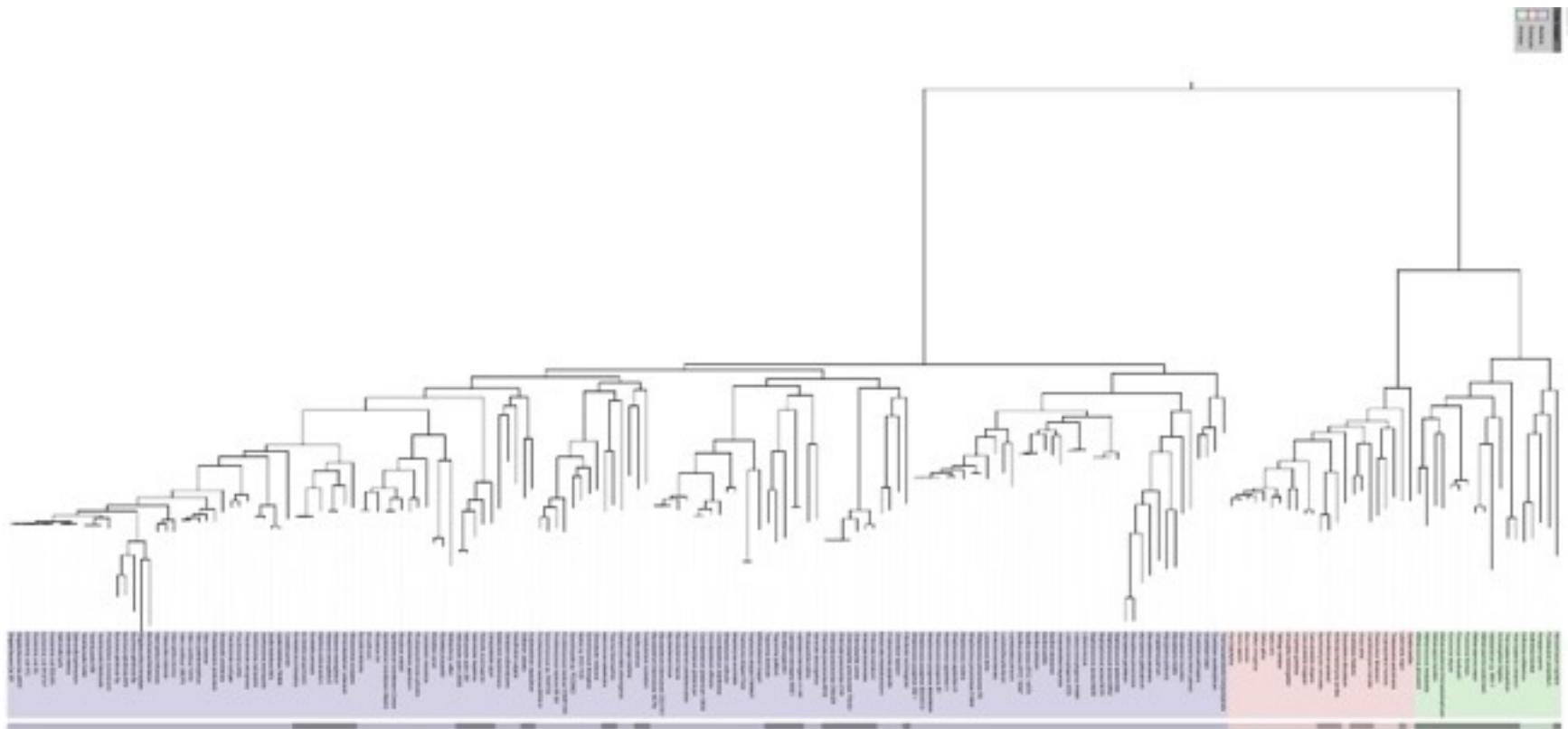
<http://www.phylowidget.org/>

PhyloWidget



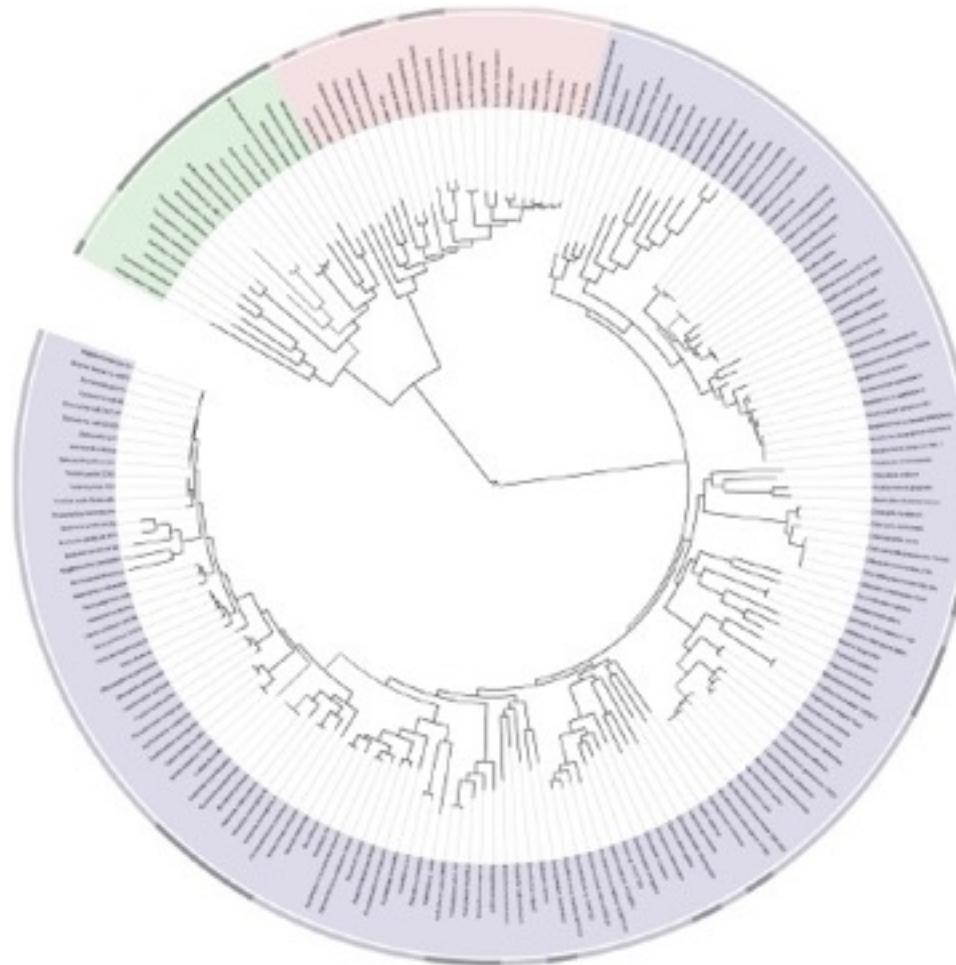
<http://www.phylowidget.org/>

Interactive ToL



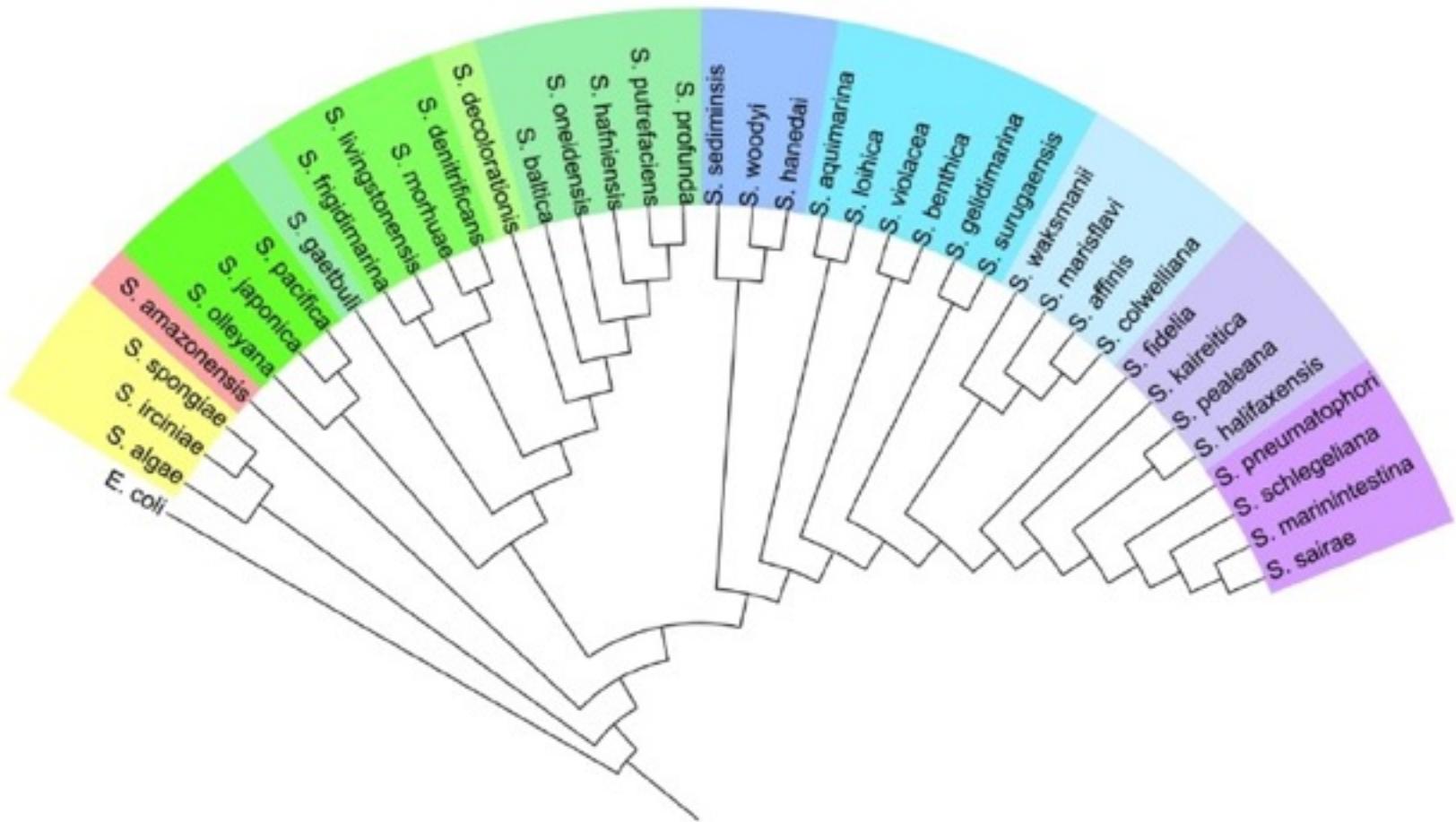
<http://itol.embl.de/>

Interactive ToL



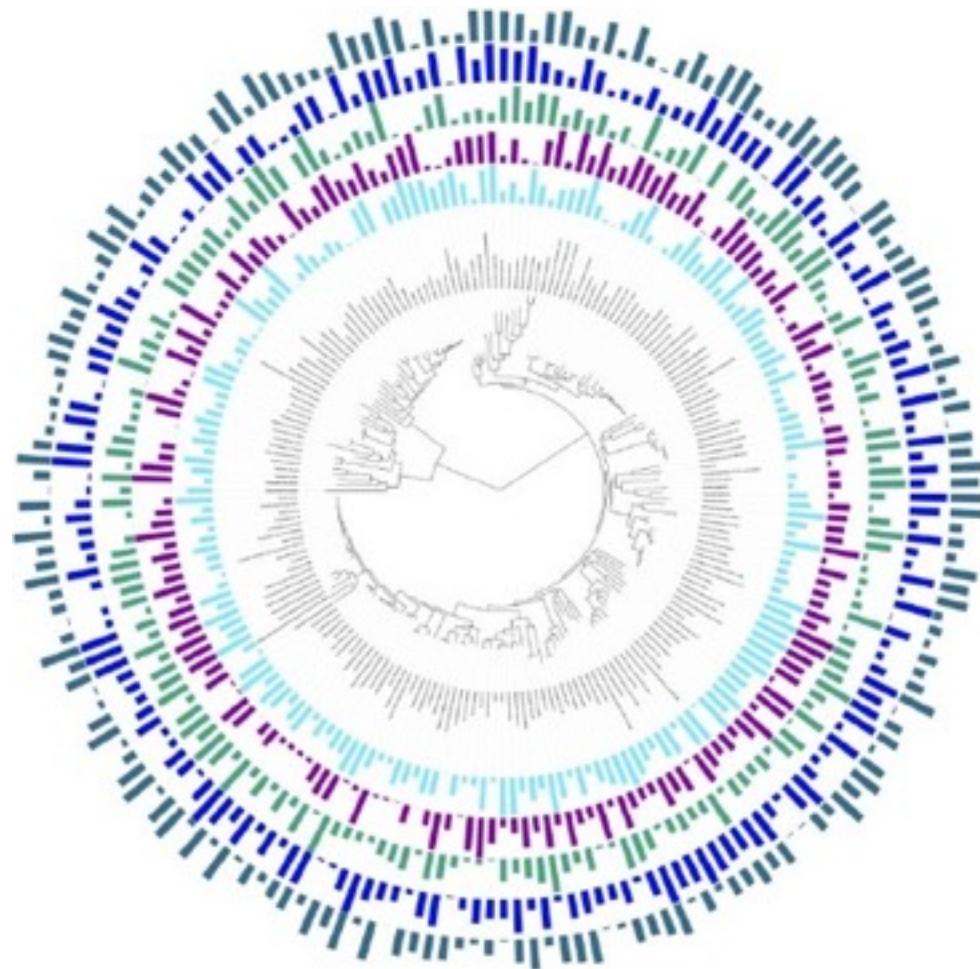
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Interactive ToL



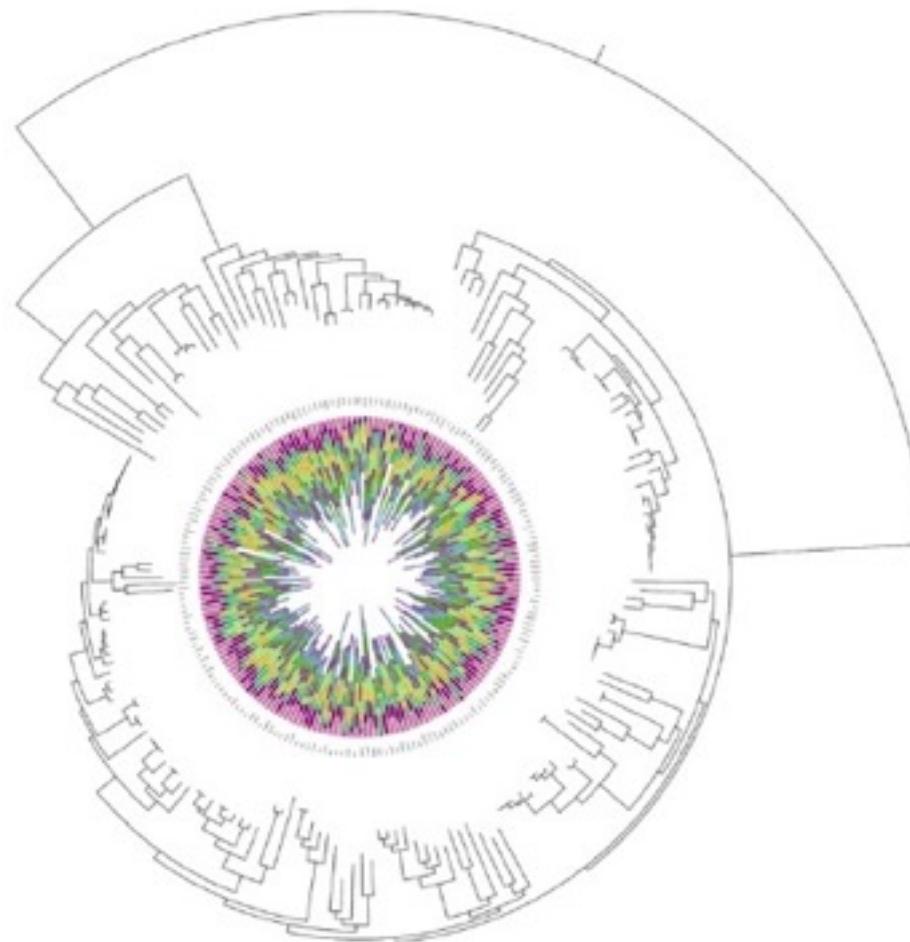
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Interactive ToL



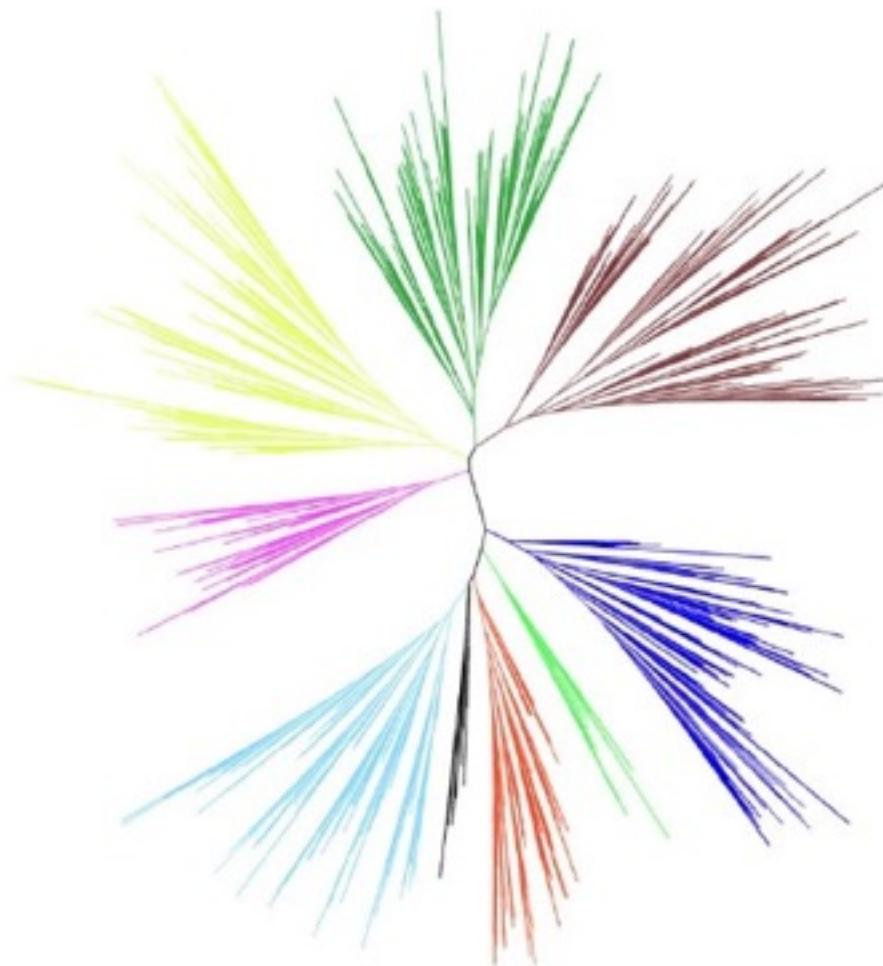
<http://itol.embl.de/>

Interactive ToL



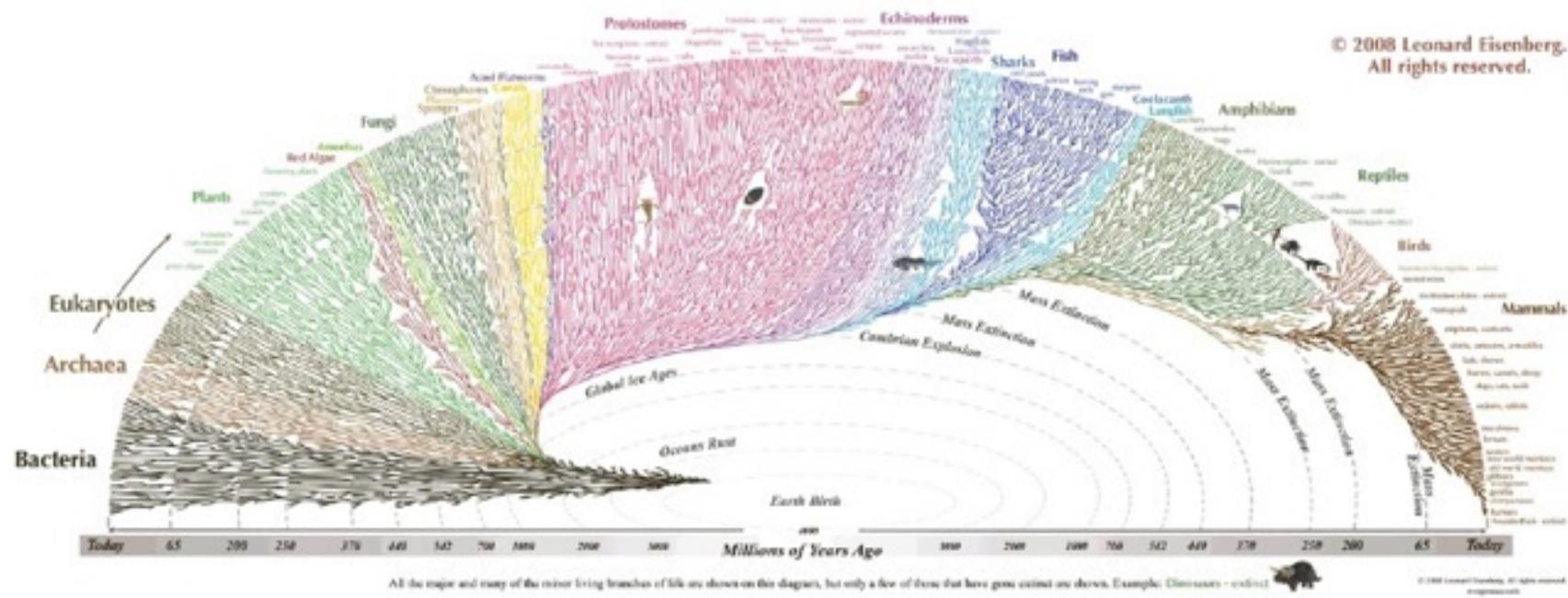
<http://itol.embl.de/>

Interactive ToL

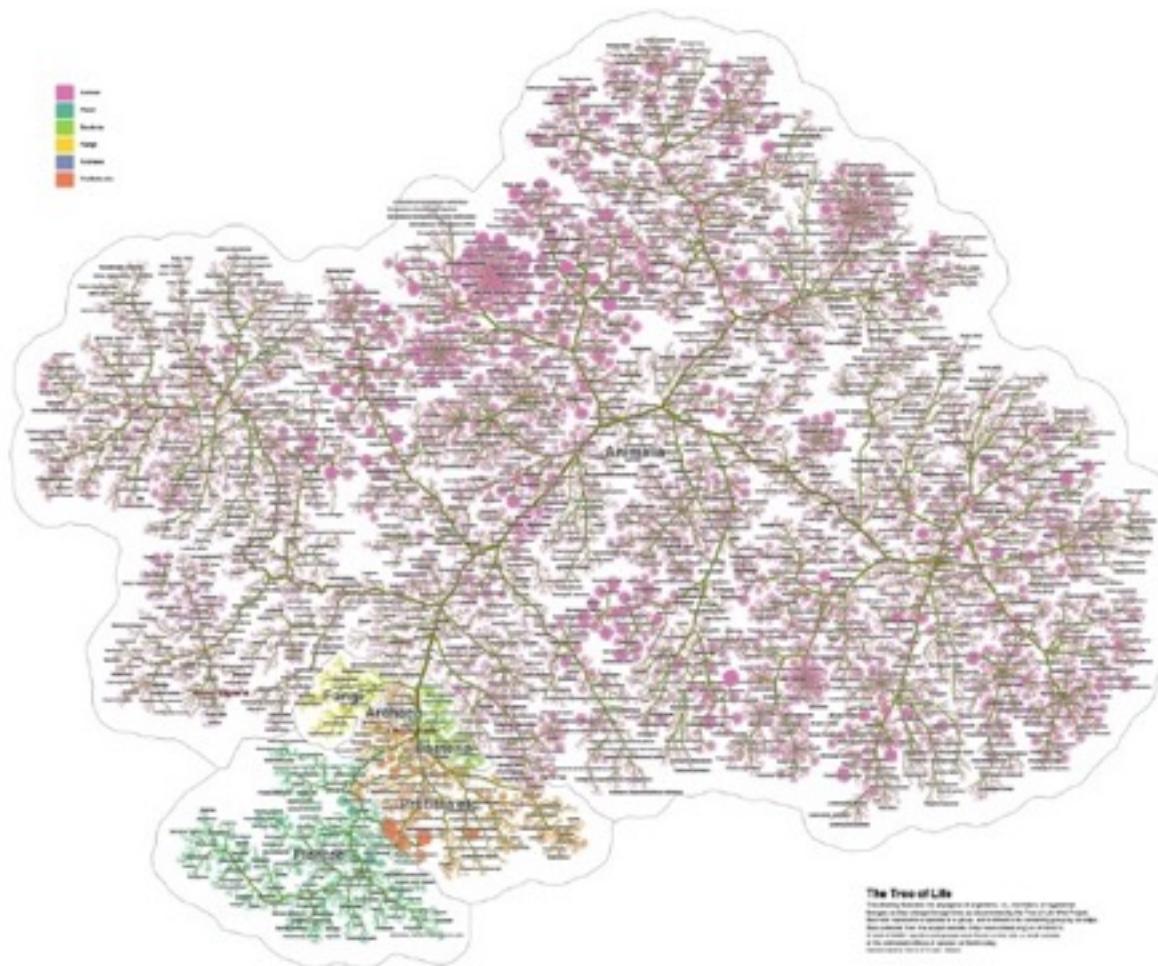


<http://itol.embl.de/>

Illustration

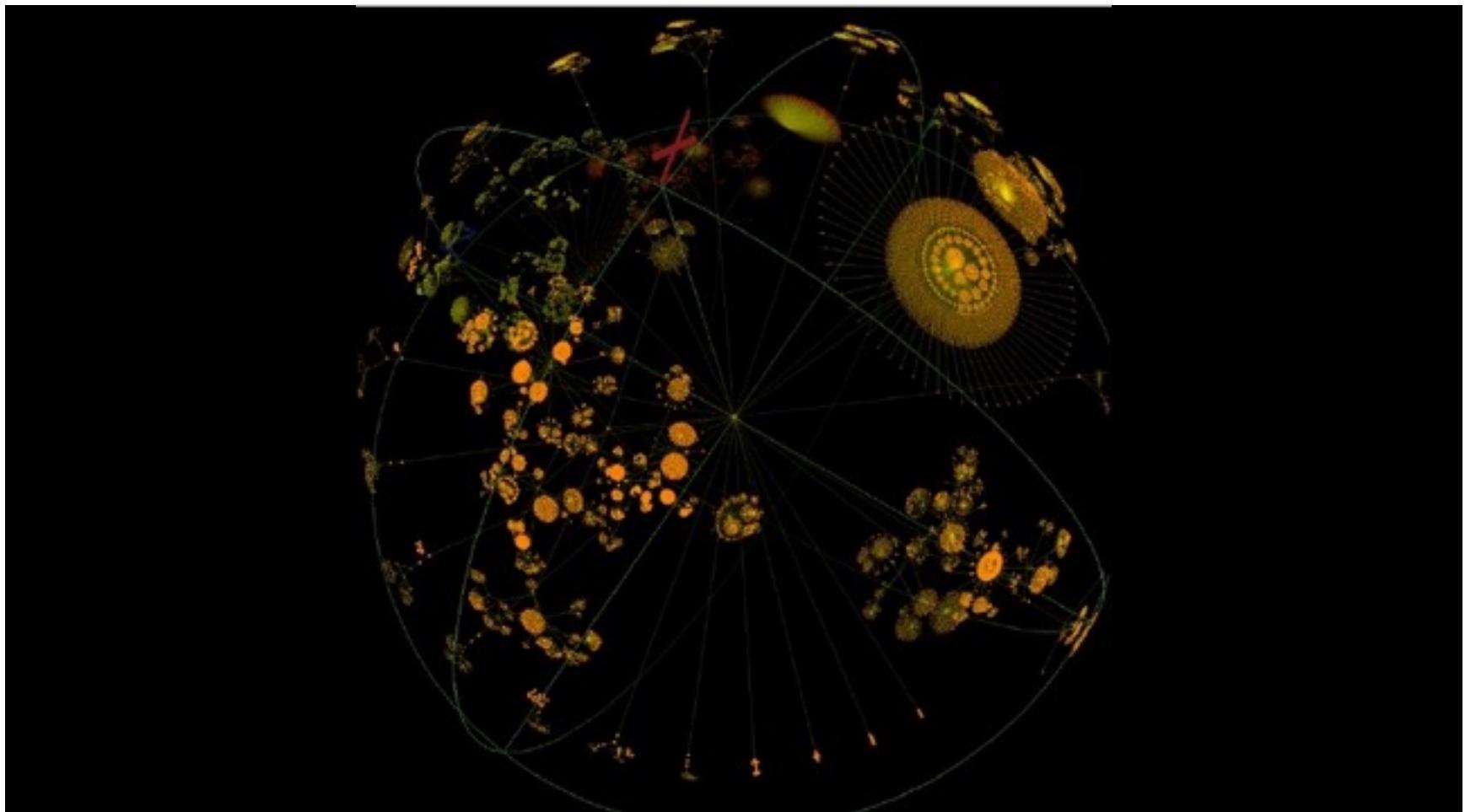


Interactive ToL (2)



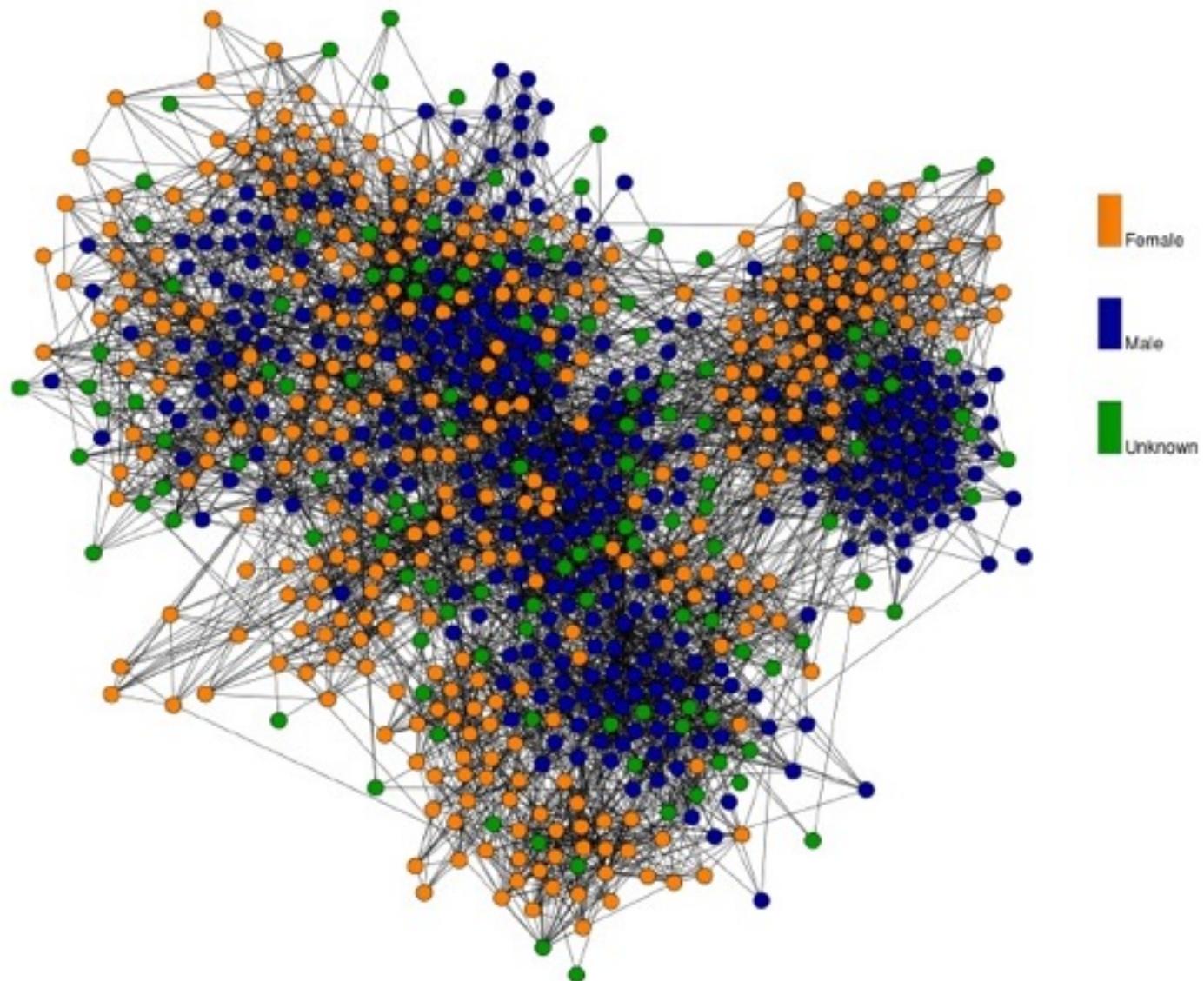
<http://www2.research.att.com/~yifanhu/TOL/>

ToL Using Walrus

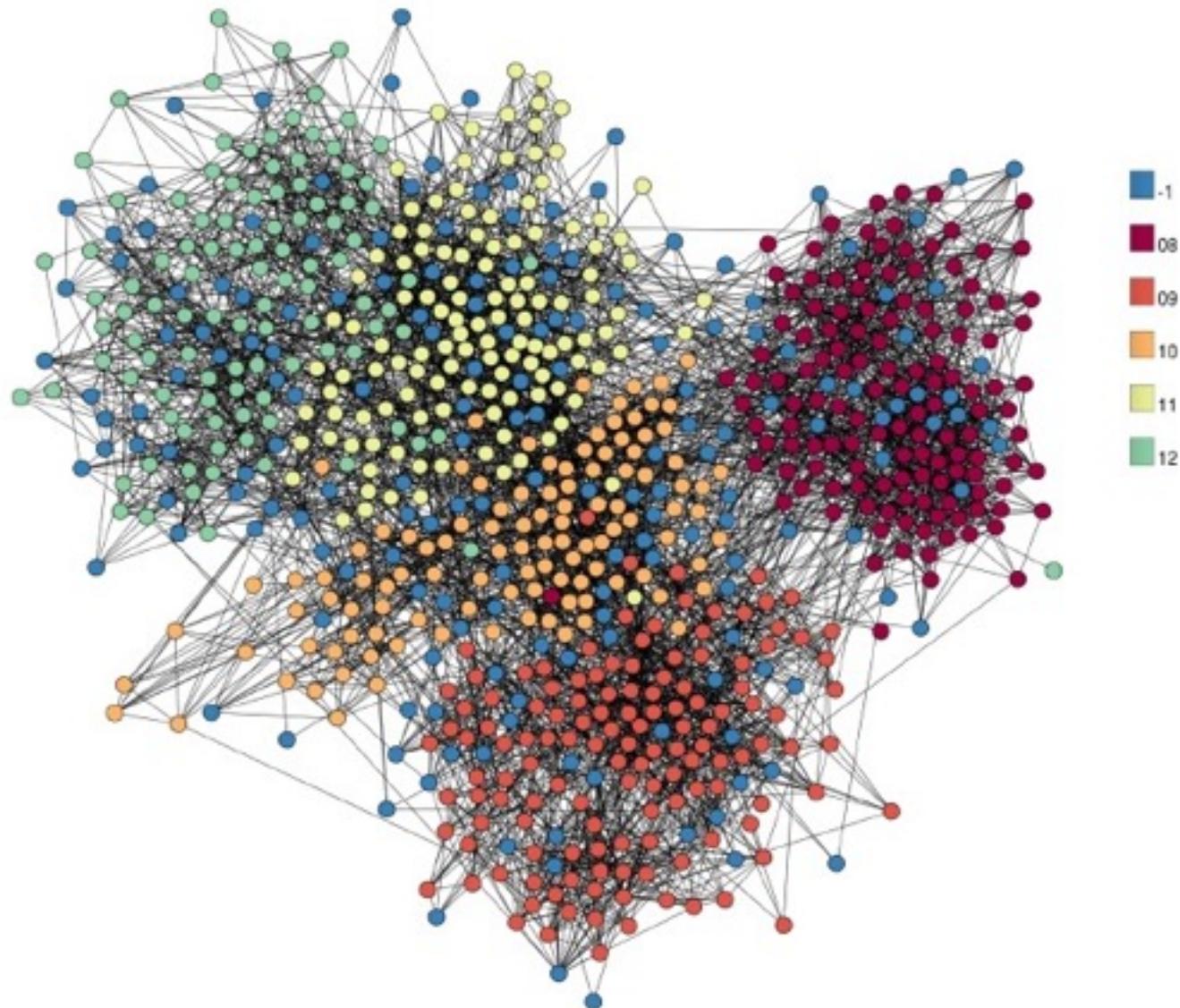


<http://digitised.info/content/view/20/51/>

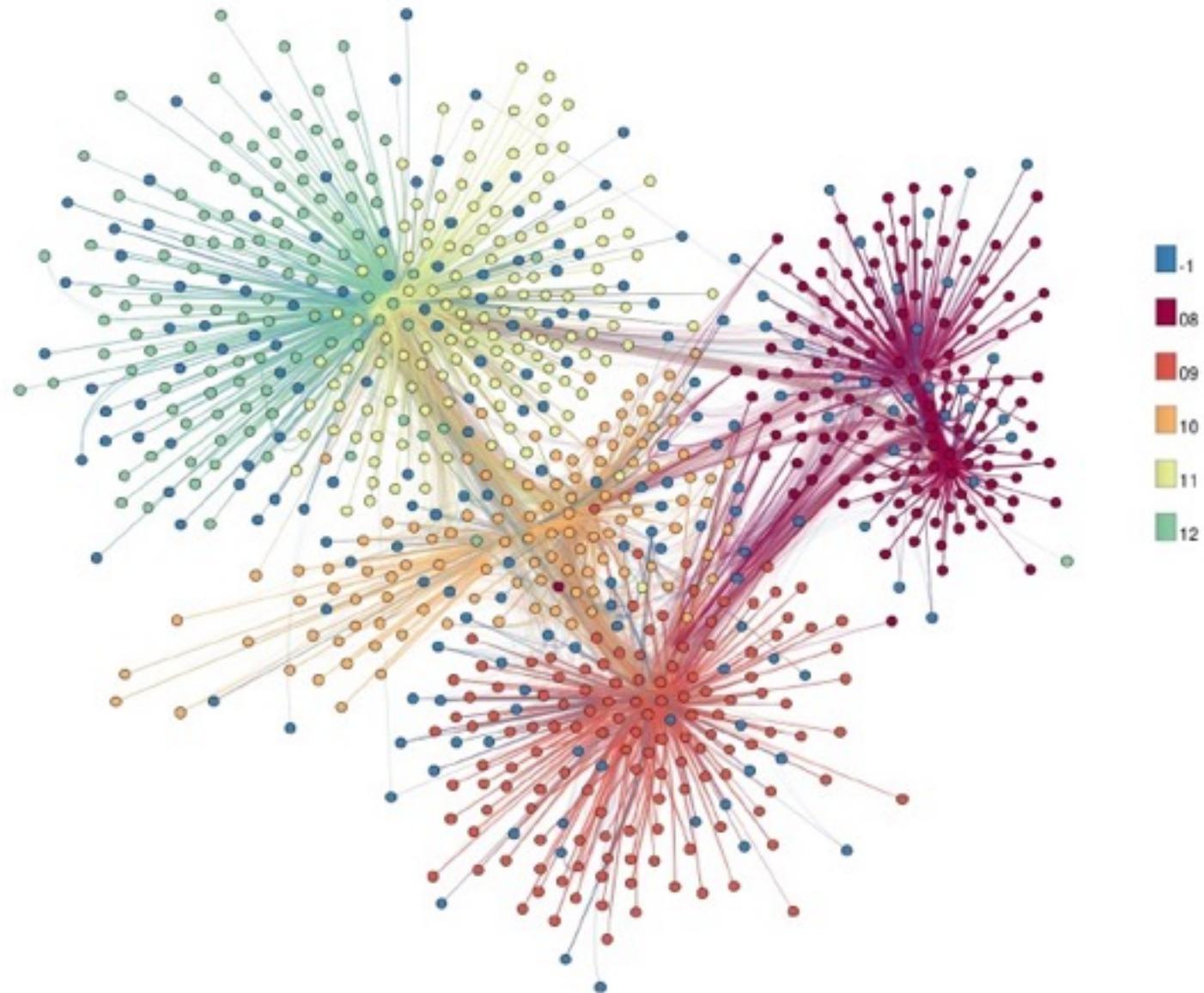
GRAPH VISUALIZATION MOTIVATION



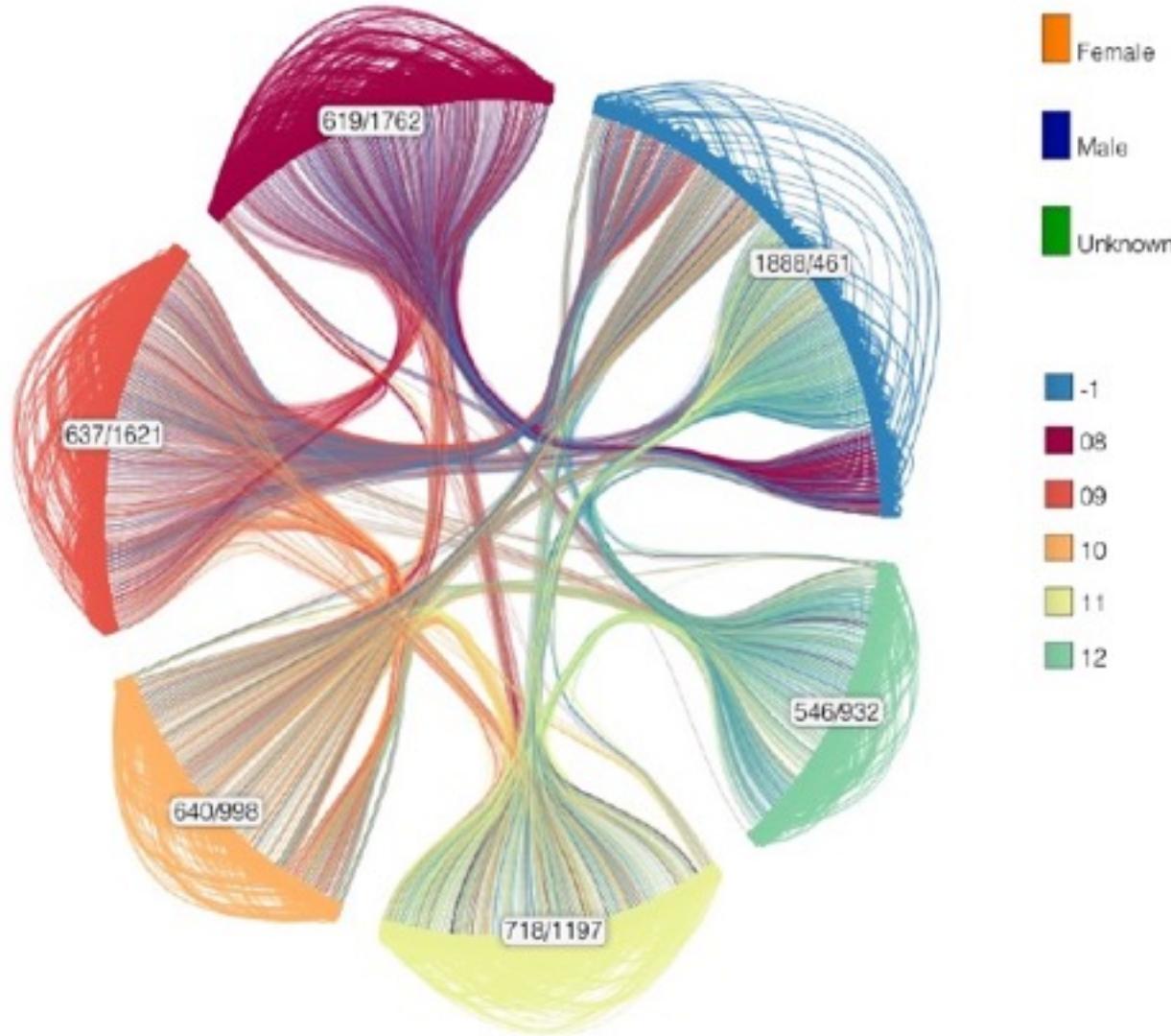
<http://vidi.cs.ucdavis.edu/projects/AggressionNetworks/>



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

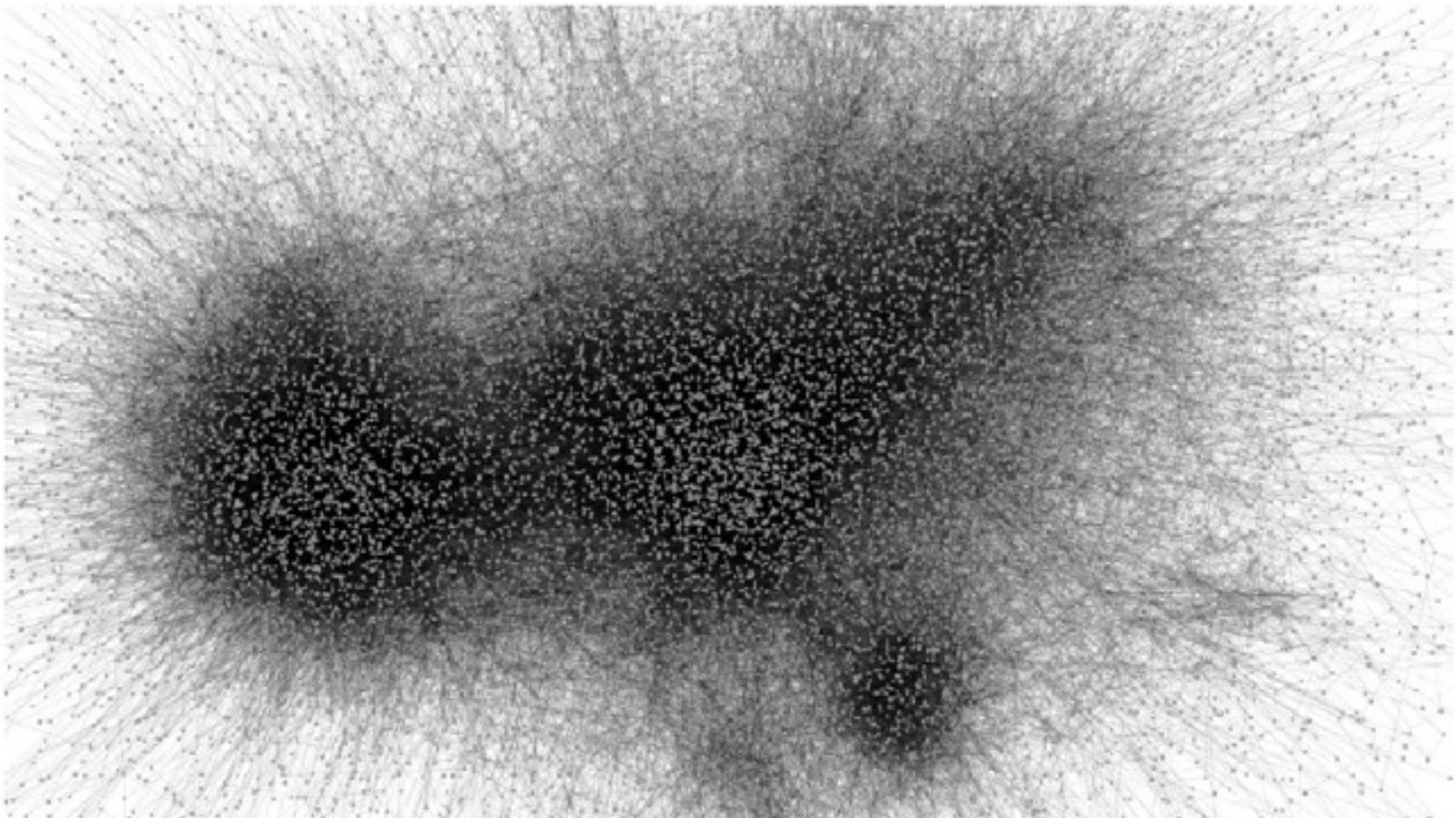


<http://vidi.cs.ucdavis.edu/projects/AggressionNetworks/>



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

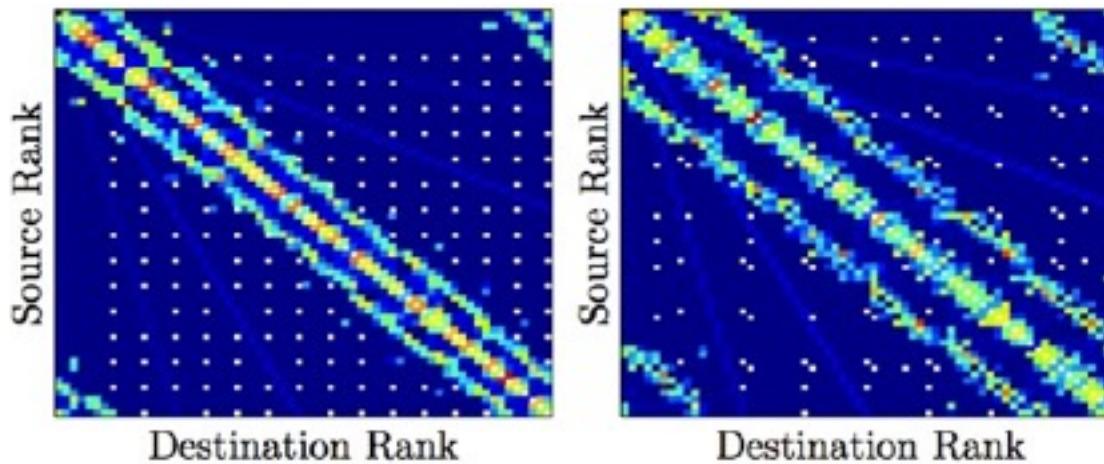
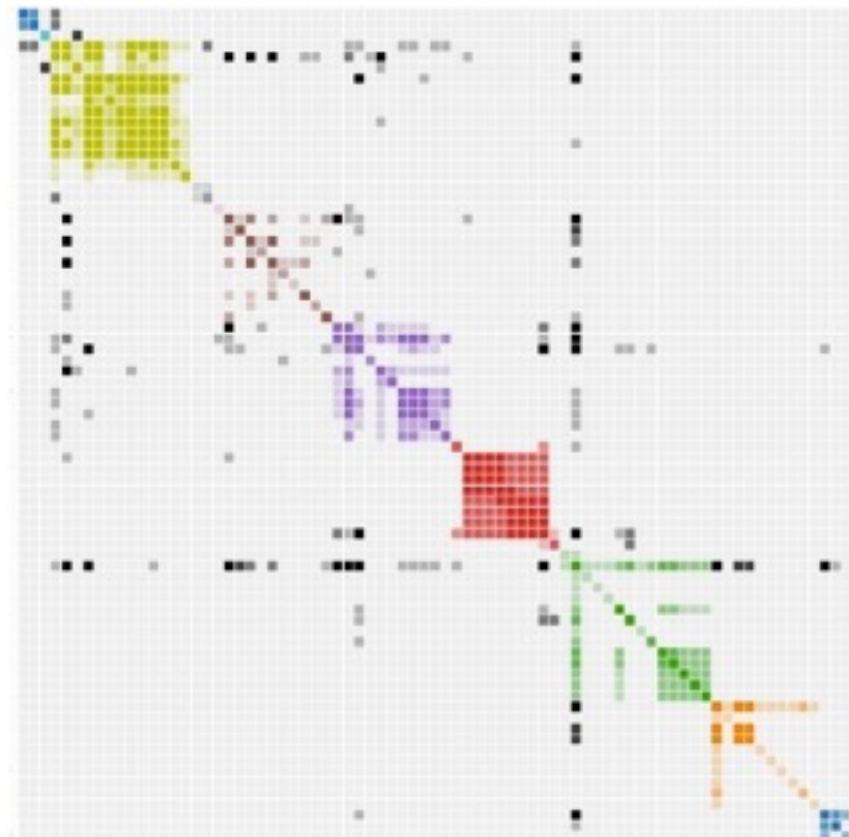
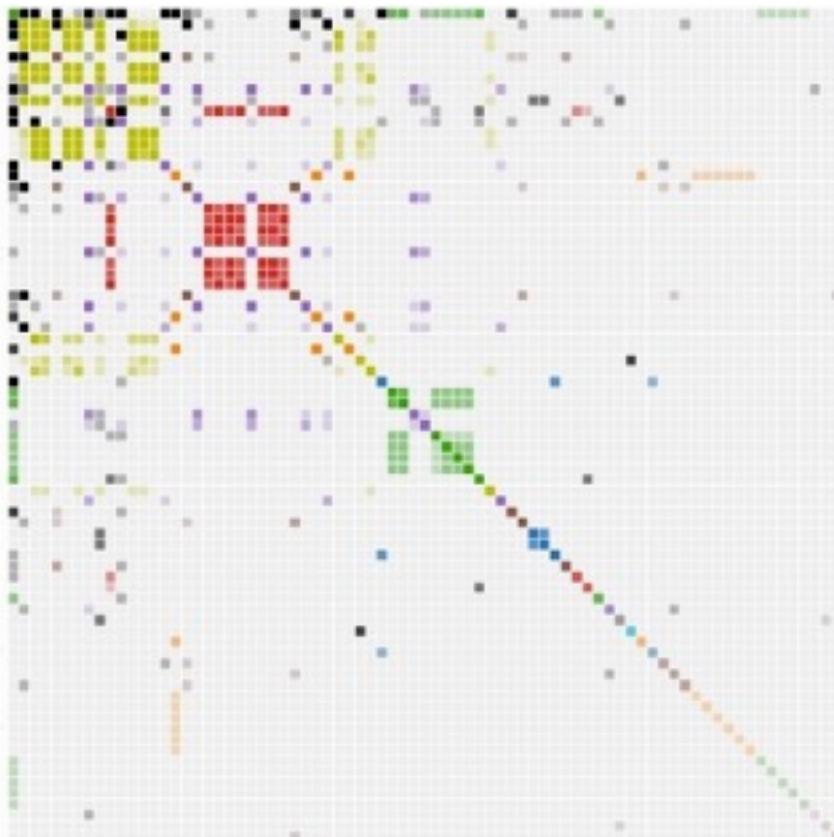


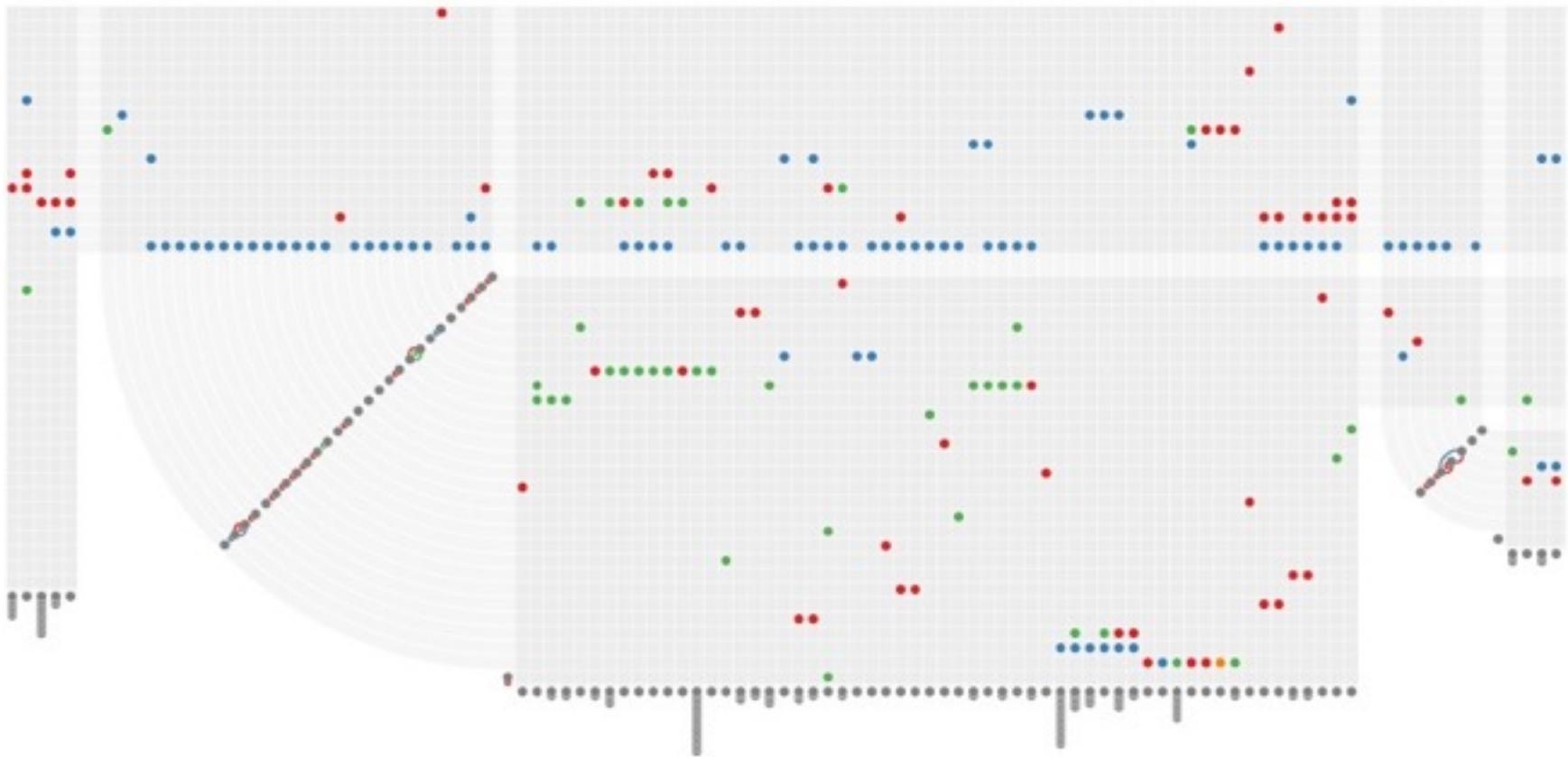
Figure 3: Data dependent topology demonstrated by molecular dynamics simulator NAMD under different molecular arrangements. The number of bytes sent between ranks is linearly mapped from dark blue (lowest) to red (highest), with white indicating an absence of communication.

Les Misérables Co-Occurrence



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

Compressed Adjacency Matrix



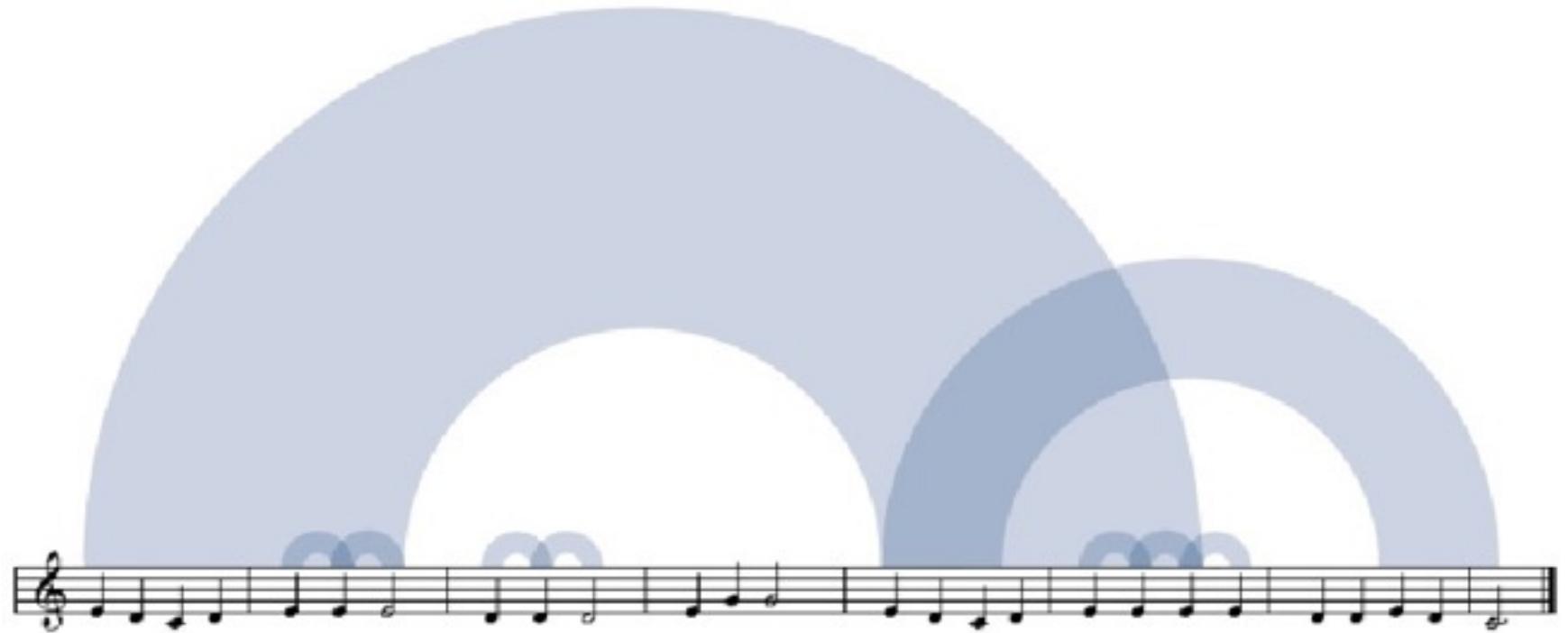
<http://www.computer.org/csdl/trans/tg/2012/12/ttg2012122457-abs.html>

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

THE SHAPE OF SONG

[What the diagrams mean](#) | [Image gallery](#) | [Home](#) | [Contact](#)

Repertoire (640 pieces)	
Composer	Title
All of Noise	Cinills
	Moments in...
Azander	Adagio
	For Tebe
	For Tebe
	Lacrimosa
Bach	✓ AMental Off...
	AMental Off...
	✓ Brandenburg...
	Invv542
	Invv543
	Invv546
	Colorminor...
	Fugue, D Minor
	Götlberg-Yull...
	Götlberg-Yull...
	Götlberg-Yull...
	Götlberg-Yull...
	Invenito 13
Bach, J.S.	Jesu Joy of M...
	Passacaglia...
Backstreet ...	I Want It That...
Beijo da Cale ...	Calling You
bdi	Infond
Bertles	x
	c
	c
	entrepô
Bernard F L ...	Just a Toy
	just a toy
Bethel	plan a concert...

Brandenburg Concerto 2. Back. Viewing track 1 of 9.

Play (all blocks)

You can add any MIDI file on the web to the repertoire.

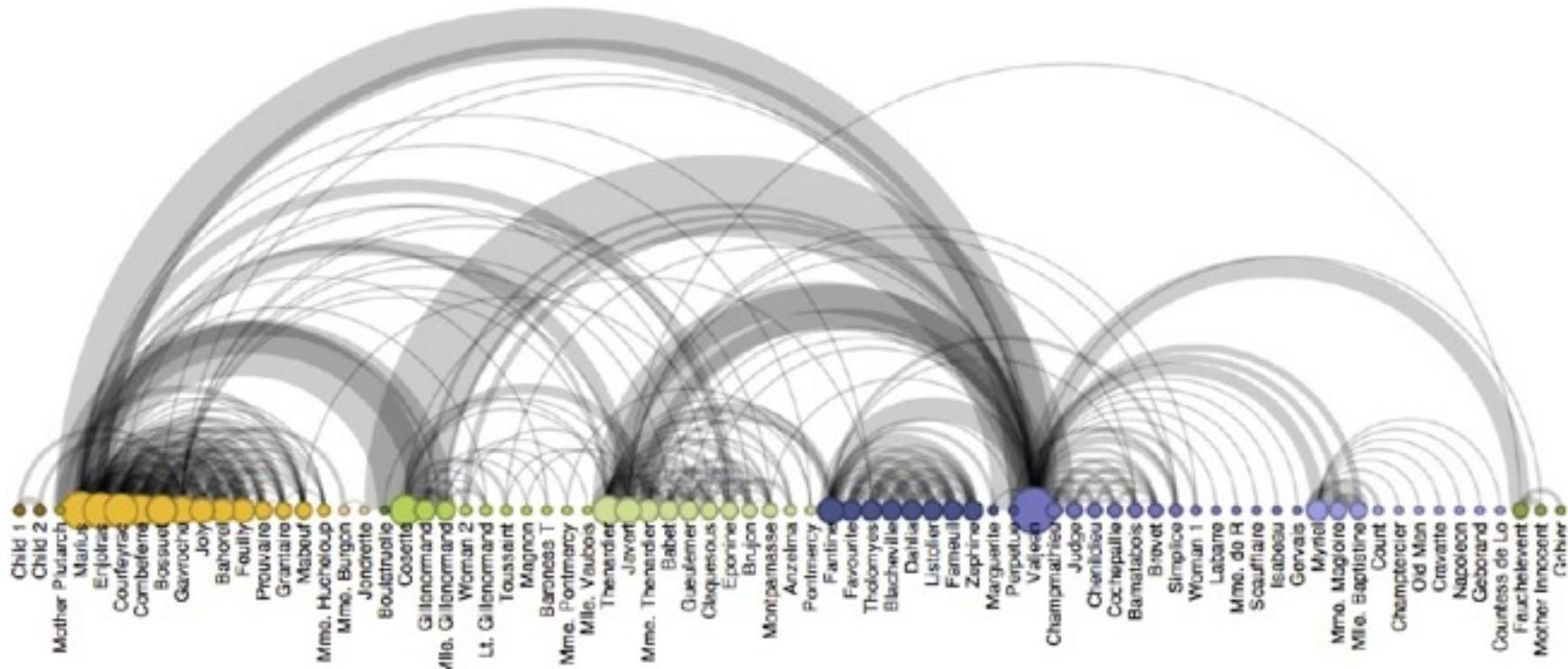
URL:

Title: Composer: Add to repertoire

Enter the URL of a MIDI file and the title of the piece. Composer is optional but nice.

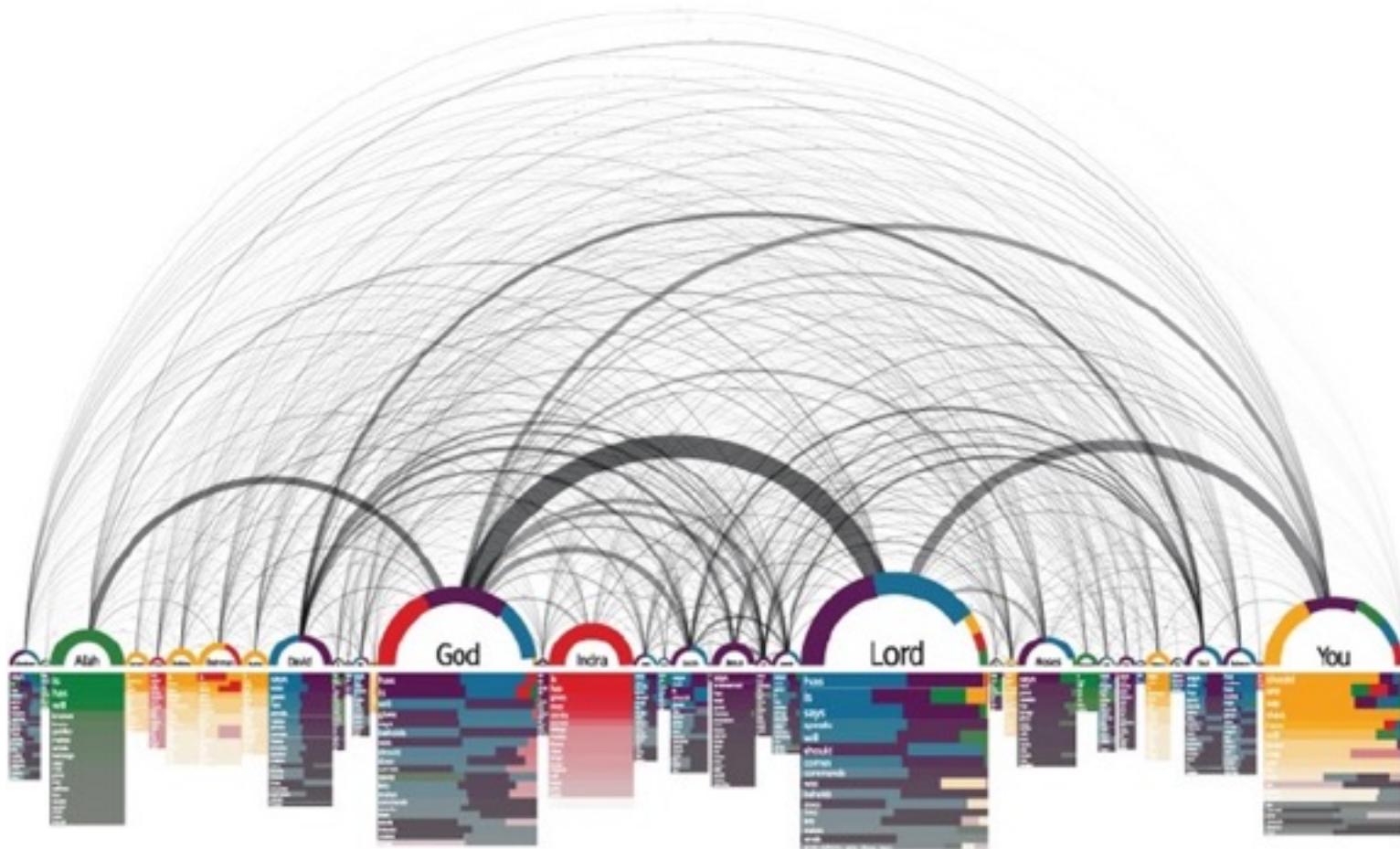
<http://www.turbulence.org/Works/song/mono.html>

Arc Diagram in Protopvis



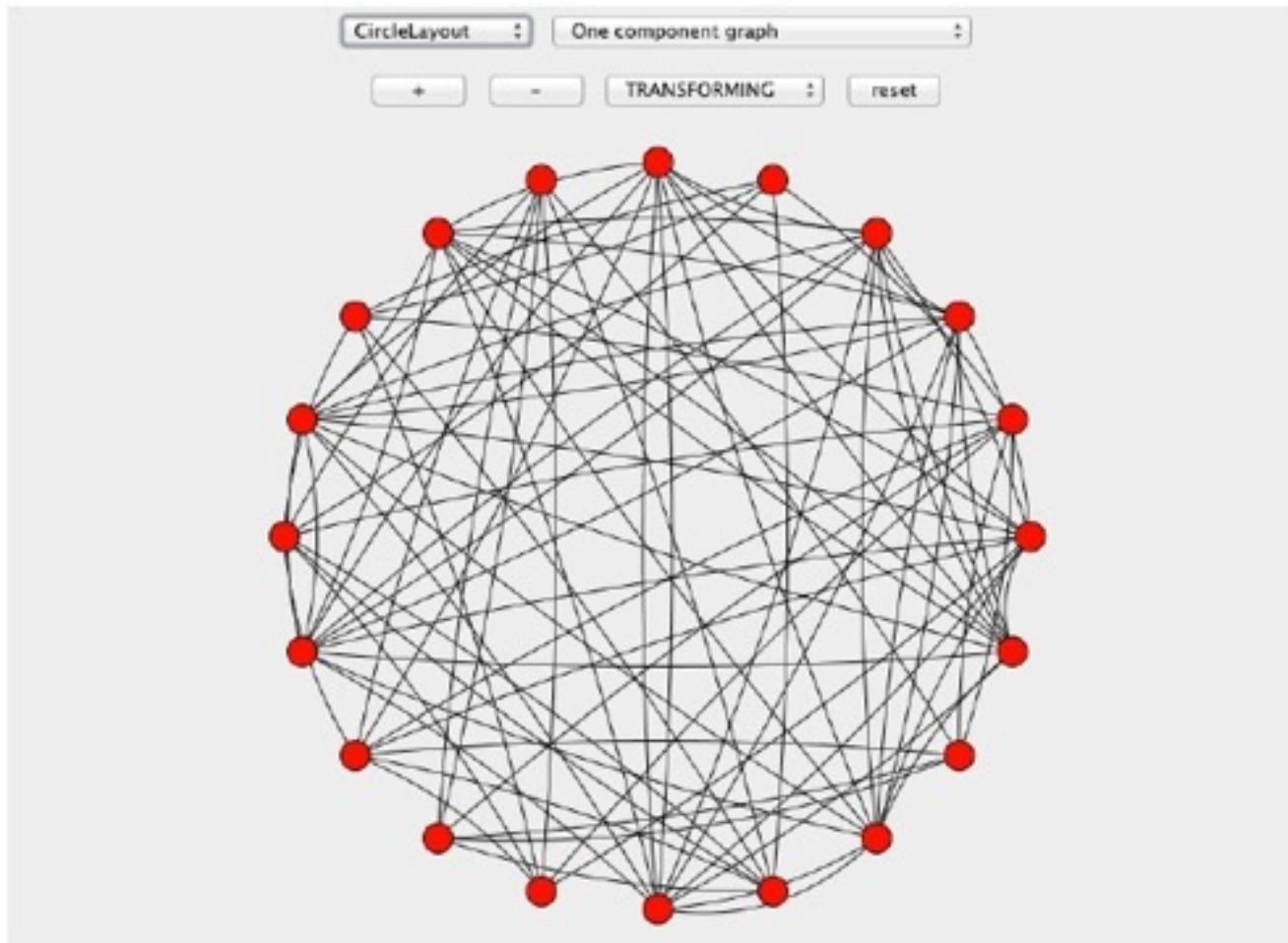
<http://mbostock.github.io/protovis/ex/arc.html>

Similar Diversity



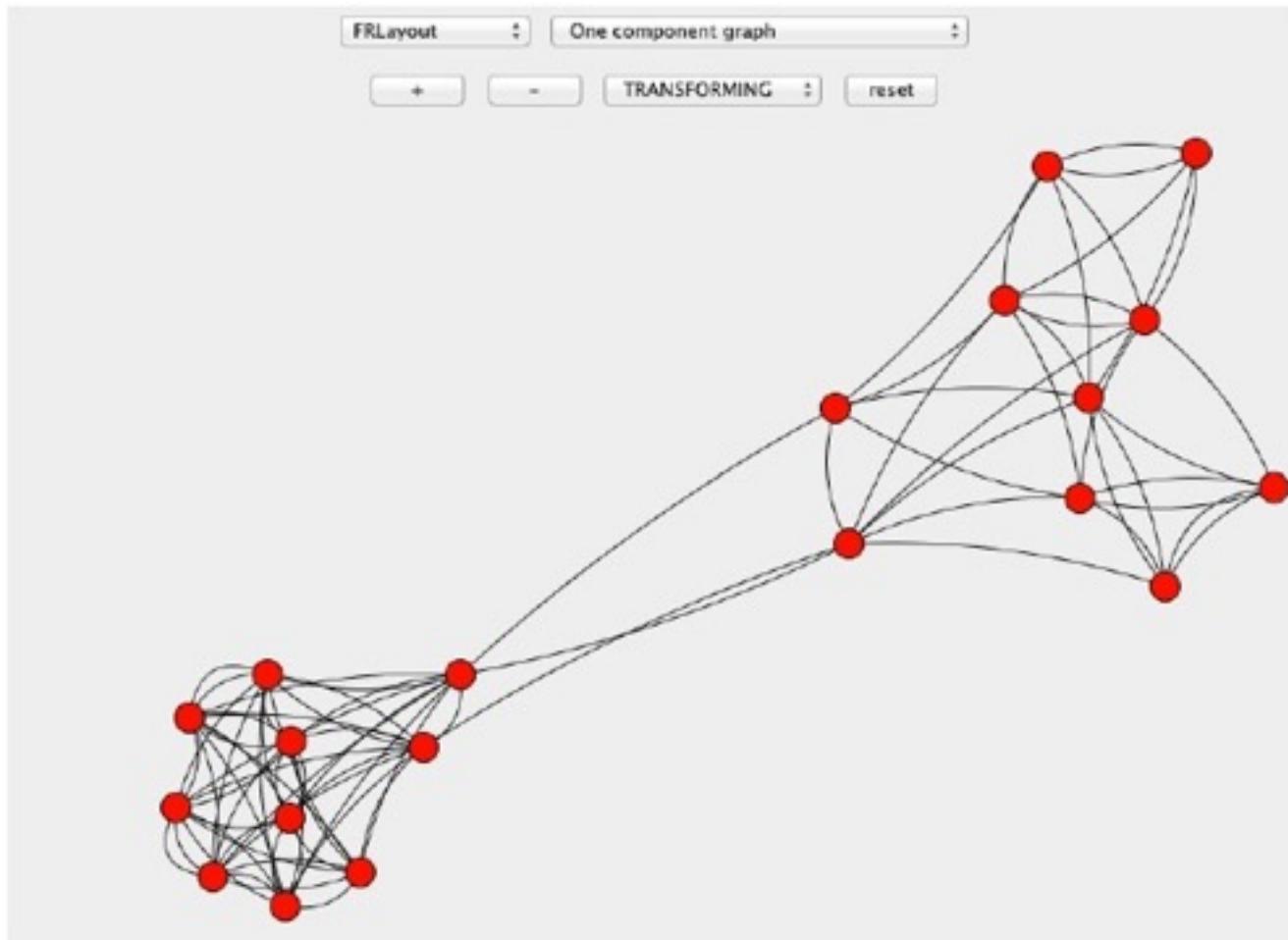
<http://similardiversity.net/about/>

JUNG Layouts



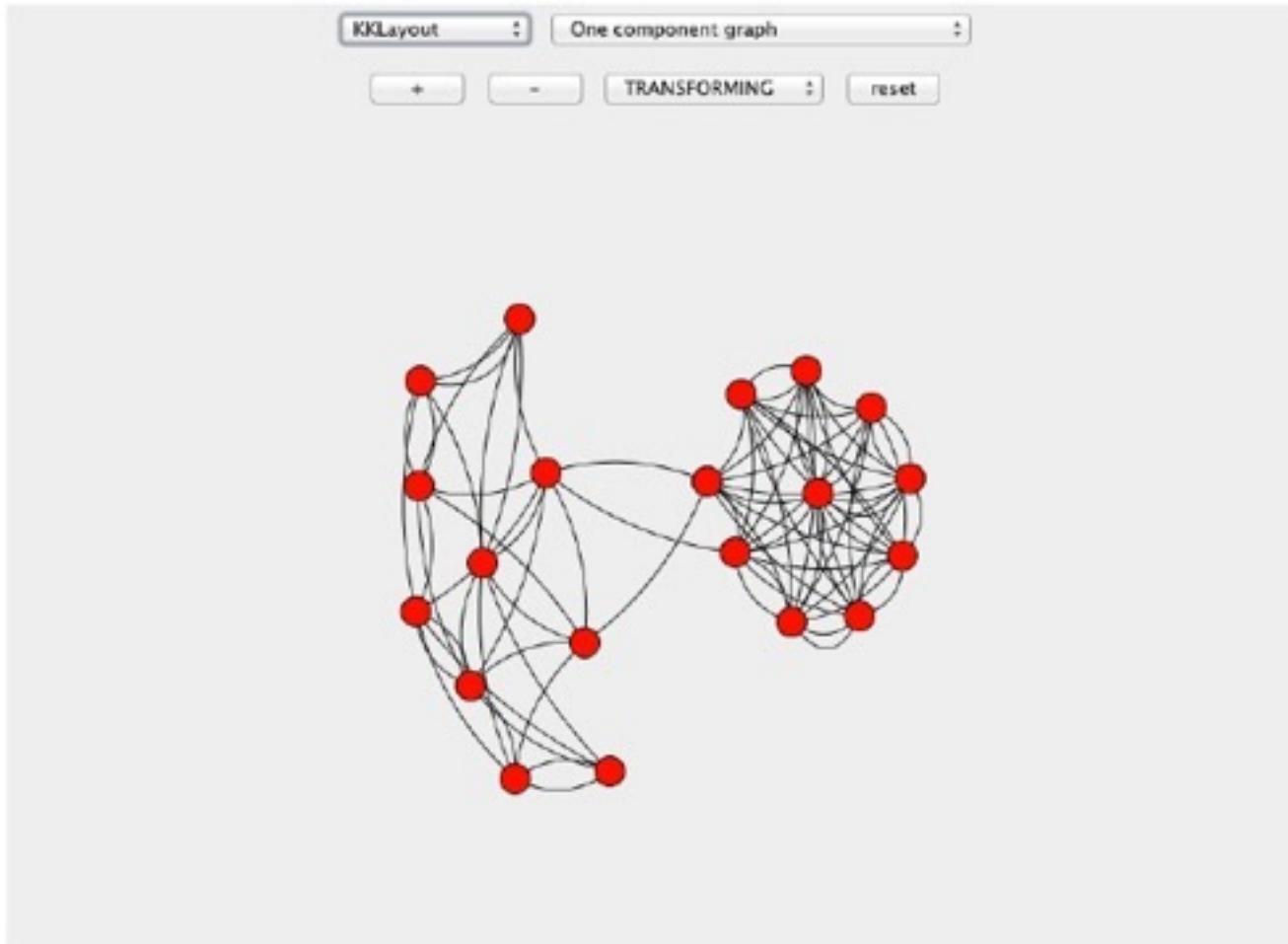
<http://jung.sourceforge.net/applet/showlayouts2.html>

JUNG Layouts



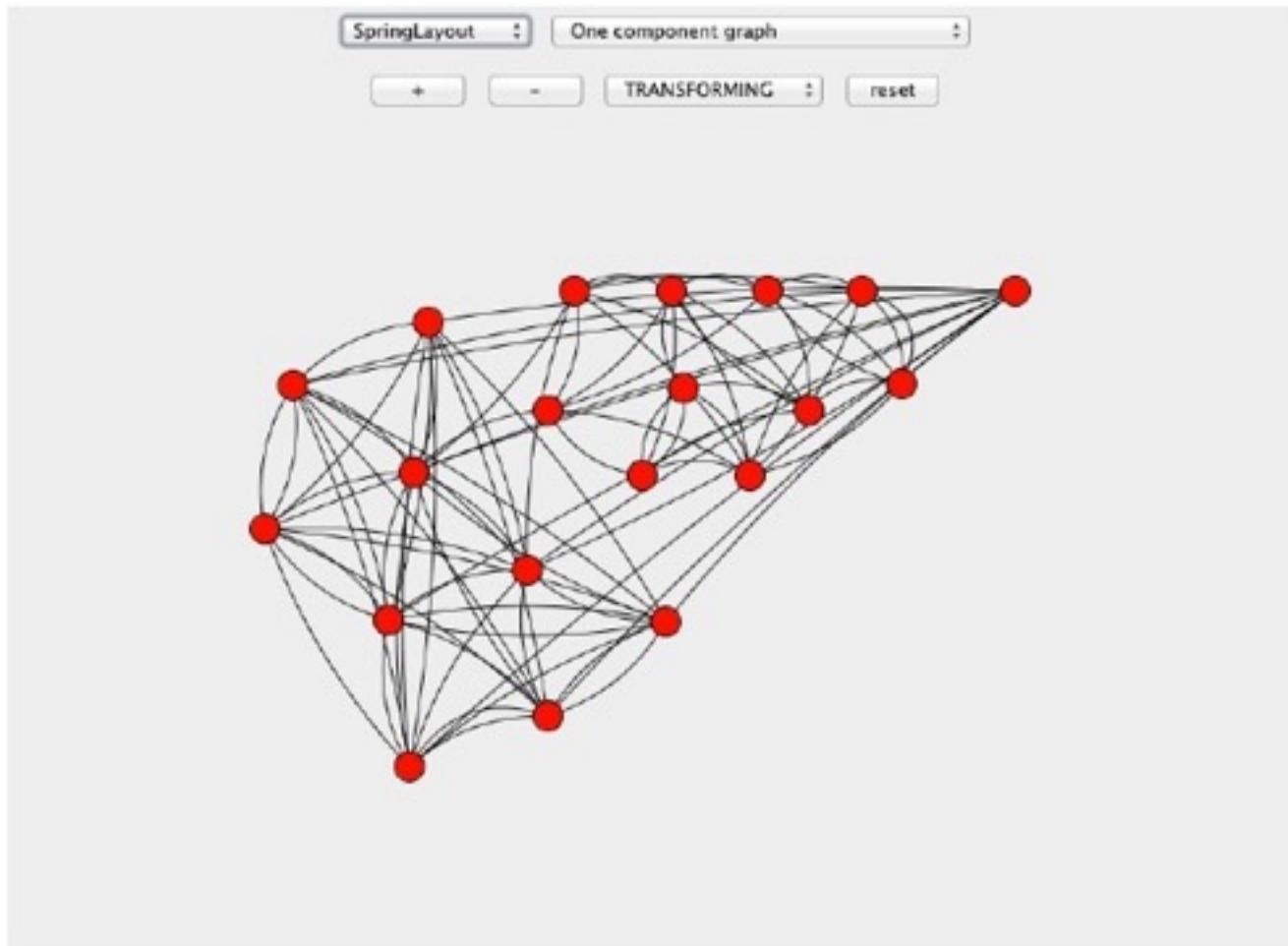
<http://jung.sourceforge.net/applet/showlayouts2.html>

JUNG Layouts



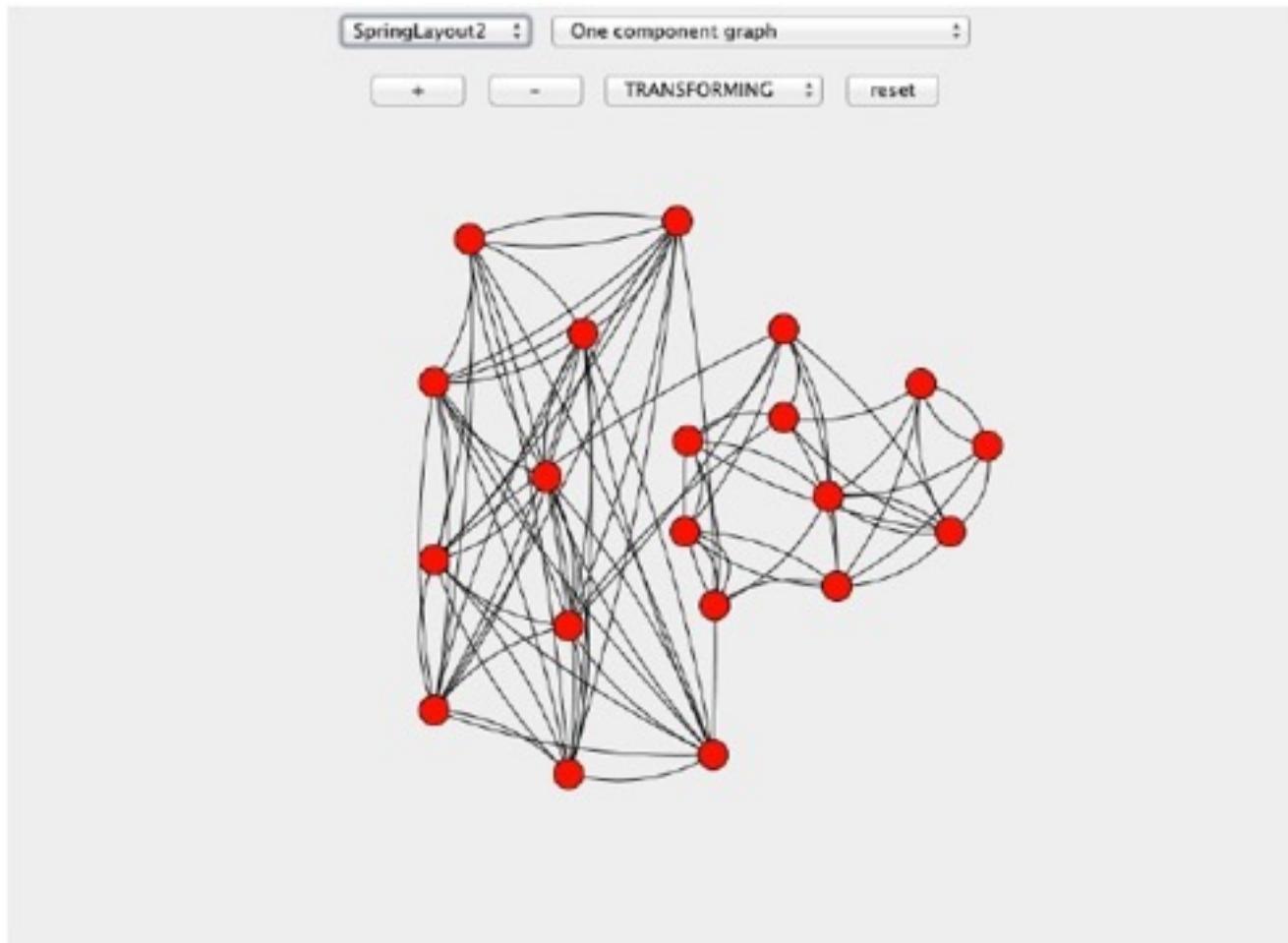
<http://jung.sourceforge.net/applet/showlayouts2.html>

JUNG Layouts



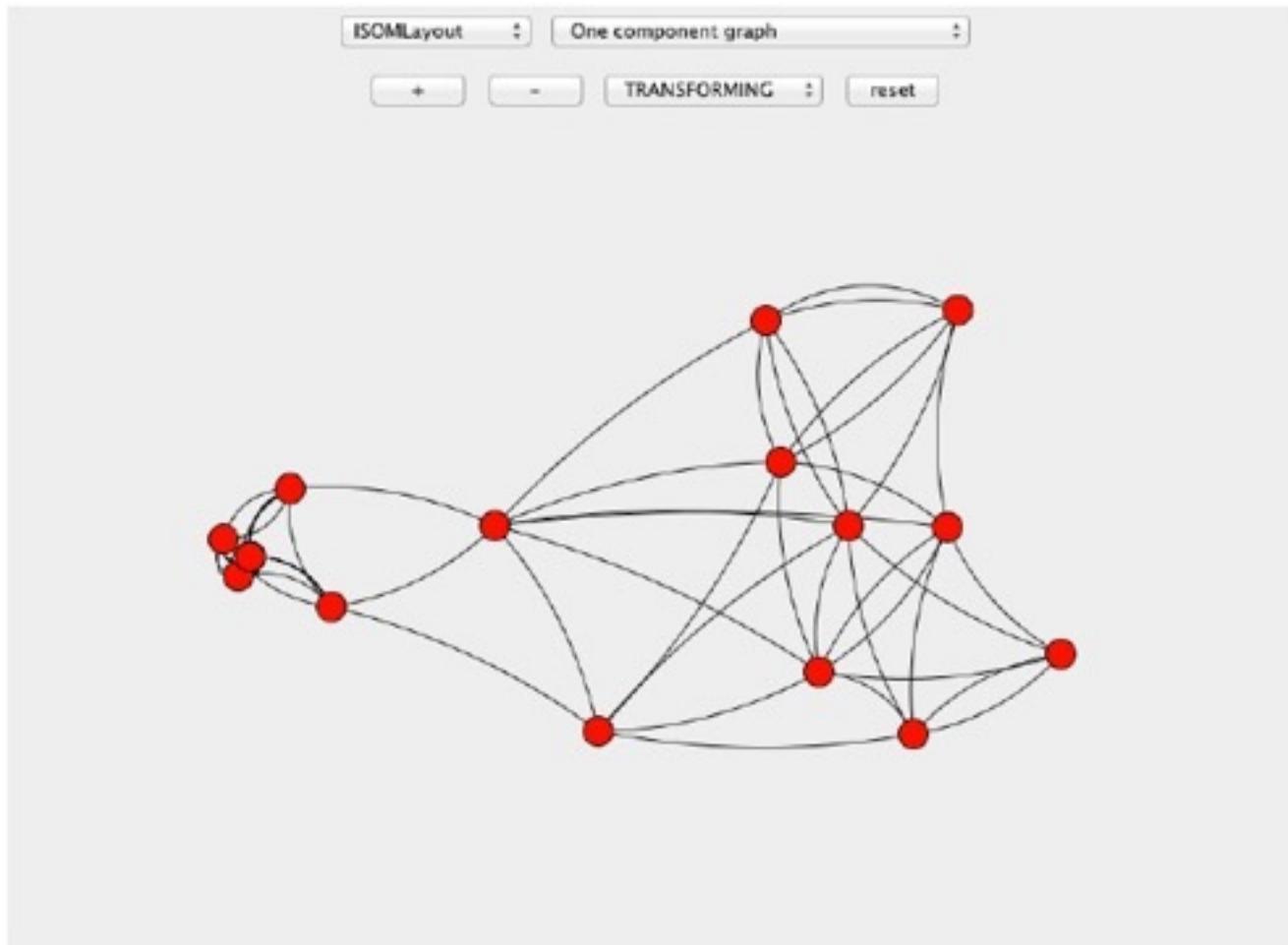
<http://jung.sourceforge.net/applet/showlayouts2.html>

JUNG Layouts



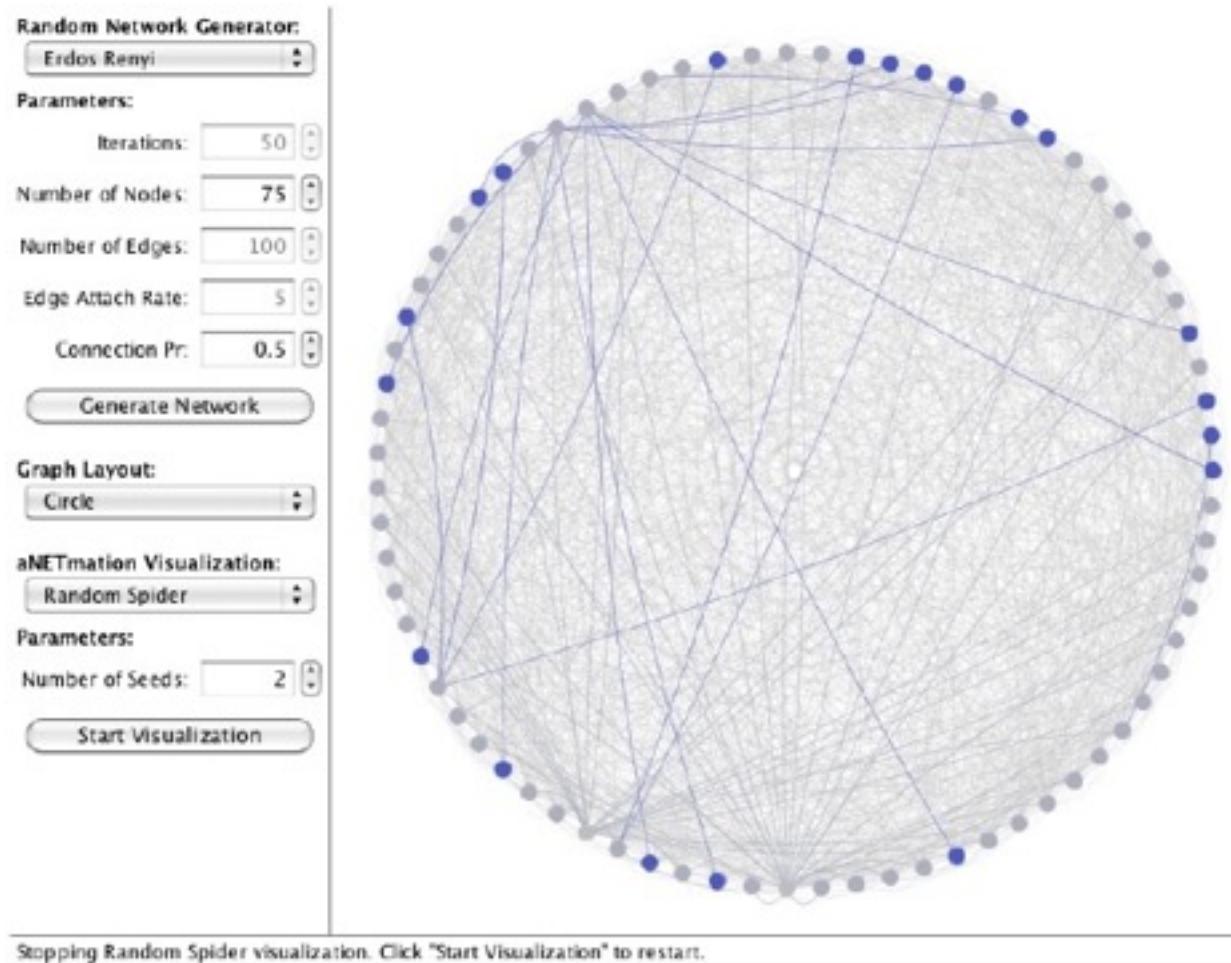
<http://jung.sourceforge.net/applet/showlayouts2.html>

JUNG Layouts



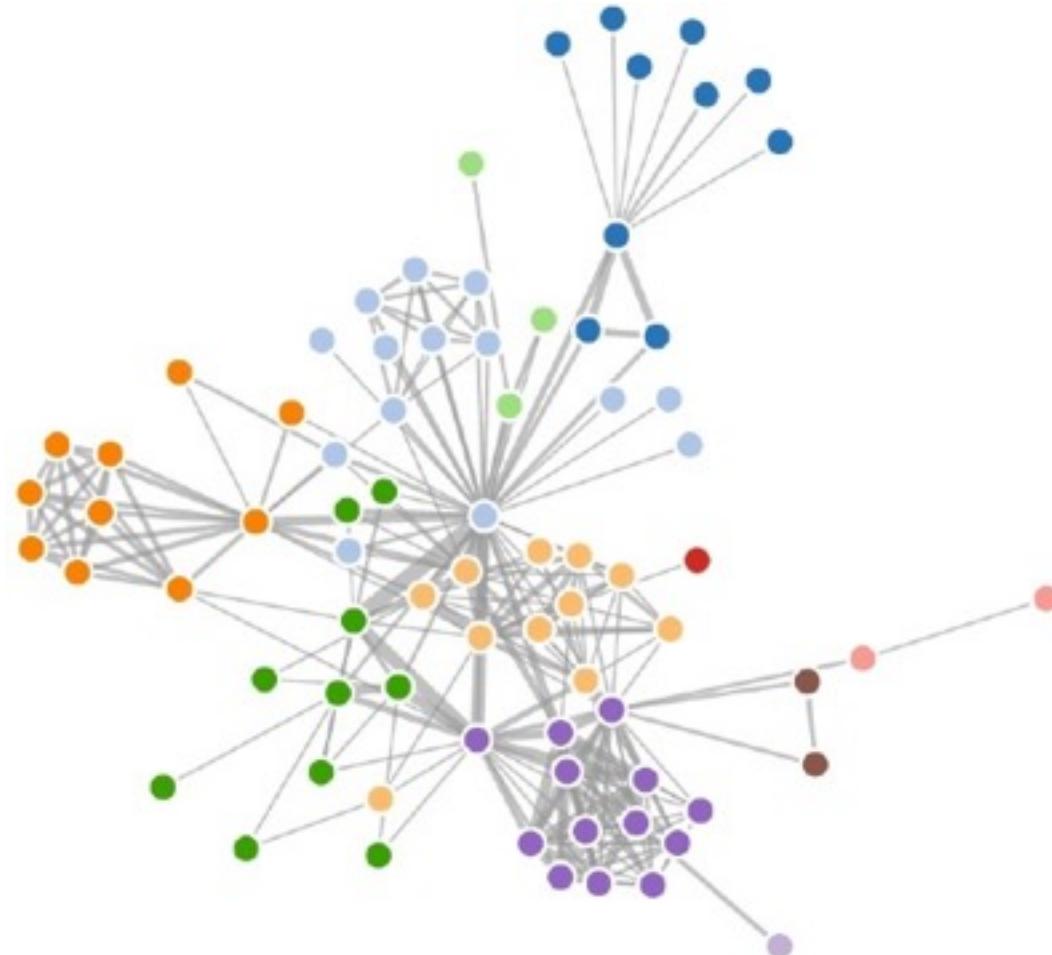
<http://jung.sourceforge.net/applet/showlayouts2.html>

aNETmation



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

Force Directed Layout in D3



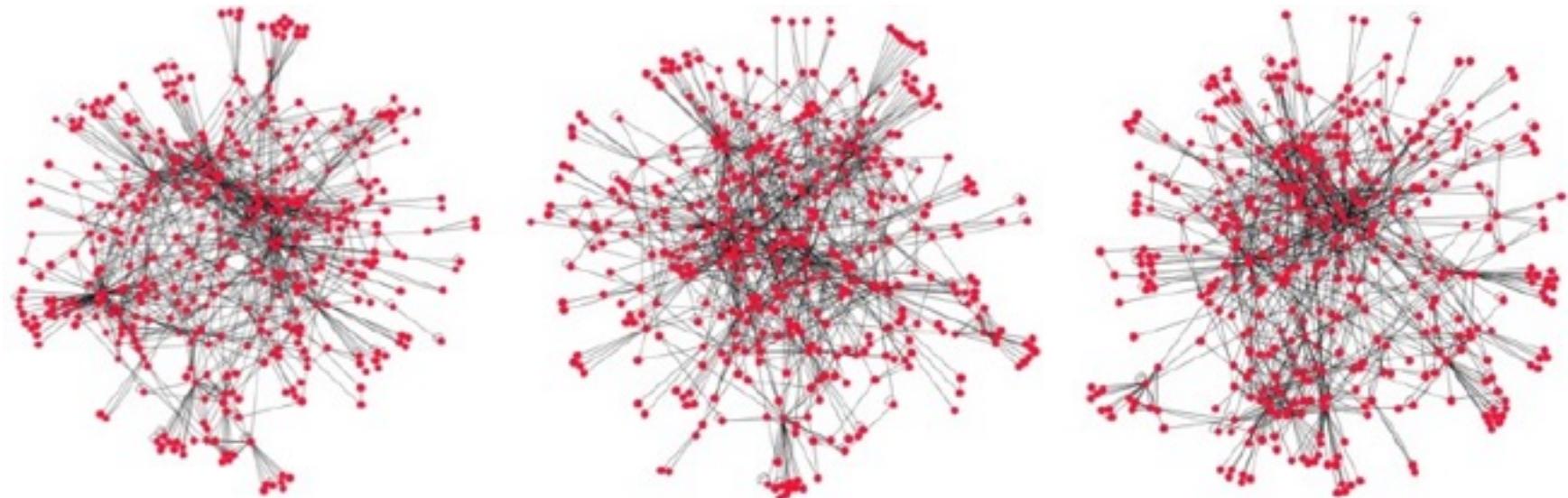
<http://bl.ocks.org/mbostock/4062045>

HIVE PLOTS

Hive Plots

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

Motivation

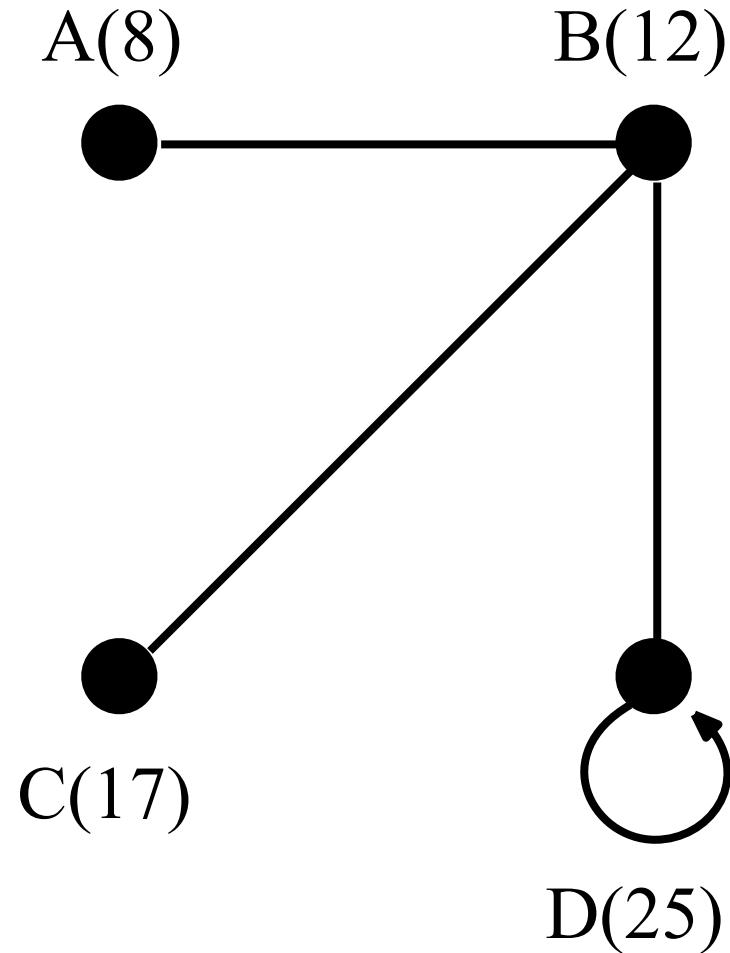


Subset of the human protein-protein interaction network rendered by Cytoscape. Each visualization uses the same layout (spring embedded), using the previous as a starting point.

Rual et al., *Nature* 437(7062):1173-8.

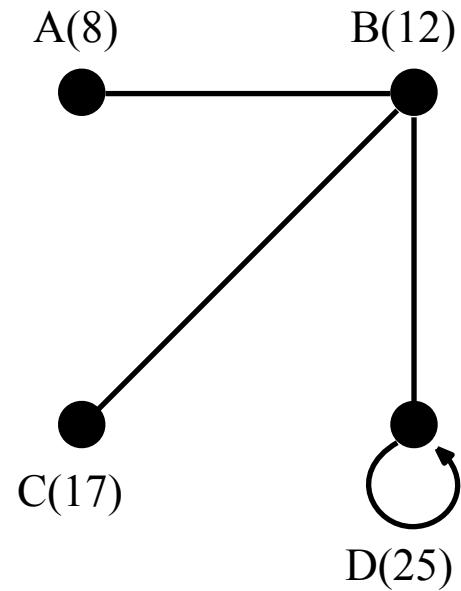
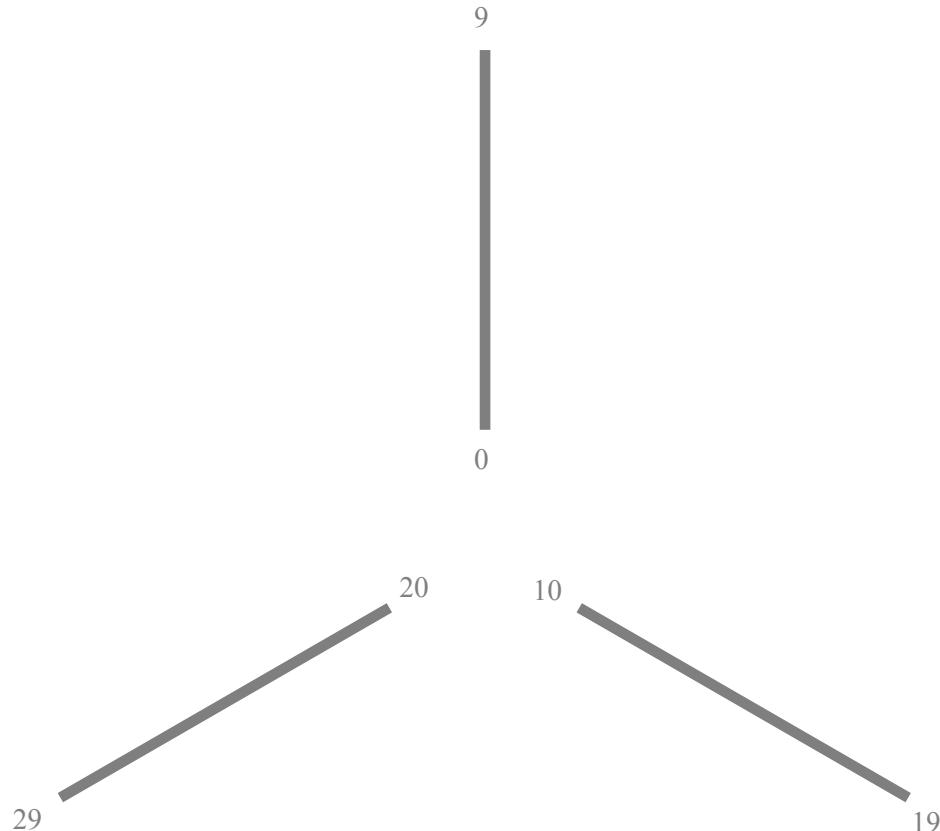
<http://www.hiveplot.net/talks/hive-plot.pdf>

Initial Network



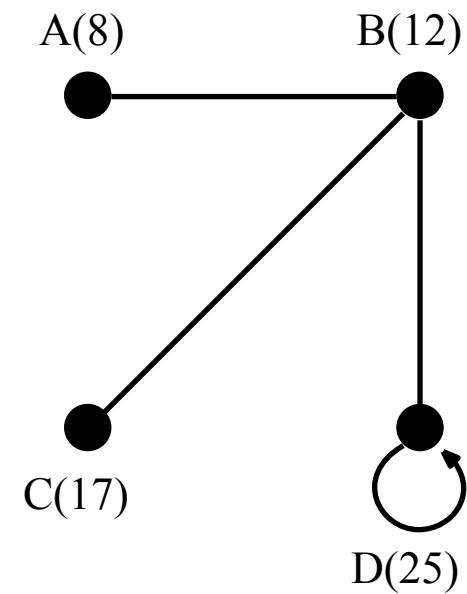
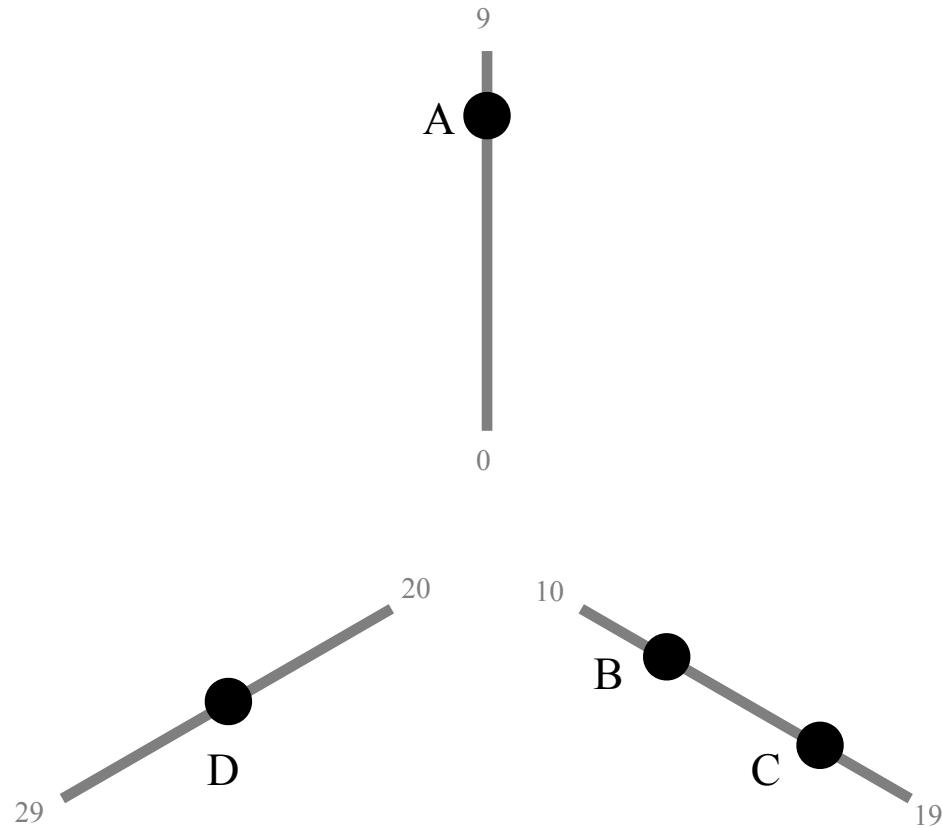
Simple network with node weights and a self-loop.

Axis Layout



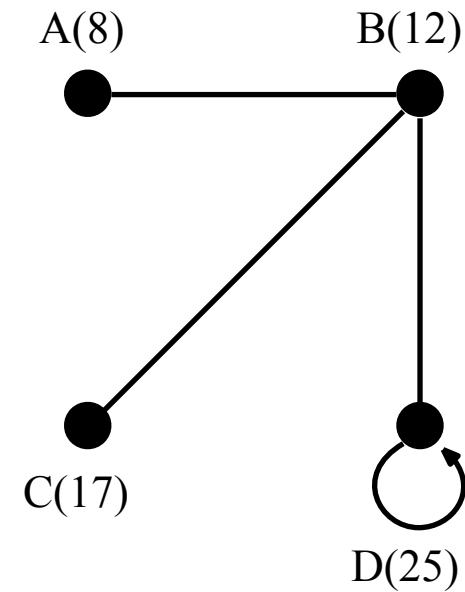
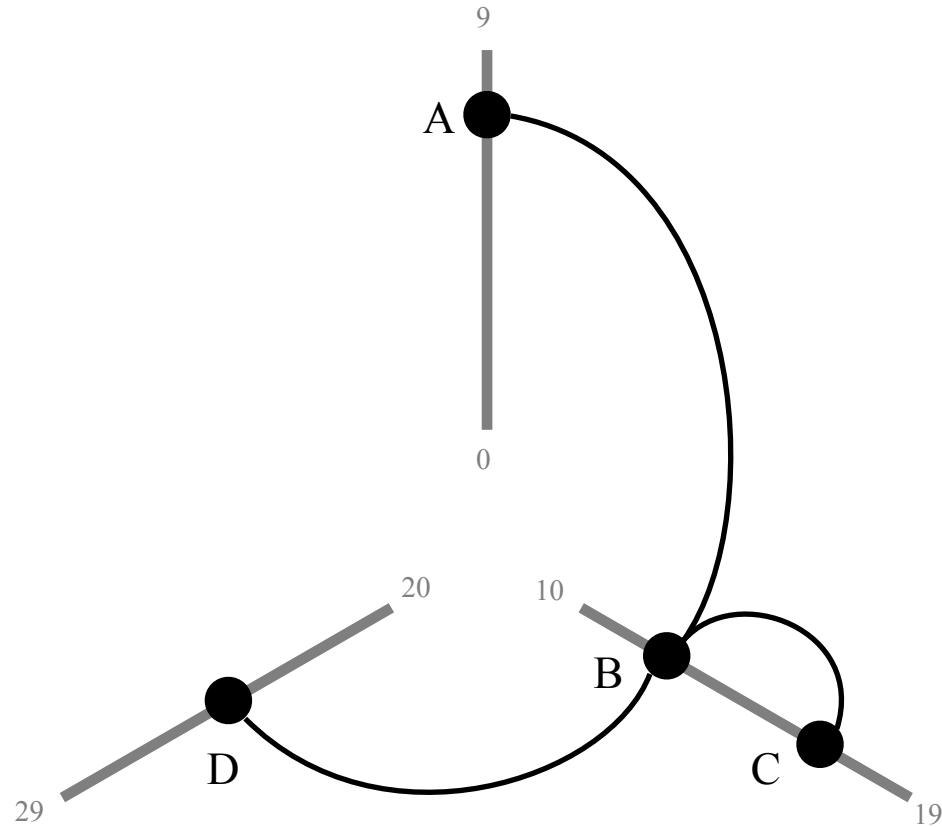
Three axis bars guarantee no edge crossings across axes. Divide node weight range between axes.

Node Layout



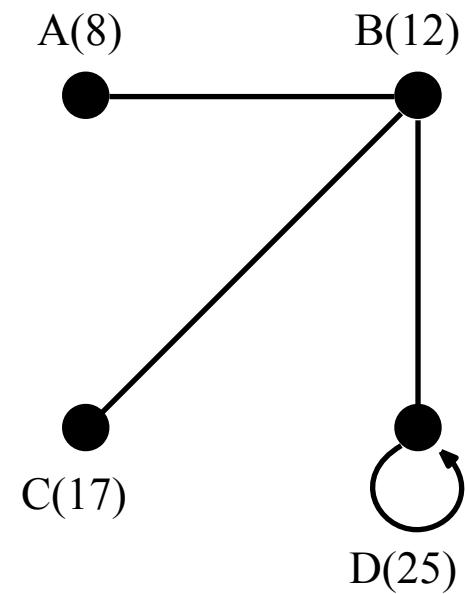
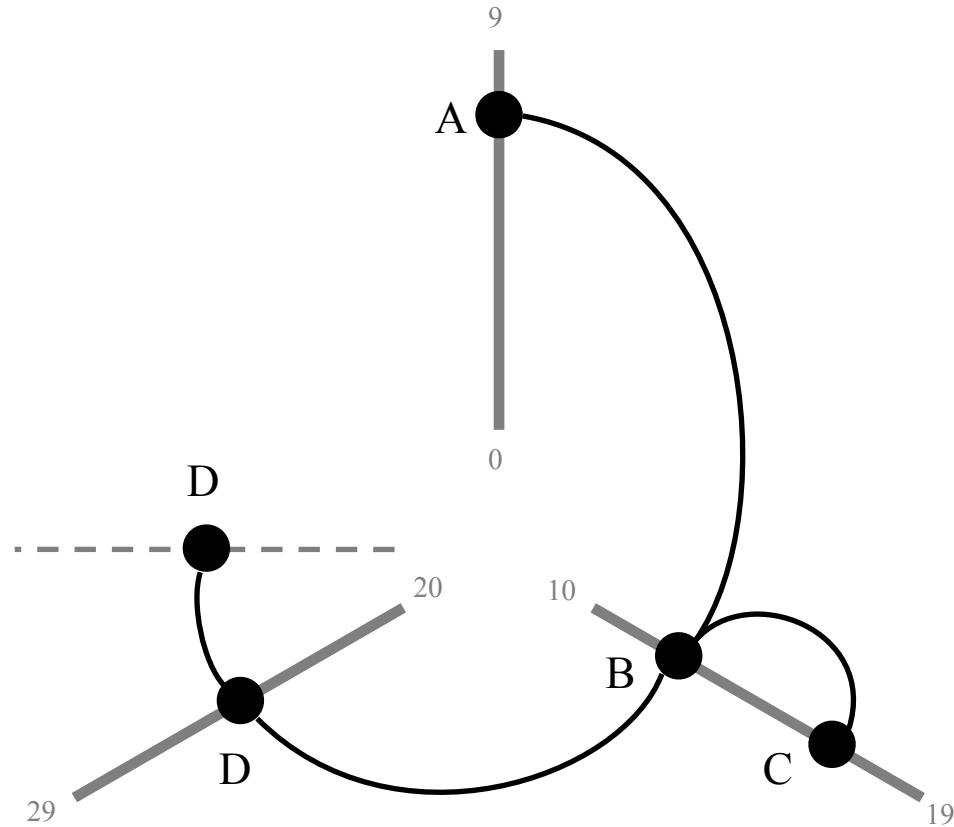
Place nodes on axis lines according to weight.

Edge Layout



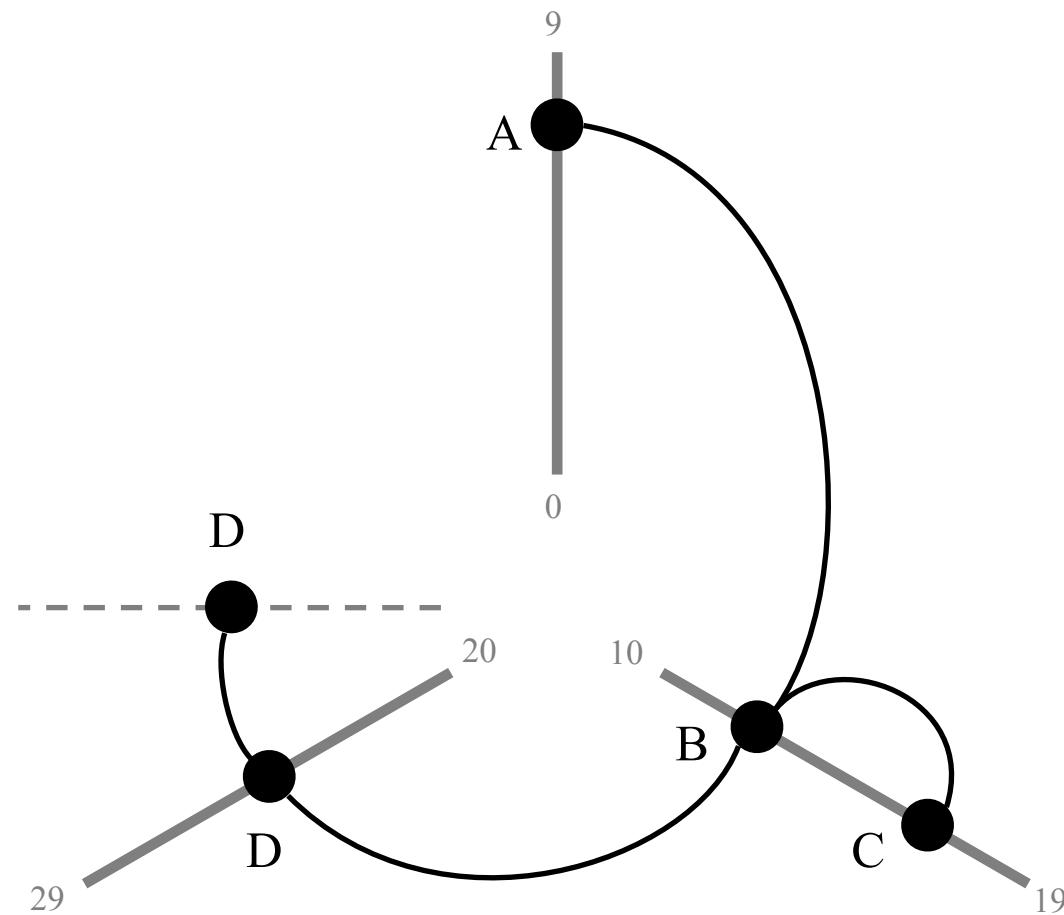
Connect nodes together accordingly.

Self Loops

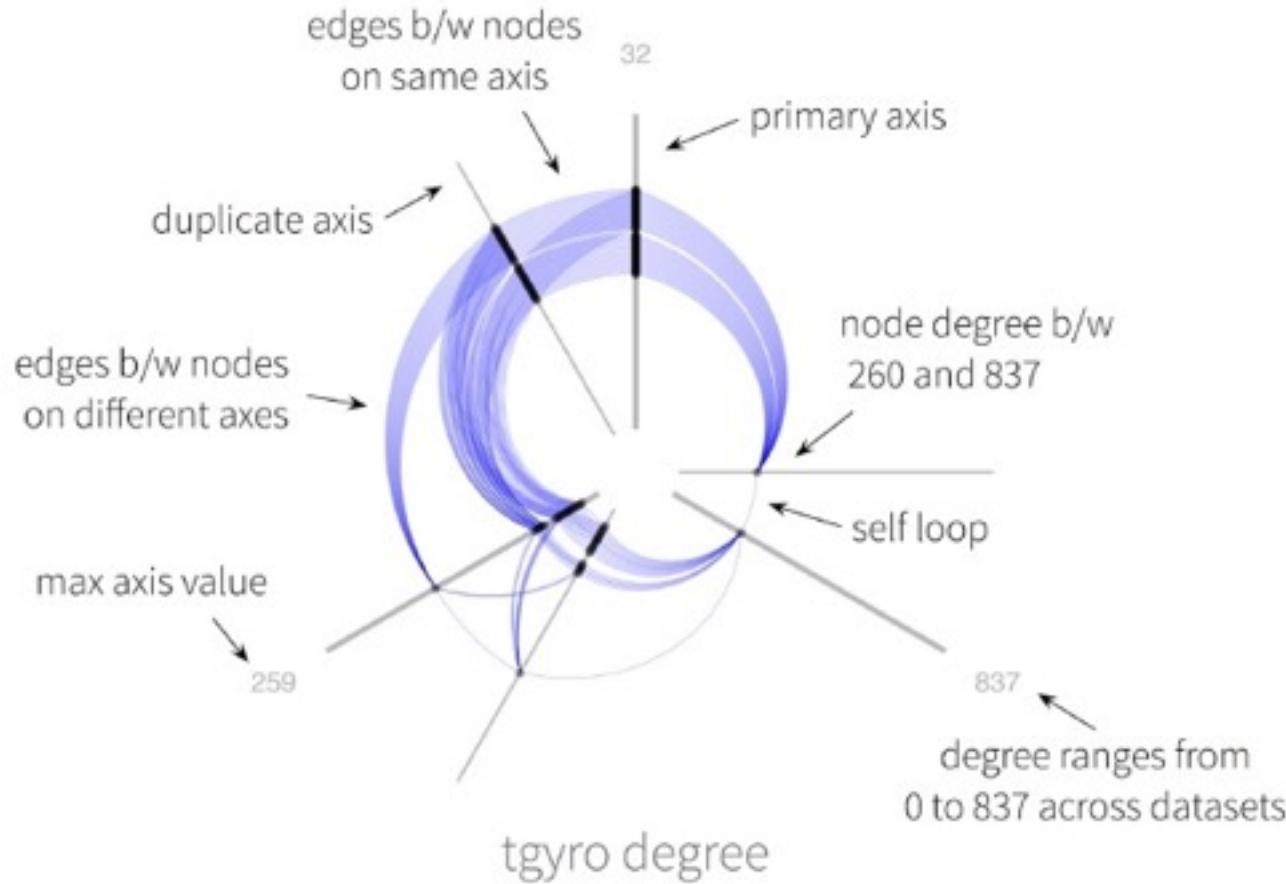


Clone axis lines to show self-loops in network.

Final Layout

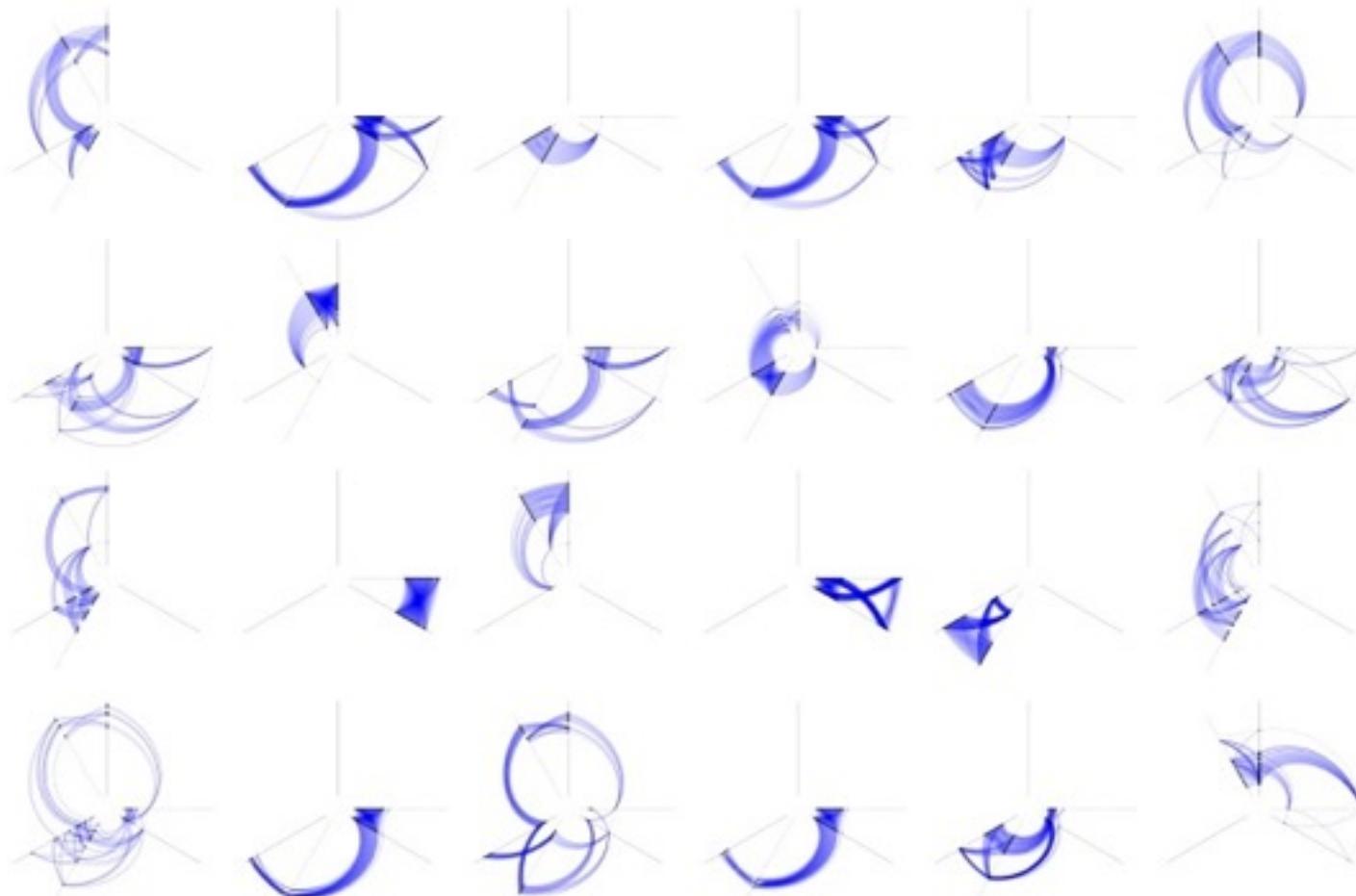


Hive Plots



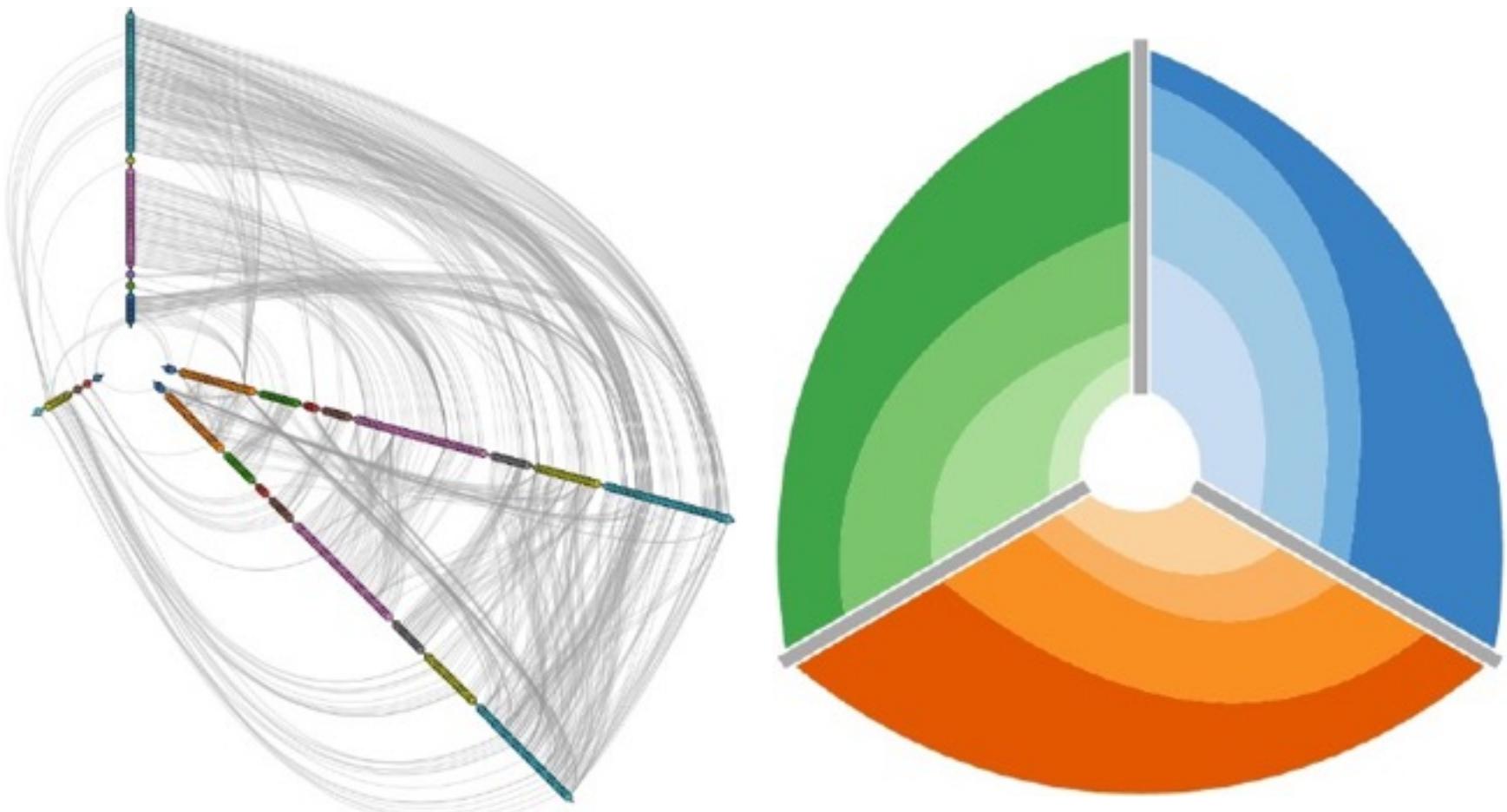
<http://dl.acm.org/citation.cfm?id=2379698>

Hive Panels



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

Hive Plots in D3

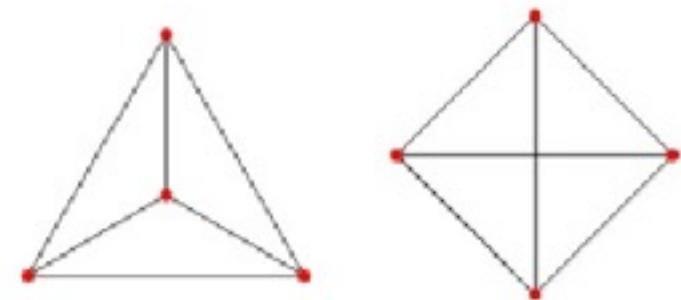


<http://bostocks.org/mike/hive/>

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.

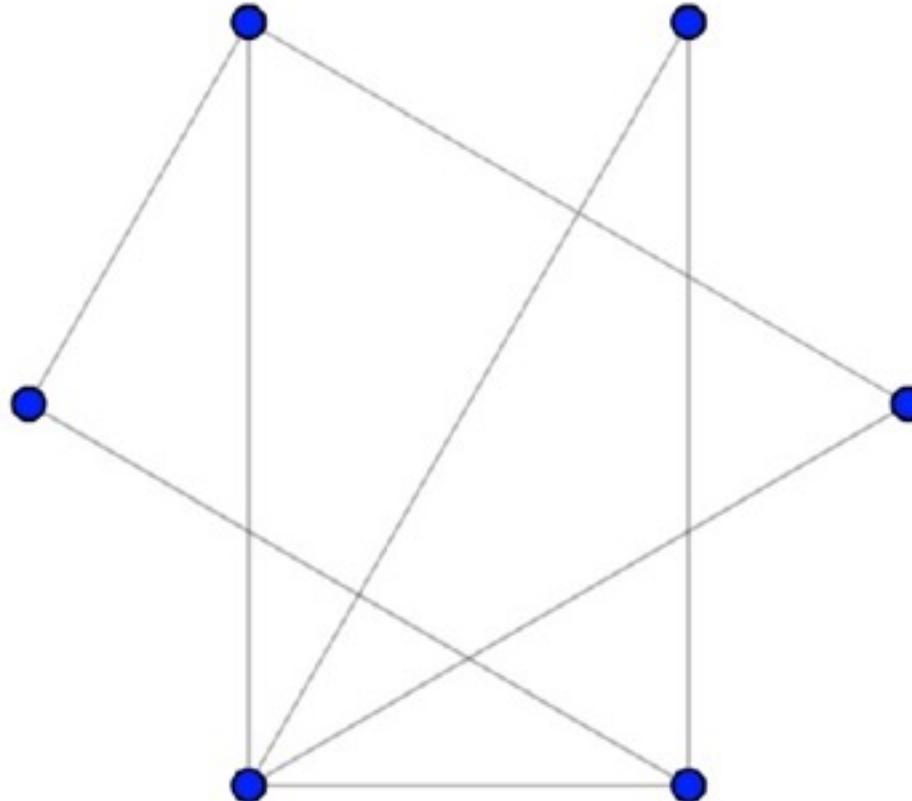


<http://mathworld.wolfram.com/PlanarGraph.html>

Planarity Game

Score: 0

Level: 1

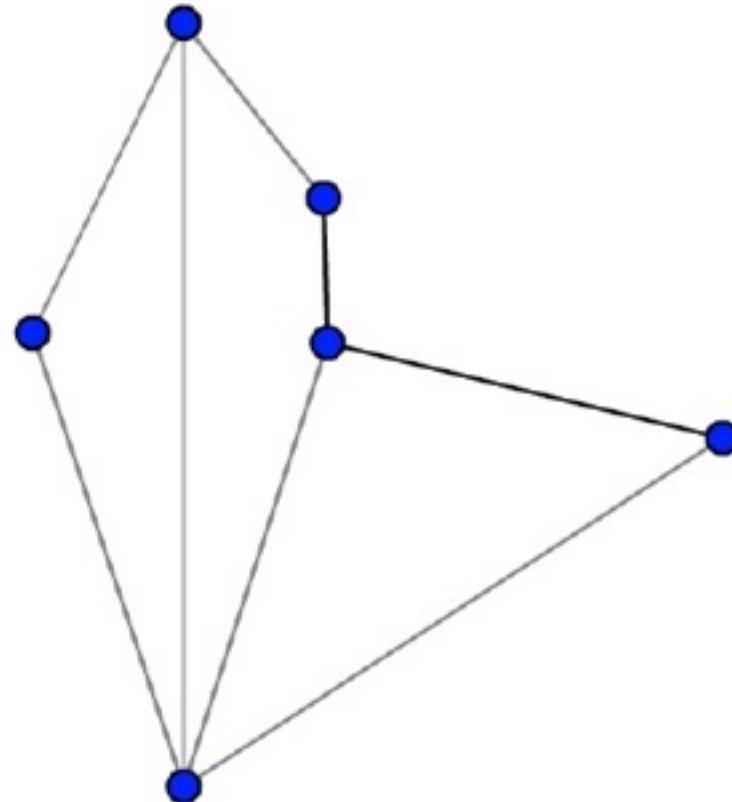


<http://www.planarity.net/>

Planarity Game

Score: 0

Level: 1

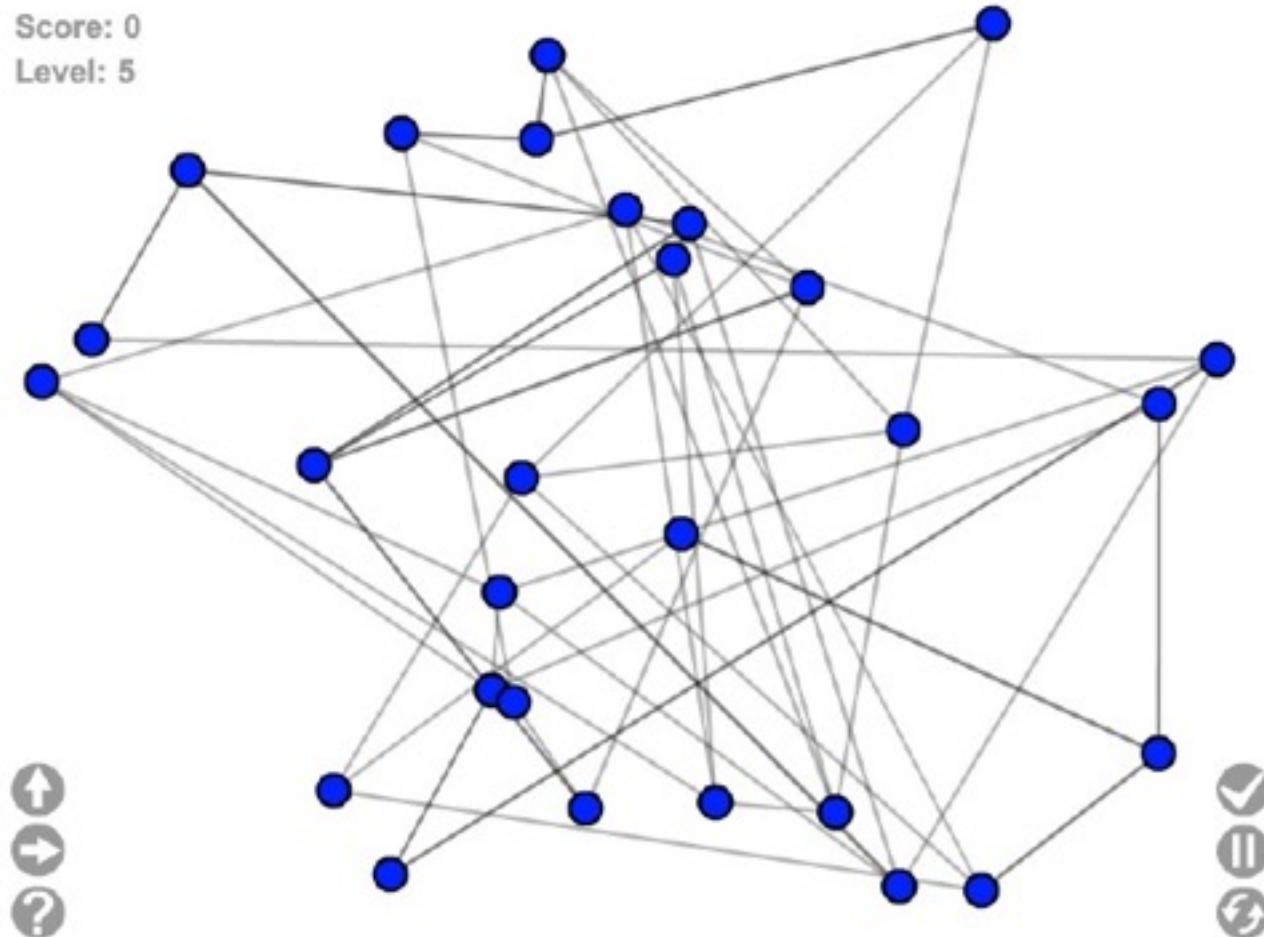


<http://www.planarity.net/>

Planarity Game

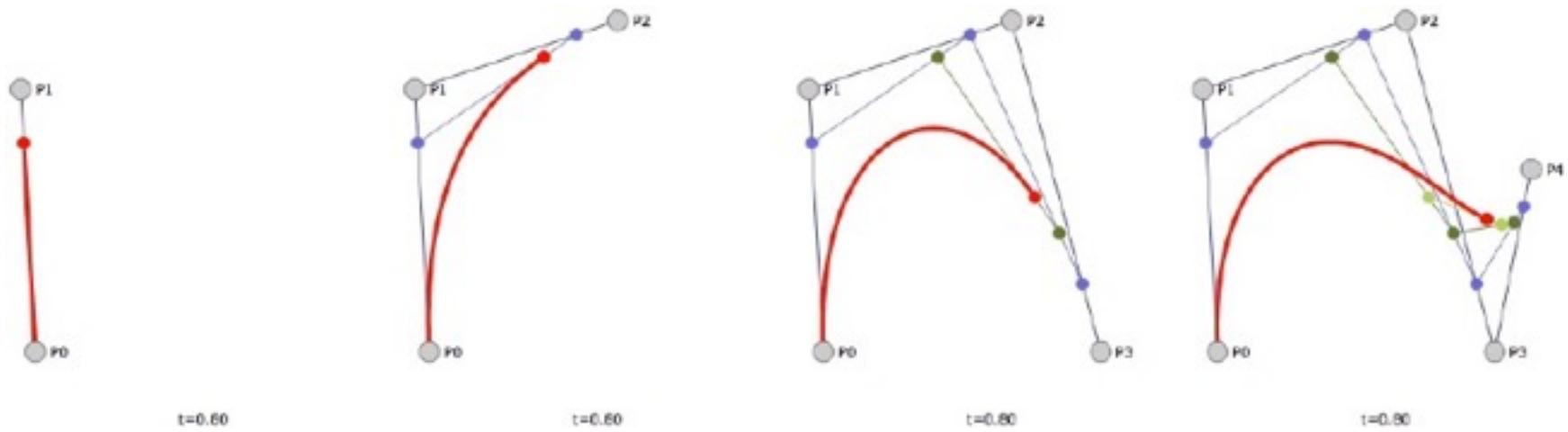
Score: 0

Level: 5



<http://www.planarity.net/>

Curved Edges



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

Edge Bundling

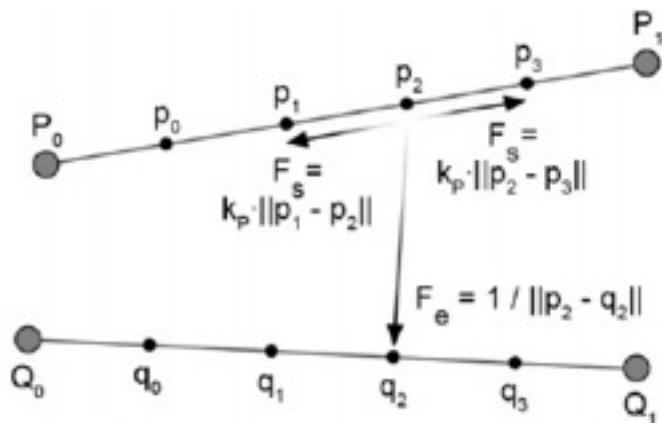


Figure 1: Two interacting edges P and Q . The spring forces F_s and the electrostatic force F_e that are exerted on subdivision point p_2 by p_1 , p_3 , and q_2 are shown.

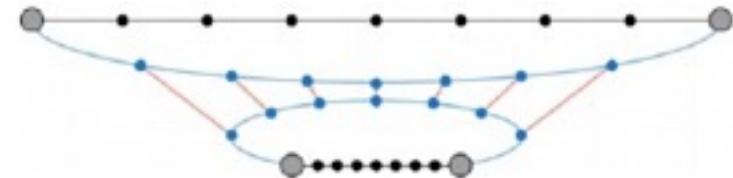


Figure 4: Bundling edges that differ considerably in length can result in noticeable stretching and curving of short edges. Original edges, curved edges and attracting forces are shown in black, blue, and red, respectively.

Edge Bundling

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

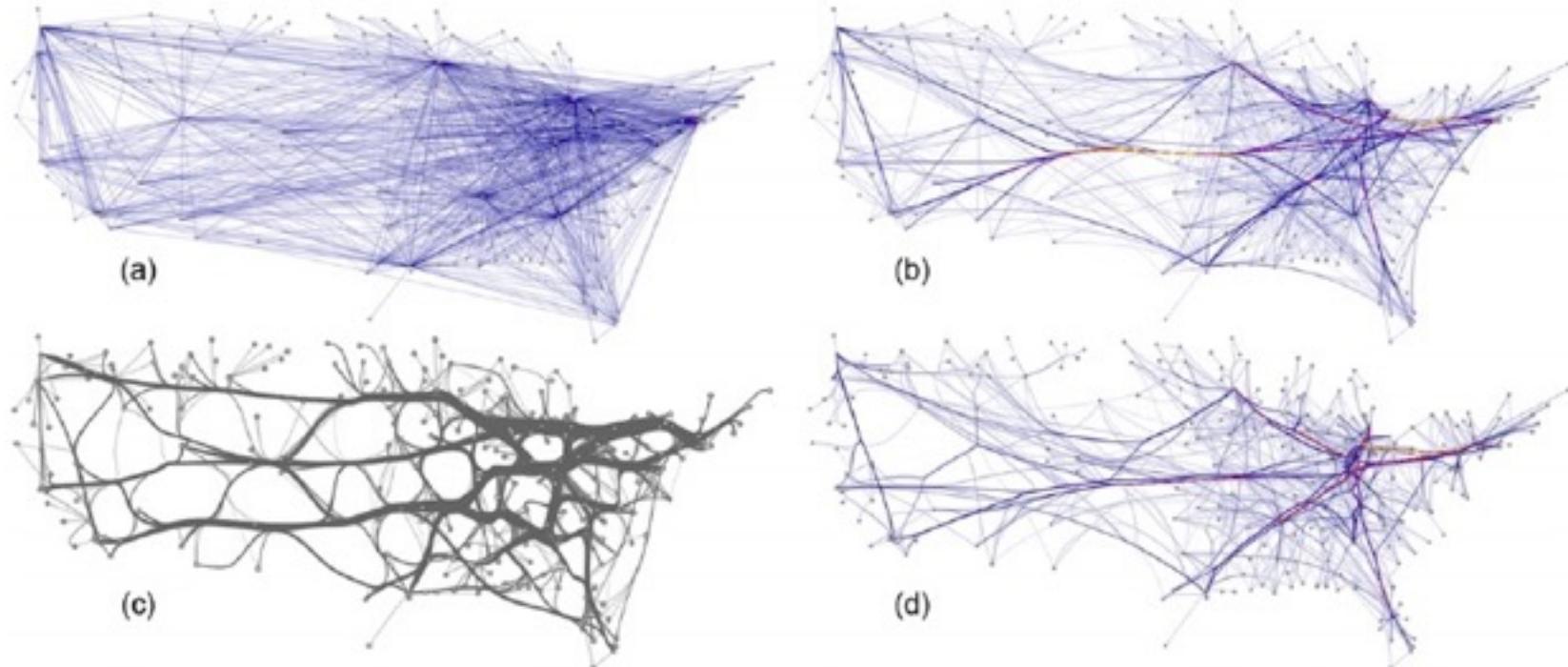
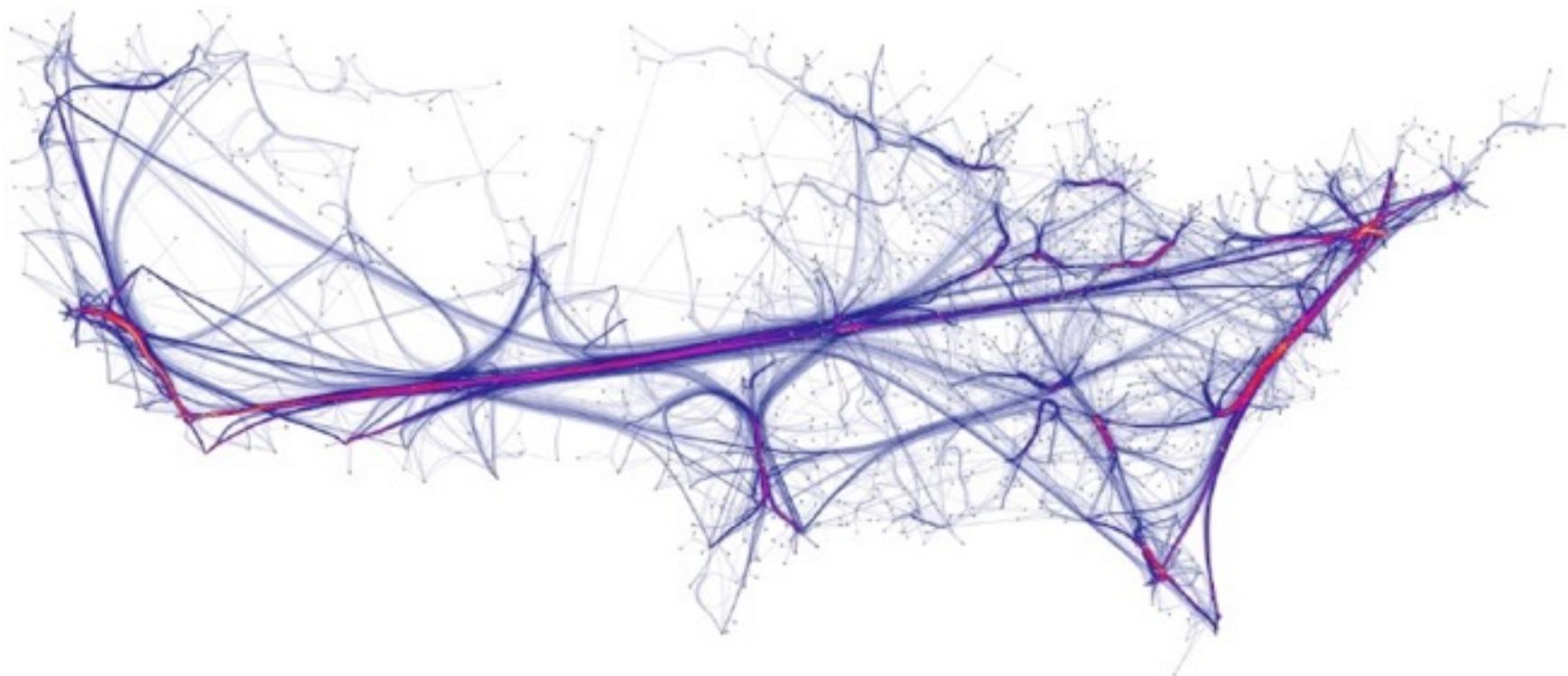


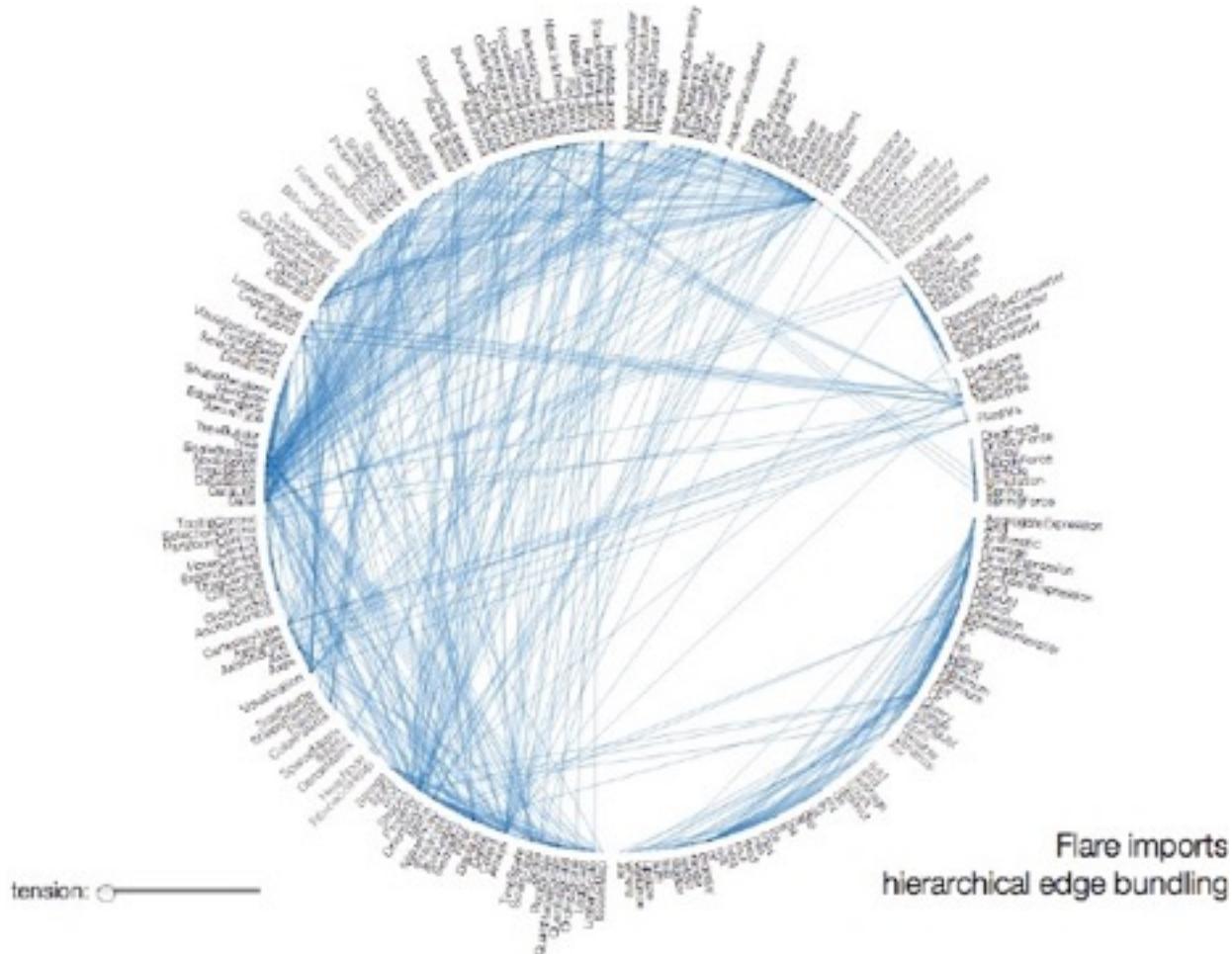
Figure 7: US airlines graph (235 nodes, 2101 edges) (a) not bundled and bundled using (b) FDEB with inverse-linear model, (c) GBEB, and (d) FDEB with inverse-quadratic model.

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

Edge Bundling

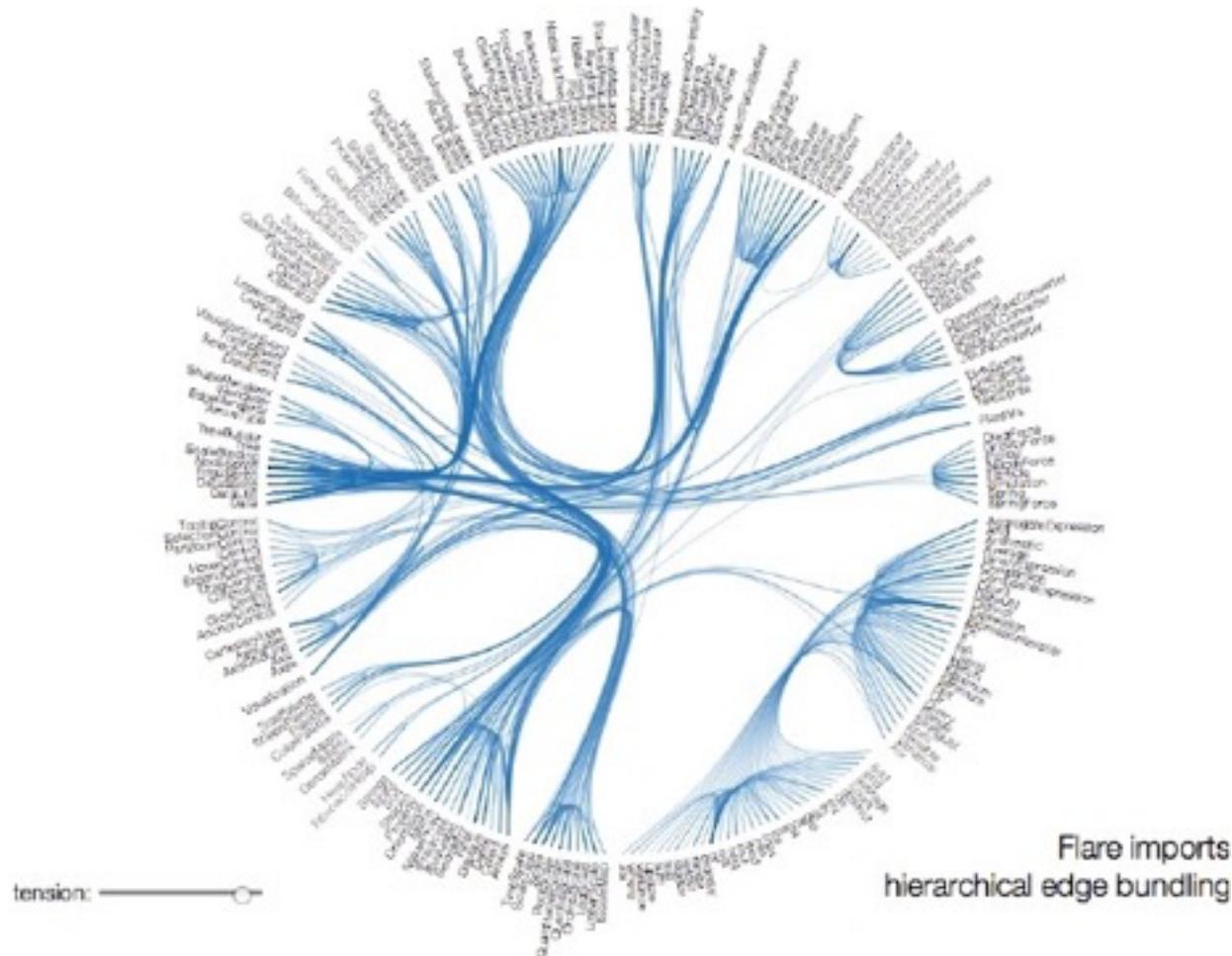


Edge Bundling



<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