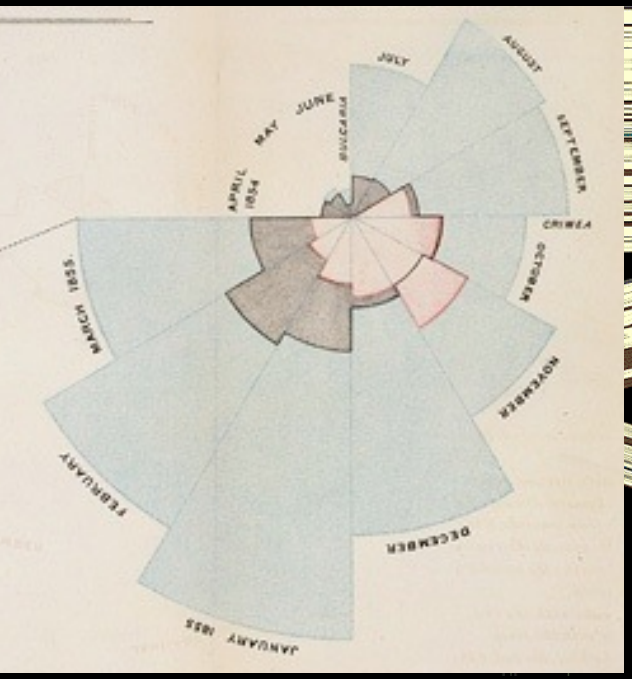
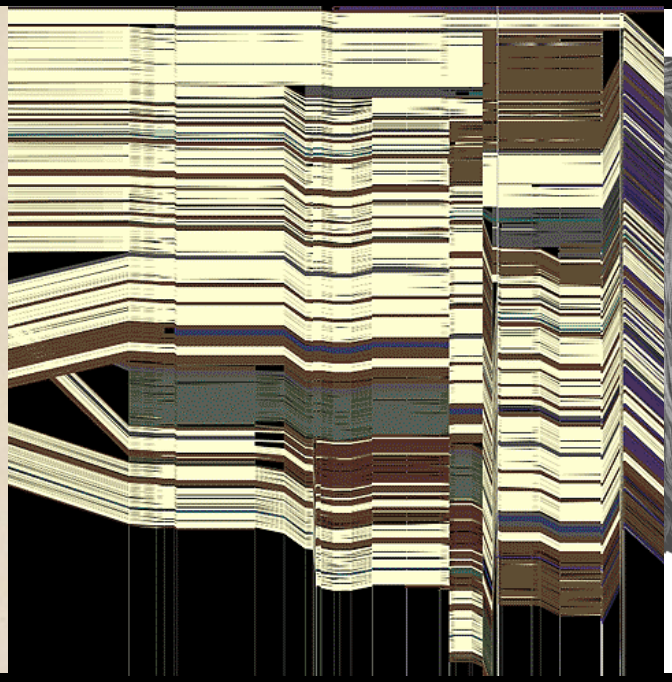
CSE 412 - Intro to Data Visualization

Networks





Jane Hoffswell University of Washington

Guest Lecture: Scalable Visualization

Fri May 21 - Guest: Jeffrey Heer (UW)

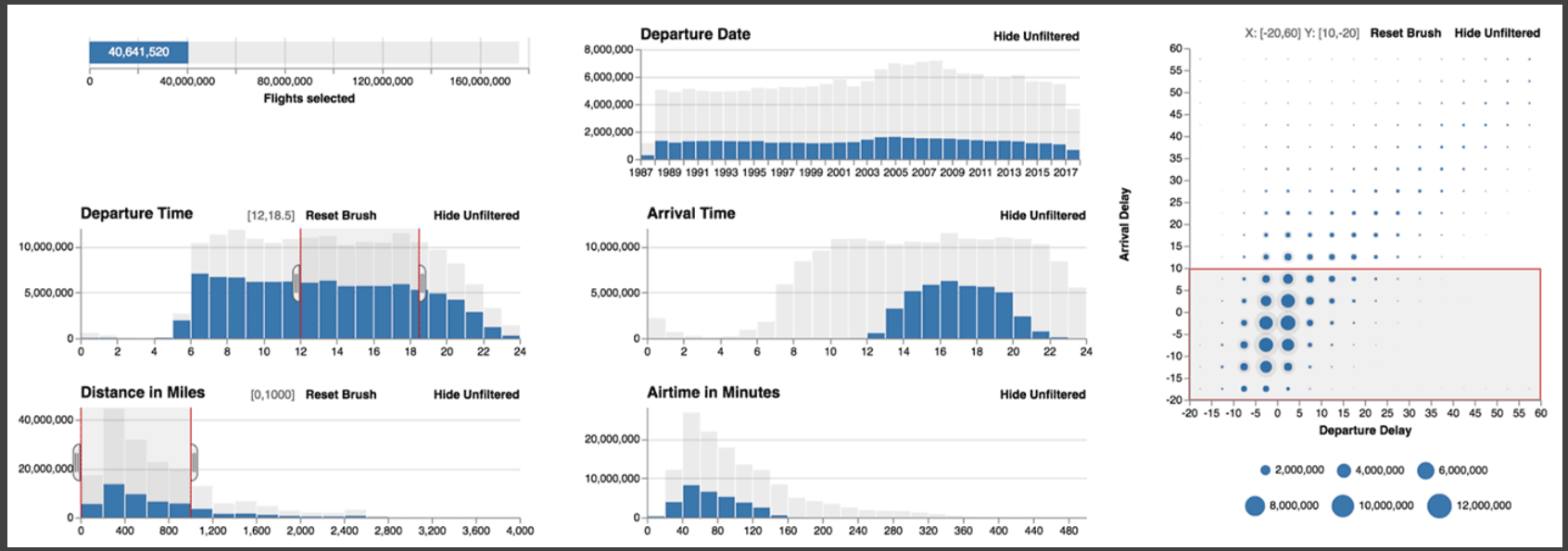
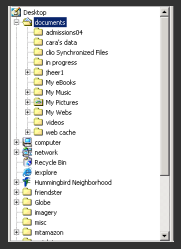
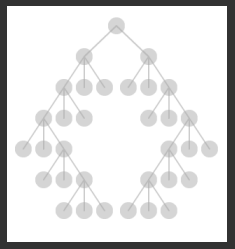
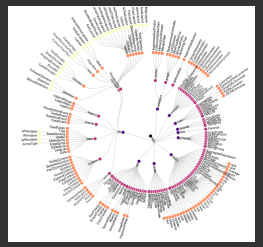
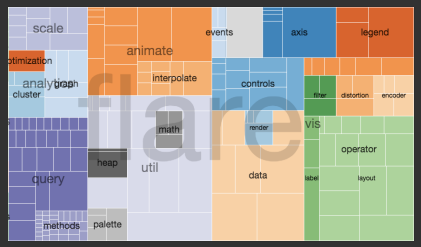
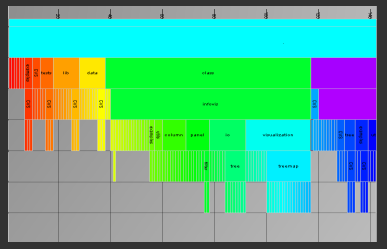
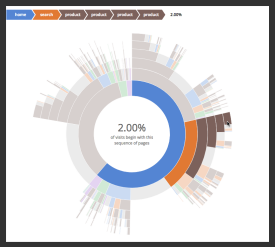


Image: "Falcon: Balancing Interactive Latency and Resolution Sensitivity for Scalable Linked Visualizations." CHI 2019.

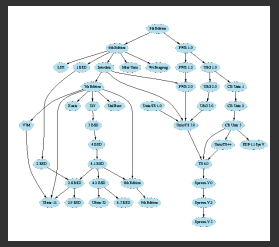
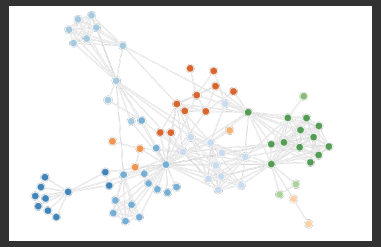
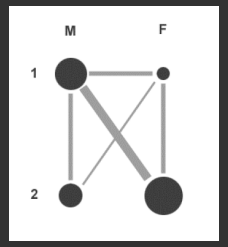
Topics

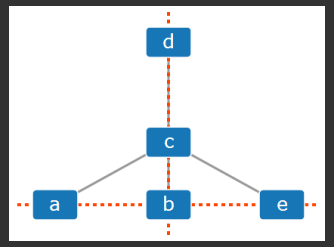
Mon - Tree Visualization

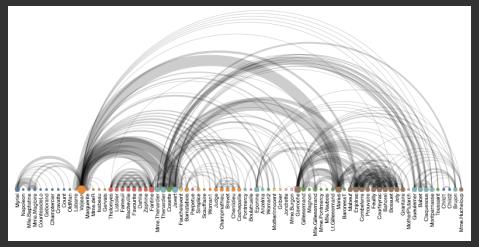





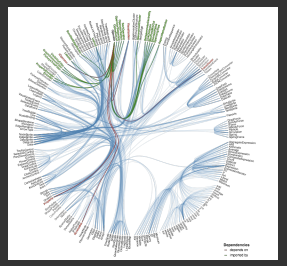
TODAY - Graph Layout: Node-Link Diagrams





TODAY - Alternative Visualizations and Techniques




Select an image to jump to those slides.

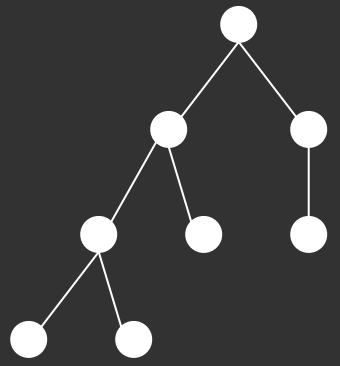
Trees and Graphs

Trees

Graphs with hierarchical structure

Connected graph with N-1 edges

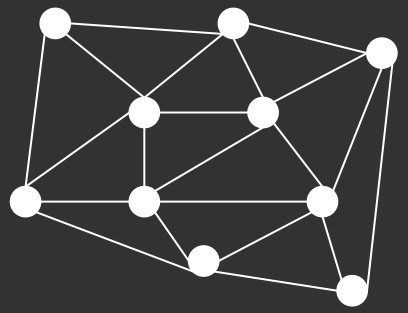
Nodes as *parents* and *children*



Graphs

Model relations among data

Nodes and *edges*



Network Analysis Tasks [Pretorius '13]

Structure-based: relationships and connectivity

Attribute-based: specific node/link attributes

Browsing: understand paths in the data

Estimation: summarization and temporal changes

Network Analysis Tasks [Pretorius '13]

Structure-based: relationships and connectivity

Find all of the friends of friends for Taylor.
Find all of the people who are friends with Jordan and Alex.
Six degrees of separation: shortest path between two individuals.

Attribute-based: specific node/link attributes

Browsing: understand paths in the data

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Find all "students" attending CSE412.
Find all the "friends" and "family" of Alex.

Browsing: understand paths in the data

Estimation: summarization and temporal changes

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Browsing: understand paths in the data

Find Alex's friend Taylor, and then Taylor's friend Jordan.

Estimation: summarization and temporal changes

Network Analysis Tasks [Pretorius '13]

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Six degrees of separation: shortest path between two individuals.

Attribute-based: specific node/link attributes

Find all "students" attending CSE412.

Find all the "friends" and "family" of Alex.

Browsing: understand paths in the data

Find Alex's friend Taylor, and then Taylor's friend Jordan.

Estimation: summarization and temporal changes

How does Jordan's friend group change over the course of the year?

Node-Link Graph Layout

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout - arranged by depth

Force-Directed Layout - physical simulation

Attribute-Driven Layout - arranged by value

Constraint-Based Layout - optimization

Arc Diagrams - aligned layout

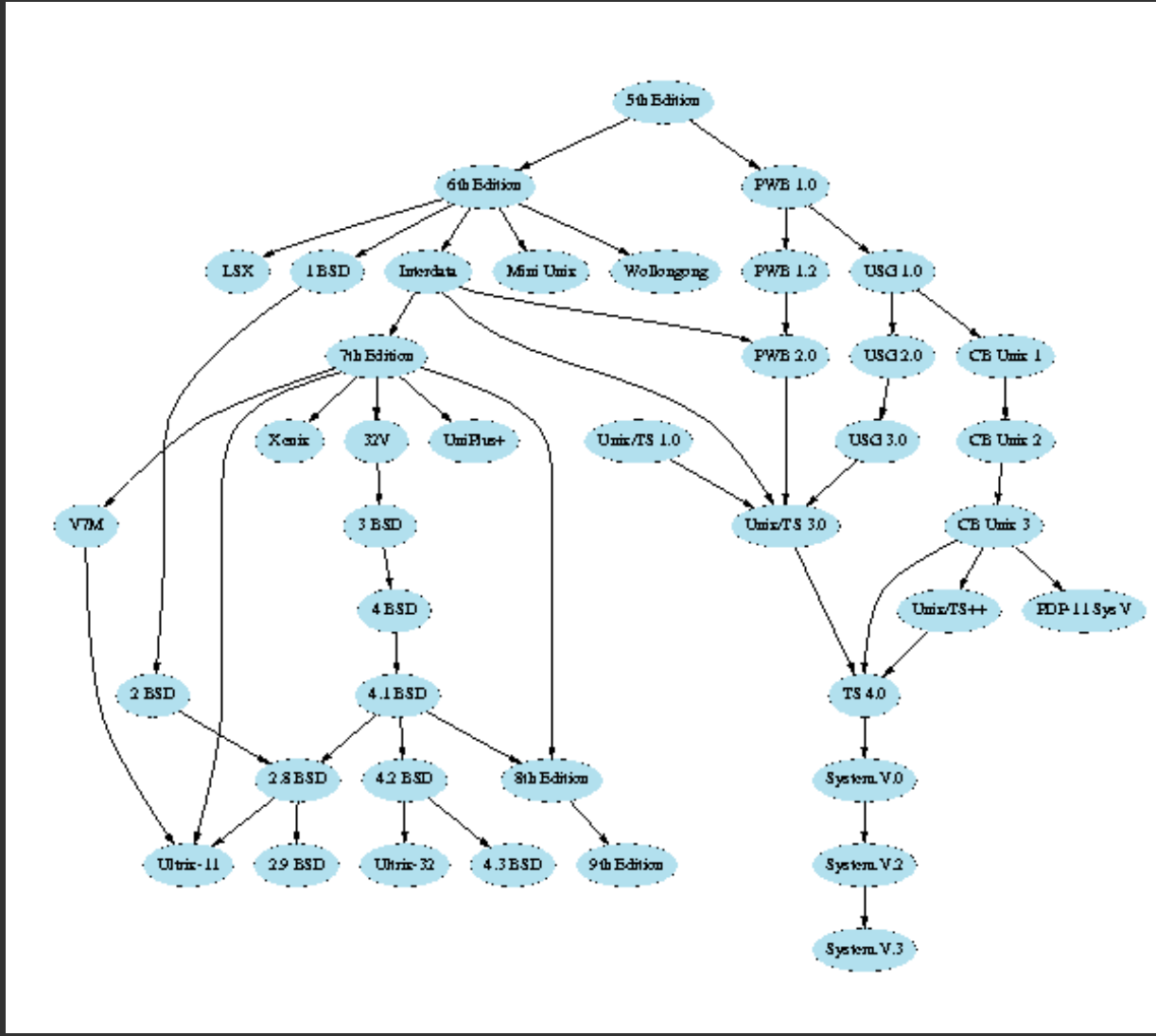
Sugiyama-Style Layout

Sugiyama-Style Layout

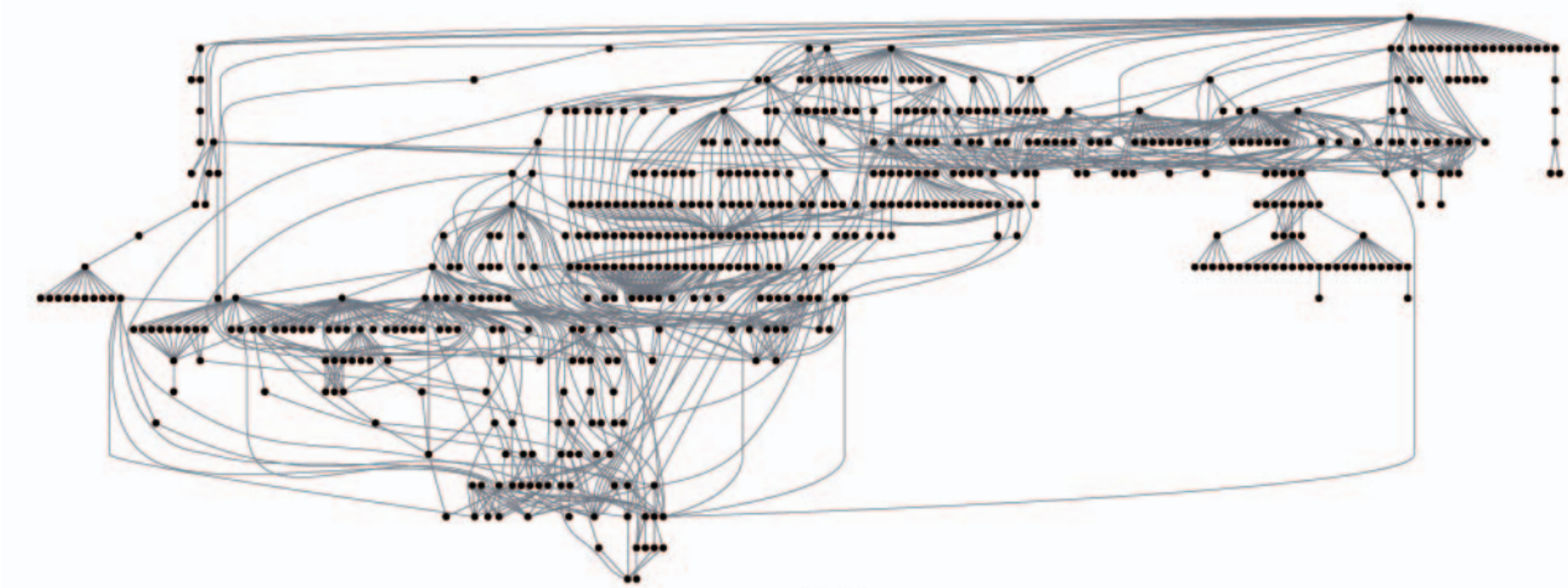
Evolution of the UNIX operating system

Hierarchical layering based on descent

GraphViz package!

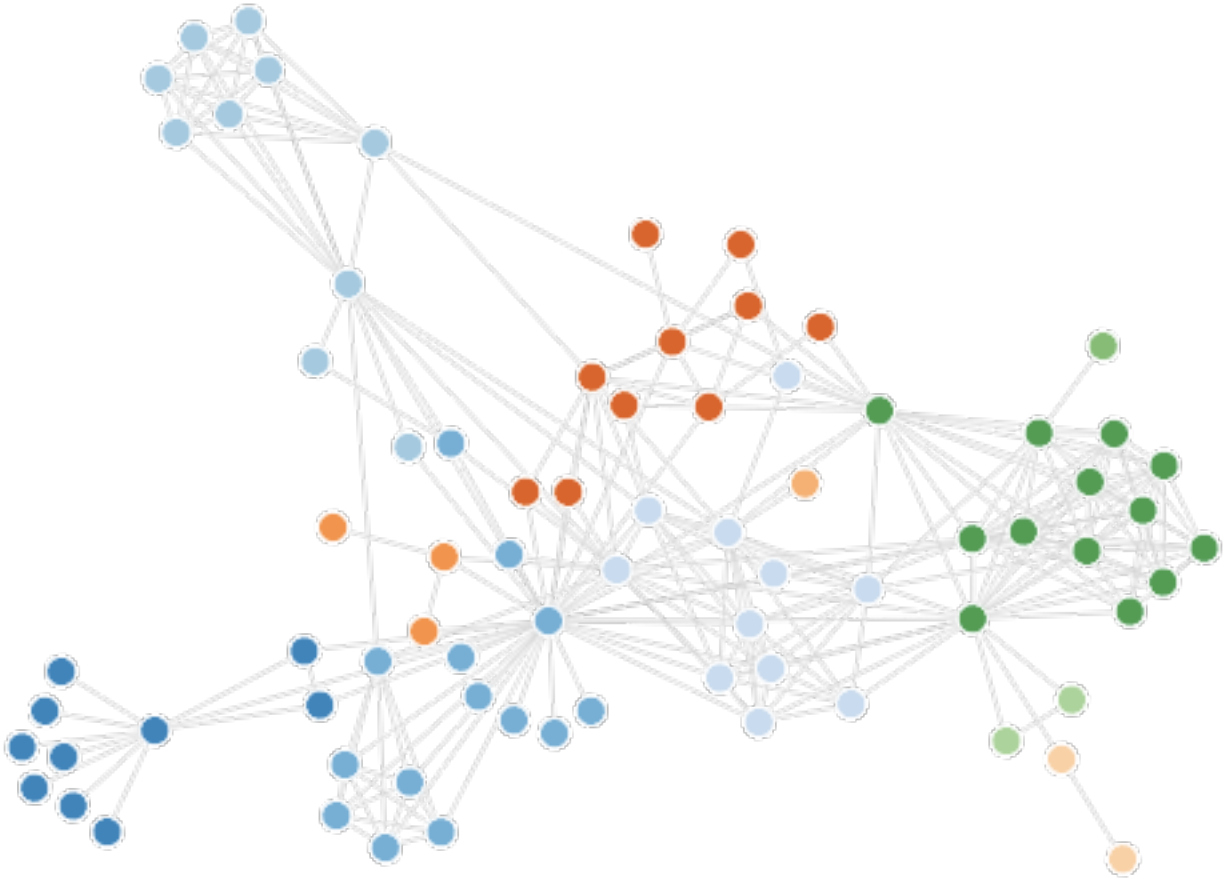


Produces Hierarchical Layouts



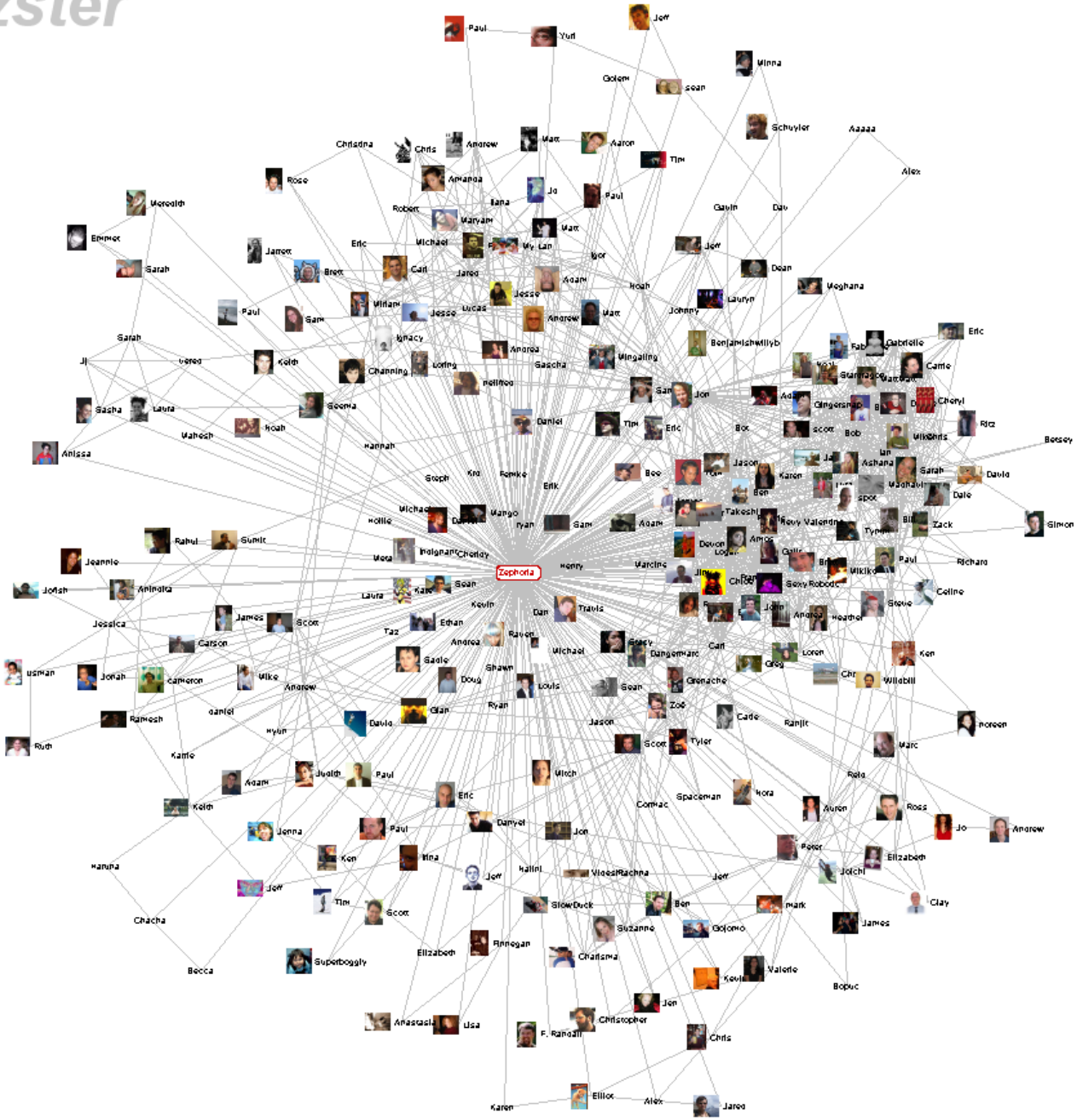
Sugiyama-style layout emphasizes hierarchy.
However, cycles in the graph may mislead.
Long edges can impede perception of proximity.

Force-Directed Layout



Interactive Example: Configurable Force Layout

vizster



community >>

Enable

search >>

Zephoria

User ID	21721
Friends	266
Age	??
Gender	Female
Status	Single
Location	San Francisco, CA
Hometown	Lancaster, PA
Occupation	researcher: social networks, identity, context
Interests	apophenia, observing people, culture, questioning power, reading, buddhism, ipseity, computer-mediated communication, social networks, technology, anthropology, stomping
Music	psytrance/goa/trance [Infected Mushroom, Son Kite... Iboga/Digital Structures], Ani Difranco, downtempo, Thievery Corporation, Beth Orton, Morcheeba, Ween, White Stripes
Books	Authors: Erving Goffman, Stanley Milgram, Jeanette Winterson, Eric Schlosser, Leslie Feinberg, Dorothy Allison, Italo Calvino, Hermann Hesse
TV Shows	??
Movies	Koyaanisqatsi, Amelie, Waking Life, Tank Girl, The Matrix, Clockwork Orange, American Beauty, Fight Club, Boys Don't Cry
Member Since	??
Last Login	2003-10-21
Last Updated	2003-10-21
About	[Some know me as danah...] I'm a geek, an activist and an academic, fascinated by people and society. I see life as a very large playground and enjoy exploring its intricacies. I revel in life's chaos, while simultaneously providing my own insane element. My musings: http://www.zephoria.org/thoughts/
Want to Meet	Someone who makes life's complexities seem simply elegant

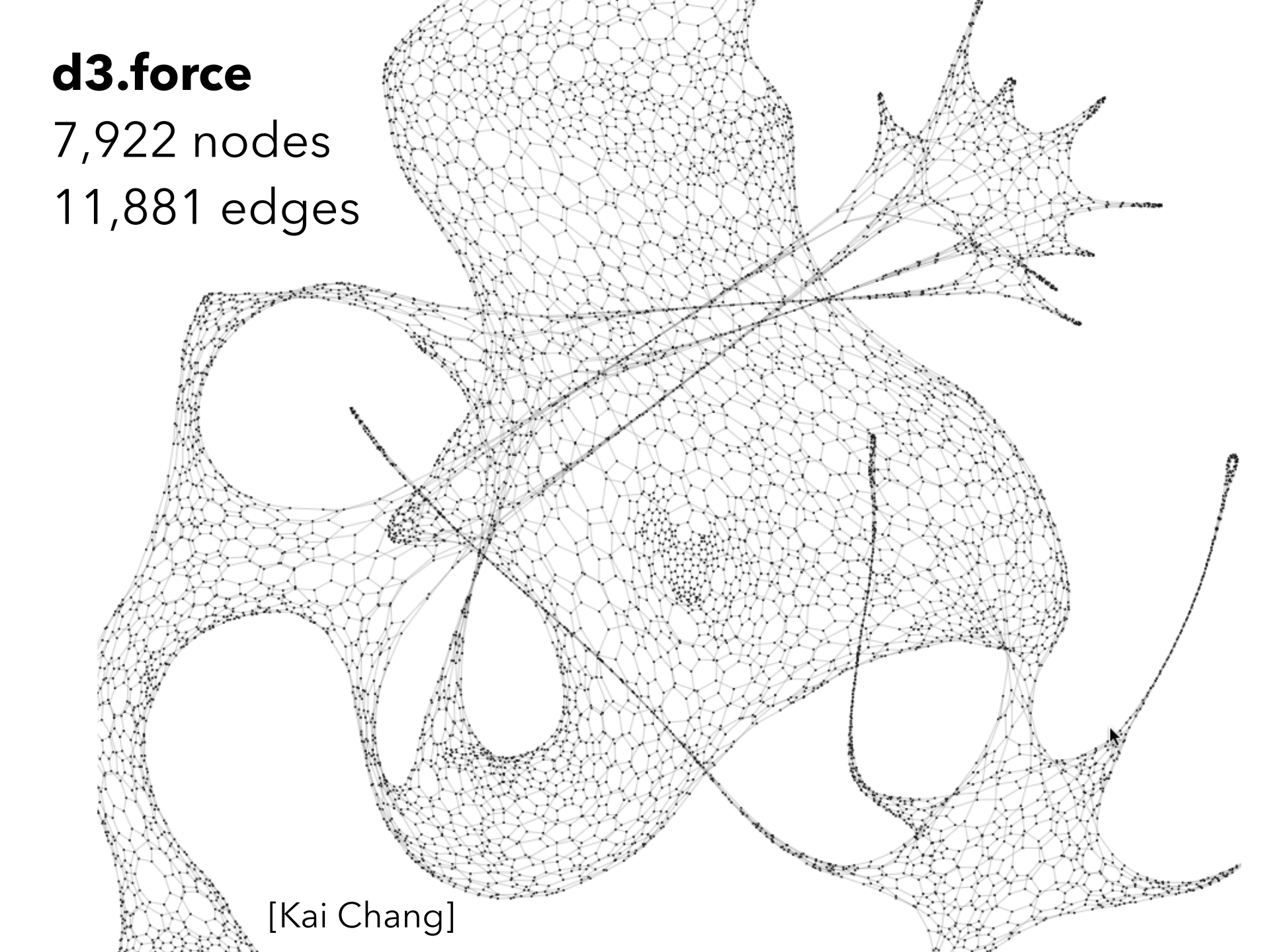
Use the Force!

http://mbostock.github.io/d3/talk/20110921/

d3.force

7,922 nodes

11,881 edges



[Kai Chang]

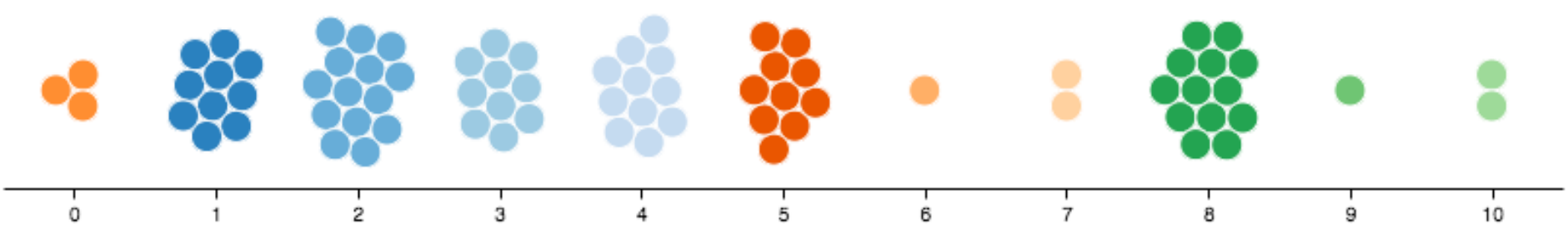
Customized Force Layouts

Different forces can be composed to create an expressive space of custom layouts.

A **beeswarm plot** can be made by combining:

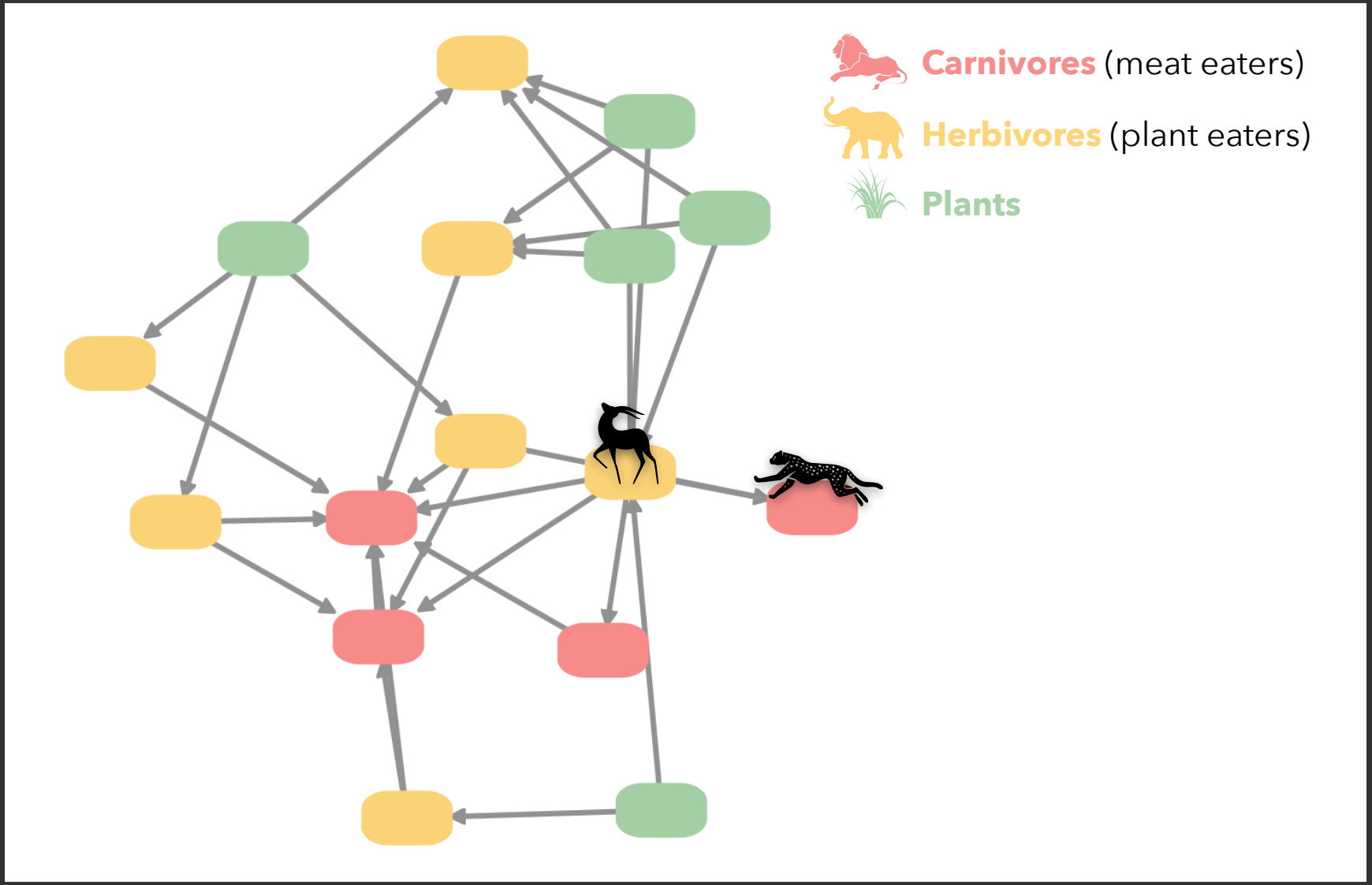
Attractive **X** and **Y** forces to draw nodes of a certain category to a desired point

Collide force to detect collision & remove overlap



Attribute-Driven Layout

How many herbivores have no predators?



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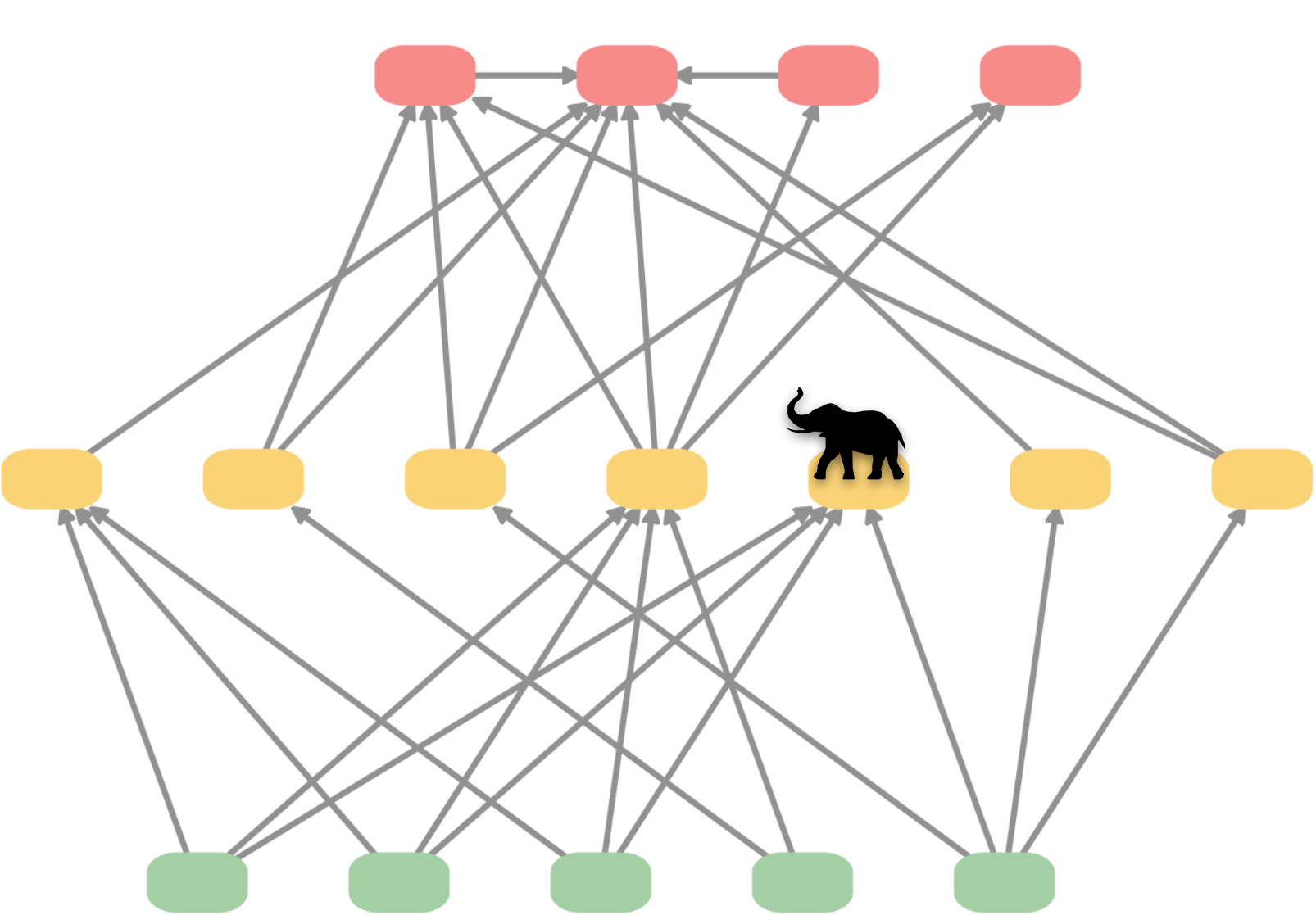


Attribute-Driven Layout

Large node-link diagrams **get messy**!
Is there additional structure we can exploit?

Idea: Use **data attributes** to perform layout
For example, scatter plot based on node values

Attributes may be associated with nodes or edges or may be statistical properties of the graph.

Use dynamic queries / brushing to explore…

Attribute-Driven Layout

The “Skitter” Layout

Internet Connectivity

Radial Scatterplot

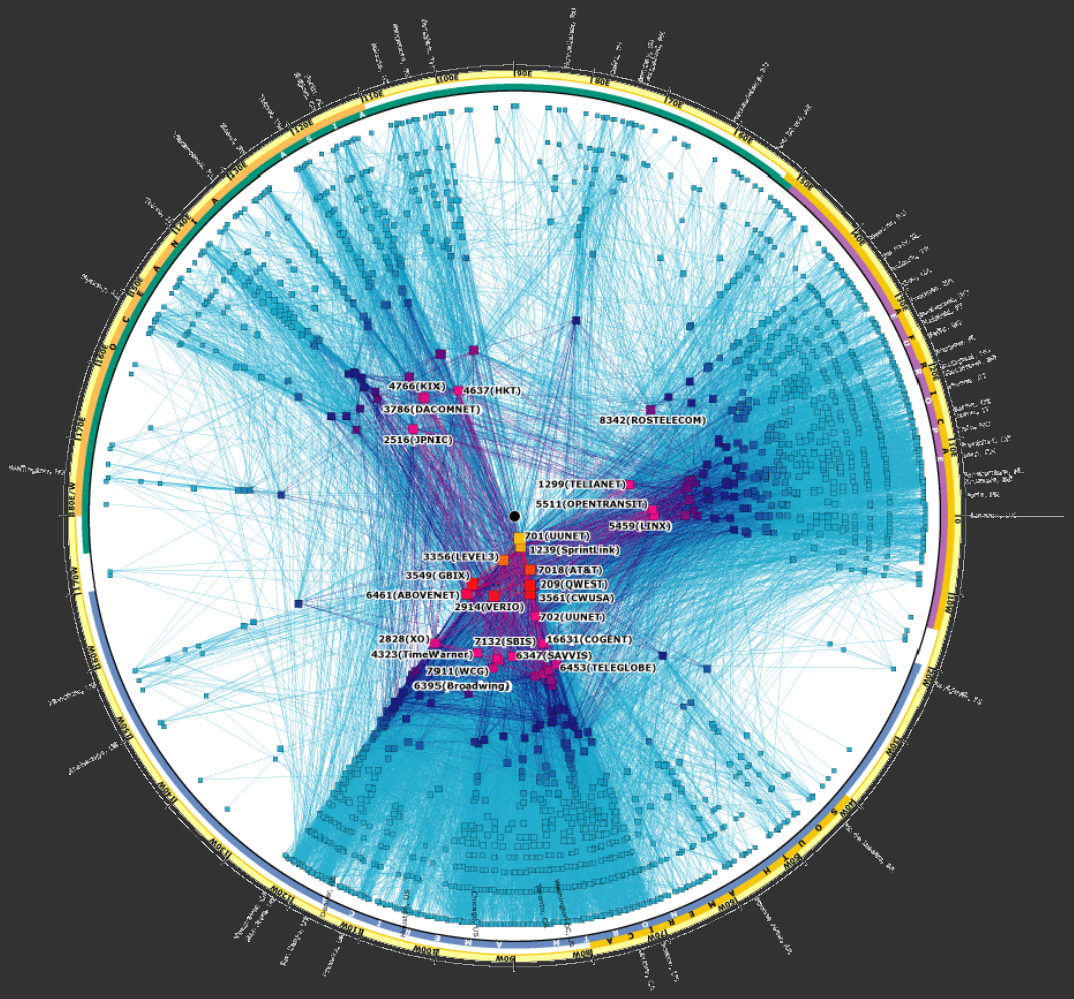
Angle = Longitude

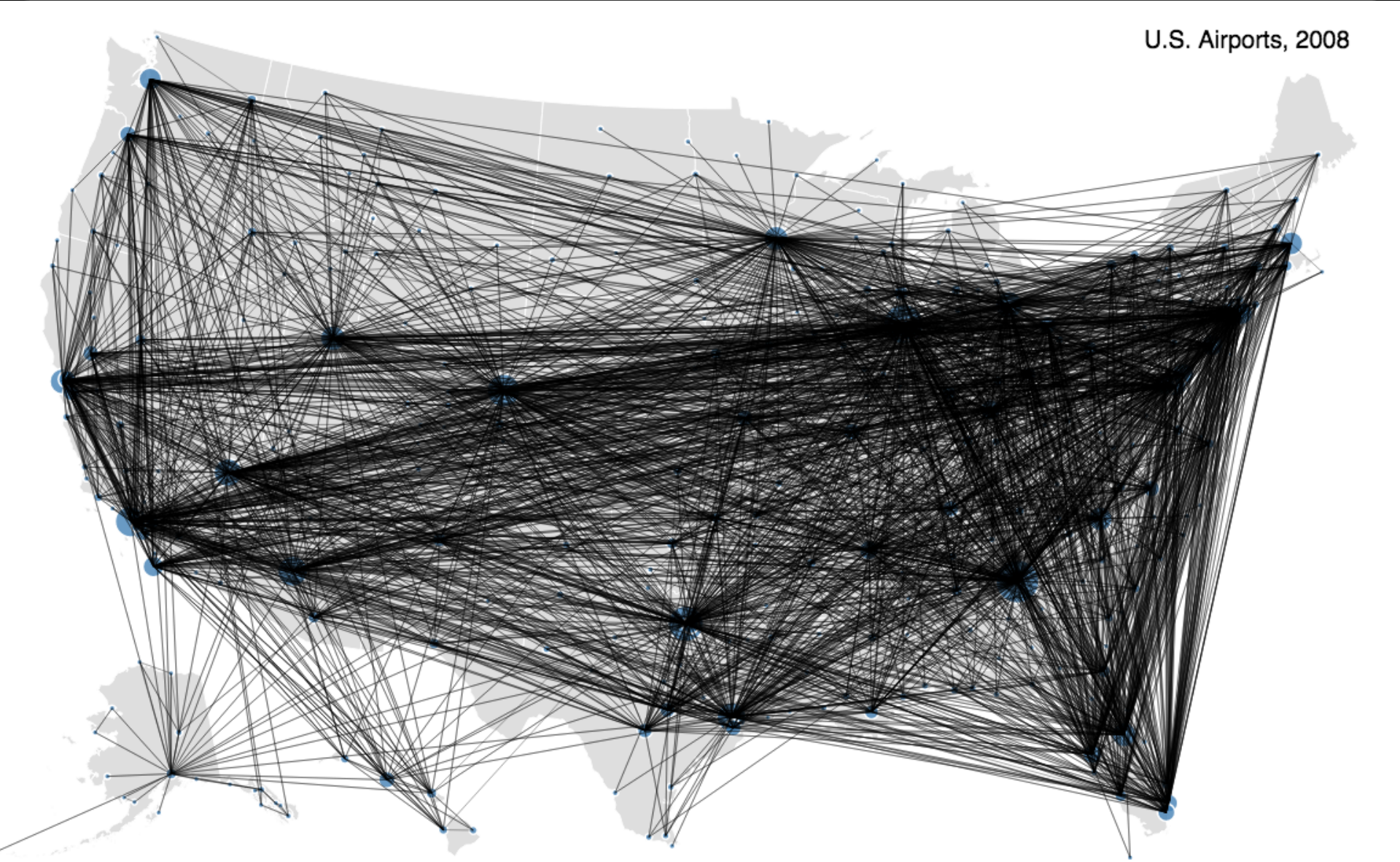
Geography

Radius = Degree

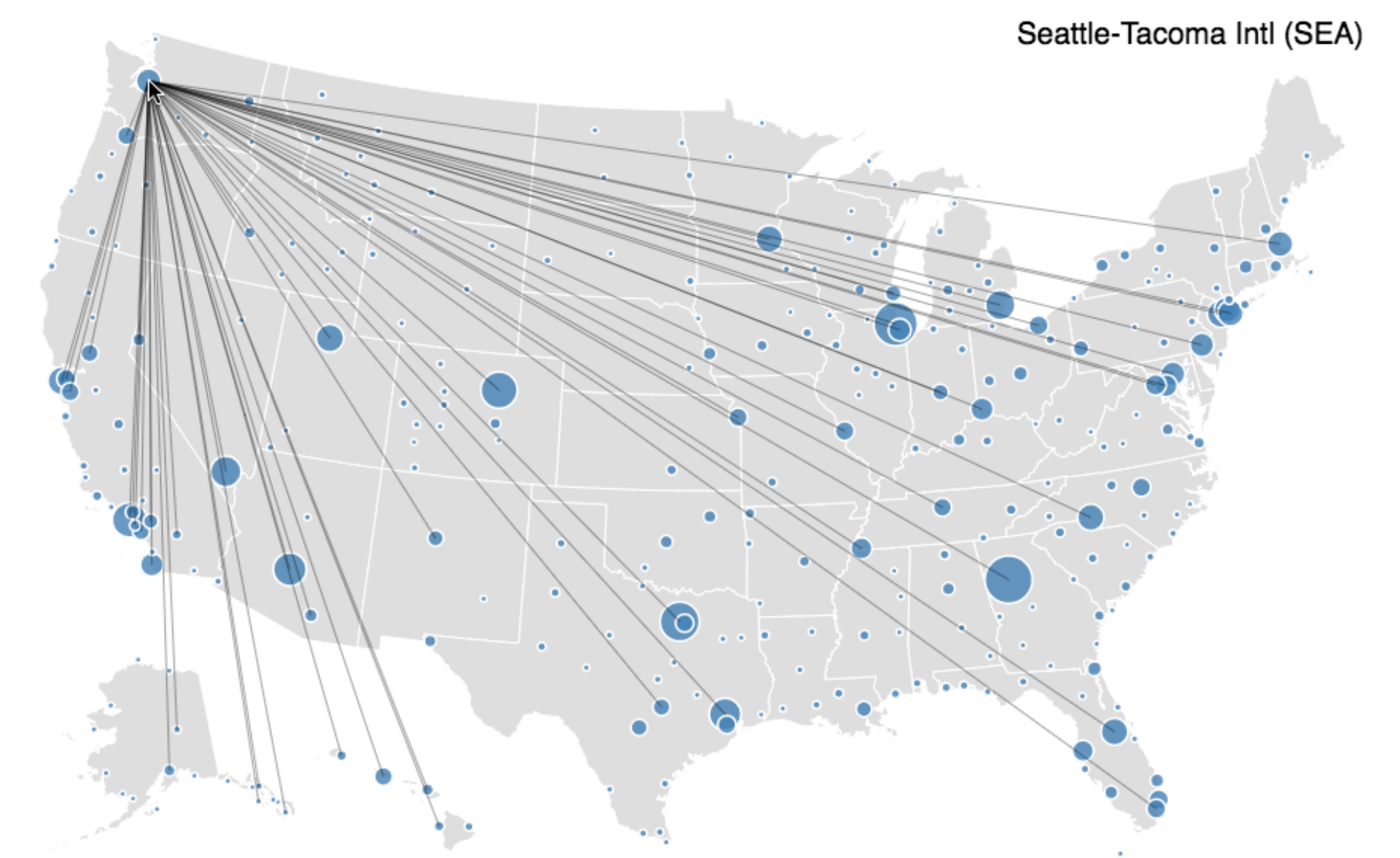
# of connections

(a statistic of the nodes)



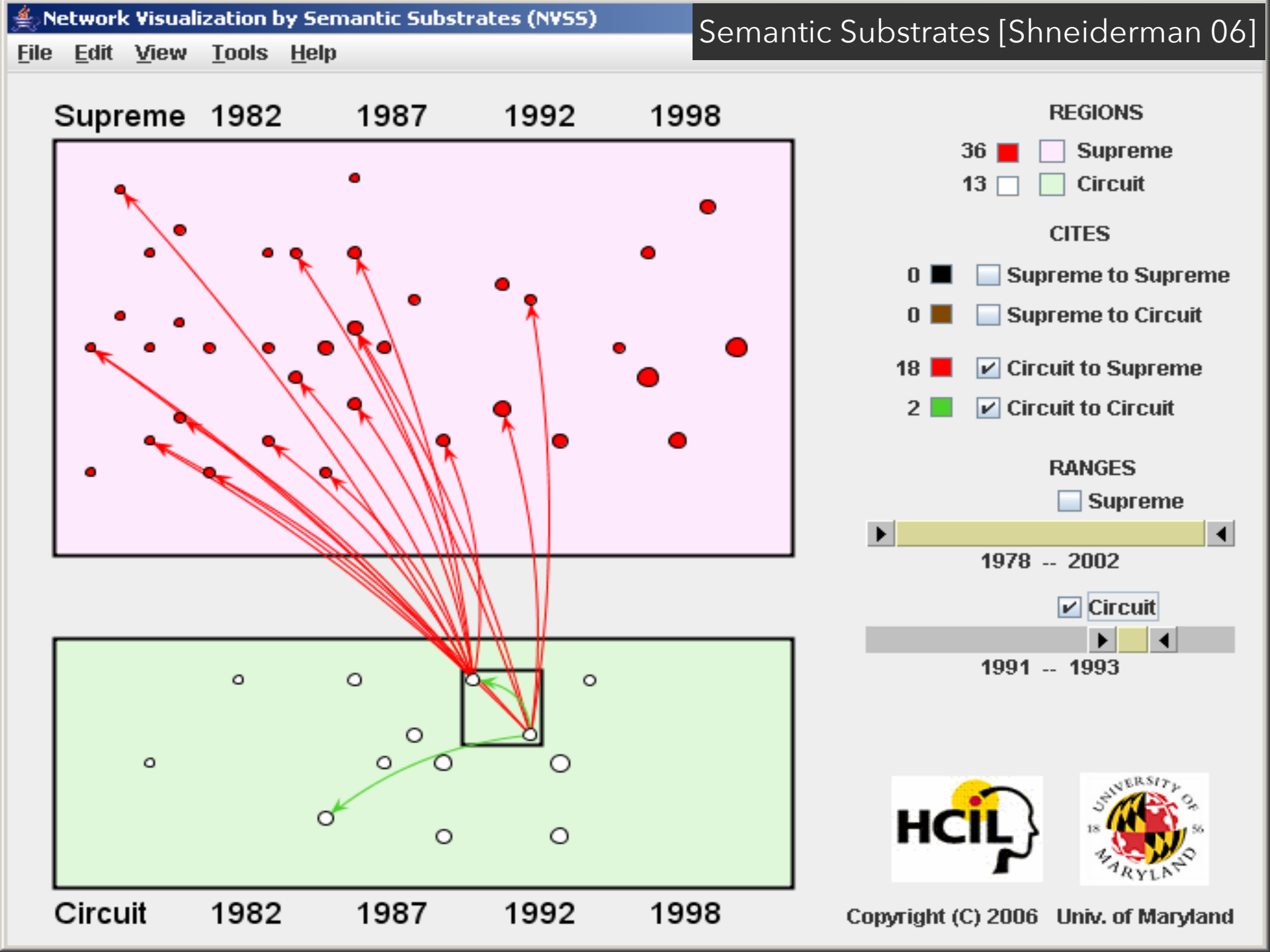


Drawing all edges is not particularly useful here…

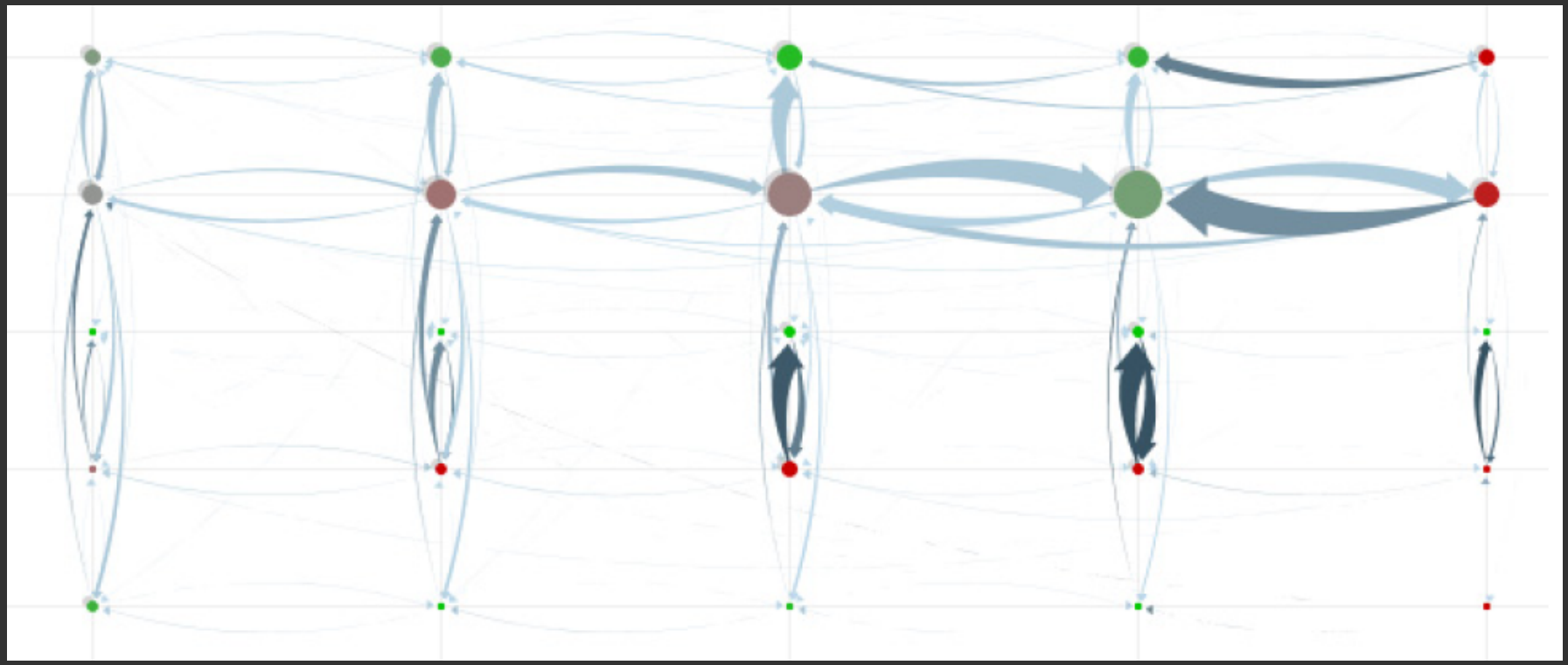


Node layout determined by geographic location.
Adjacent edges shown on node selection.

Semantic Substrates [Shneiderman 06]

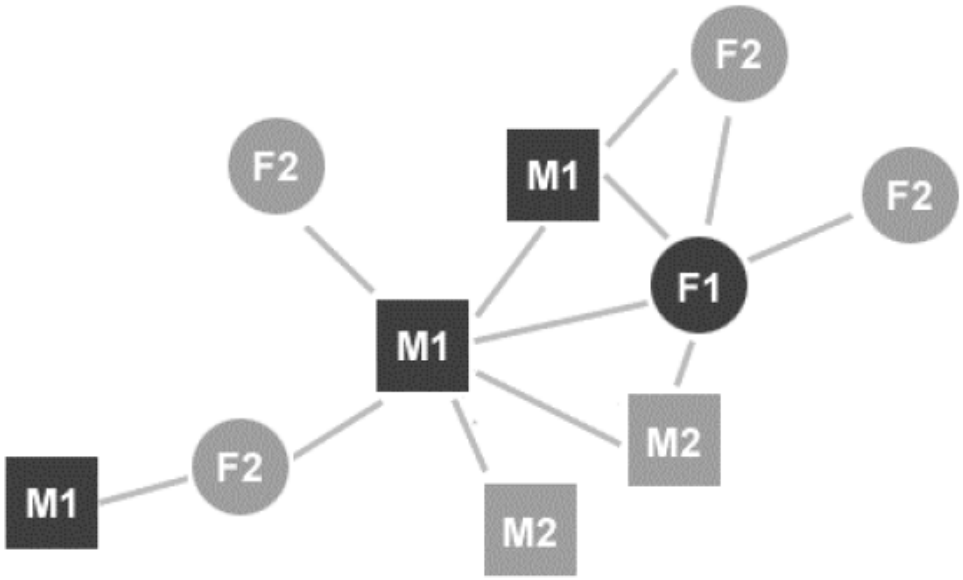


PivotGraph [Wattenberg '06]

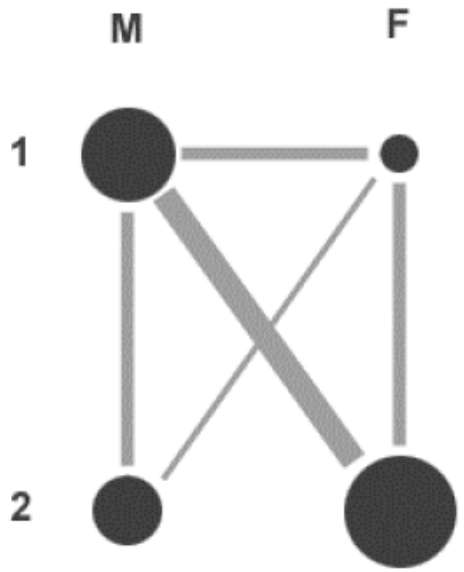


Layout aggregate graphs using node attributes.
Analogous to pivot tables and trellis display.

PivotGraph



Node and Link Diagram



PivotGraph Roll-up

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:

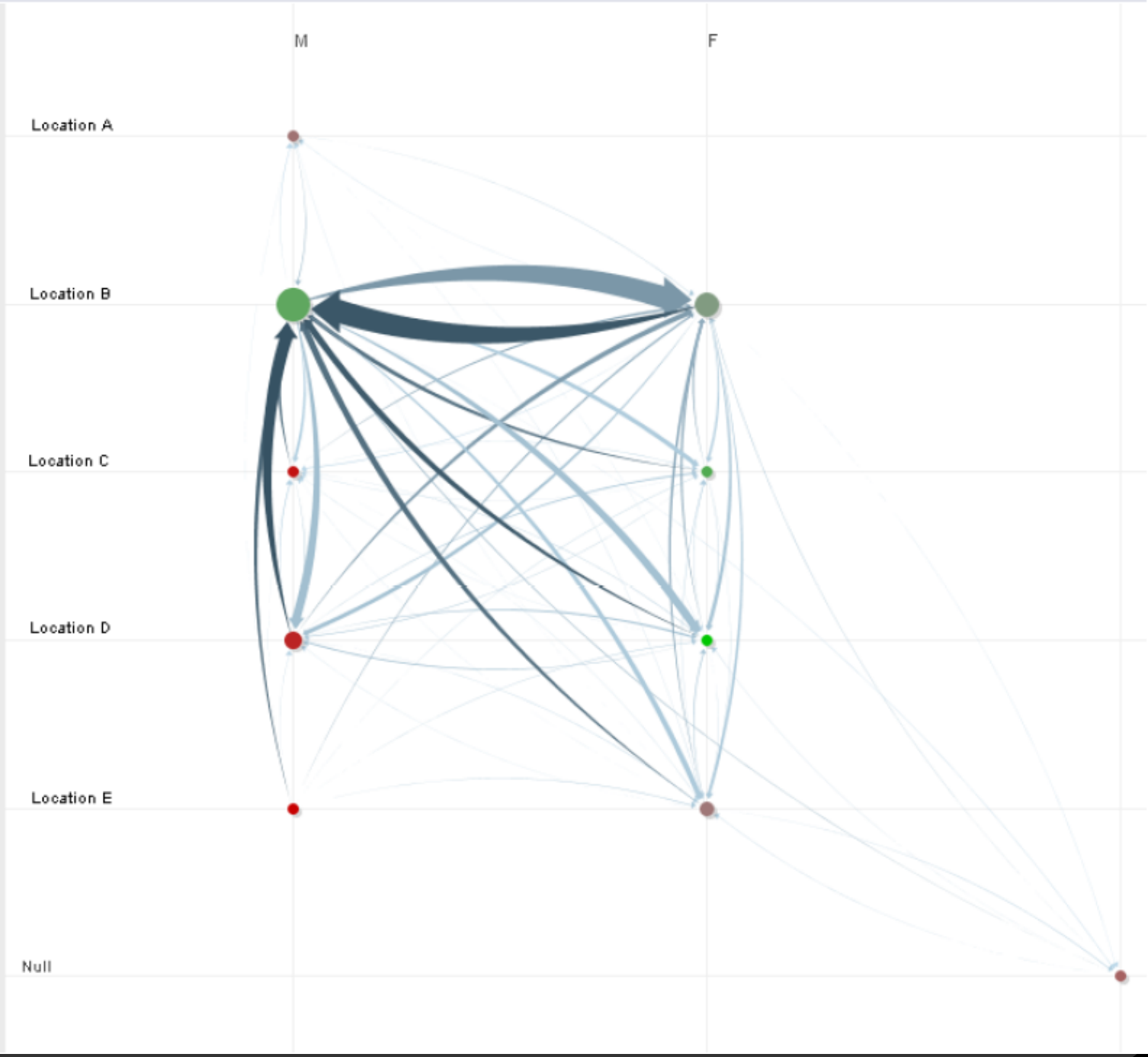
Gender
(All Values)

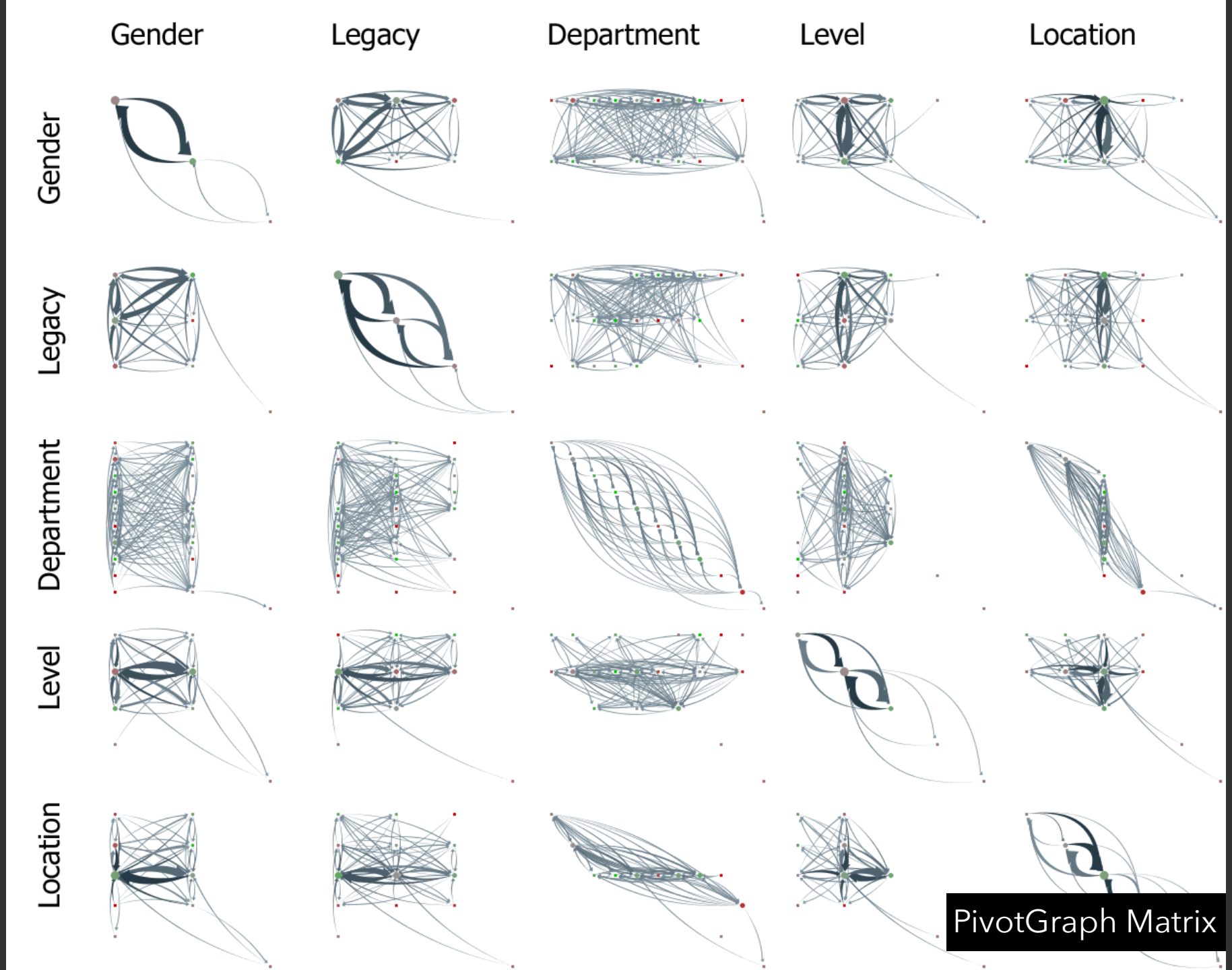
Legacy
(All Values)

Department
(All Values)

Level
(All Values)

Location
(All Values)



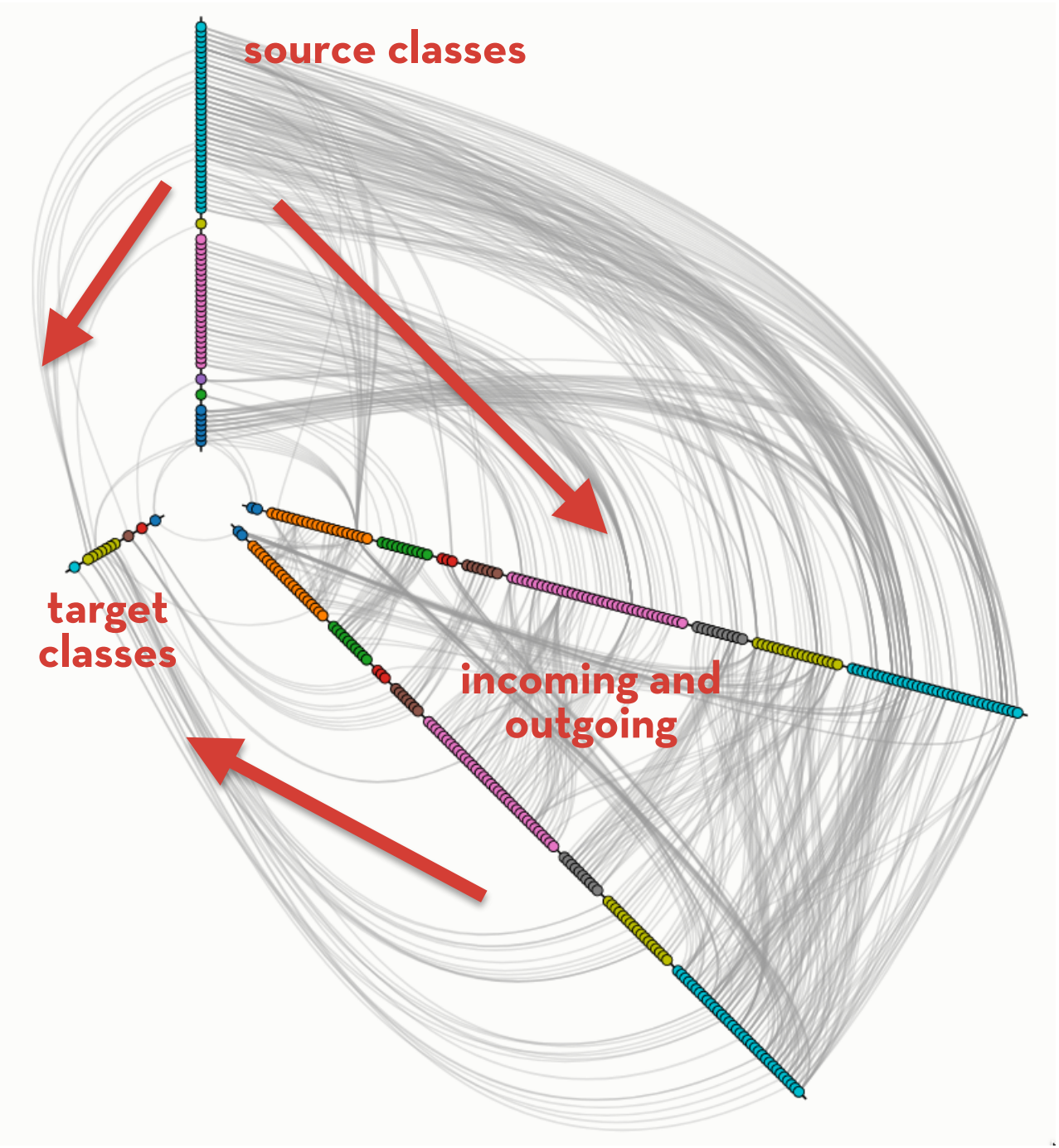

Gender
Legacy
Department
Level
Location
Gender
Legacy
Department
Level
Location
PivotGraph Matrix

Limitations of PivotGraph

Only 2 variables (no nesting as in Tableau)

Doesn’t support continuous variables

Multivariate edges?



HivePlots

[Krzywinski '11]

Nodes (dots) may be replicated.

Nodes sorted on radial axes by network statistics (e.g., by degree).

Different axes may contain different subsets of nodes.

egweb.bcgsc.ca

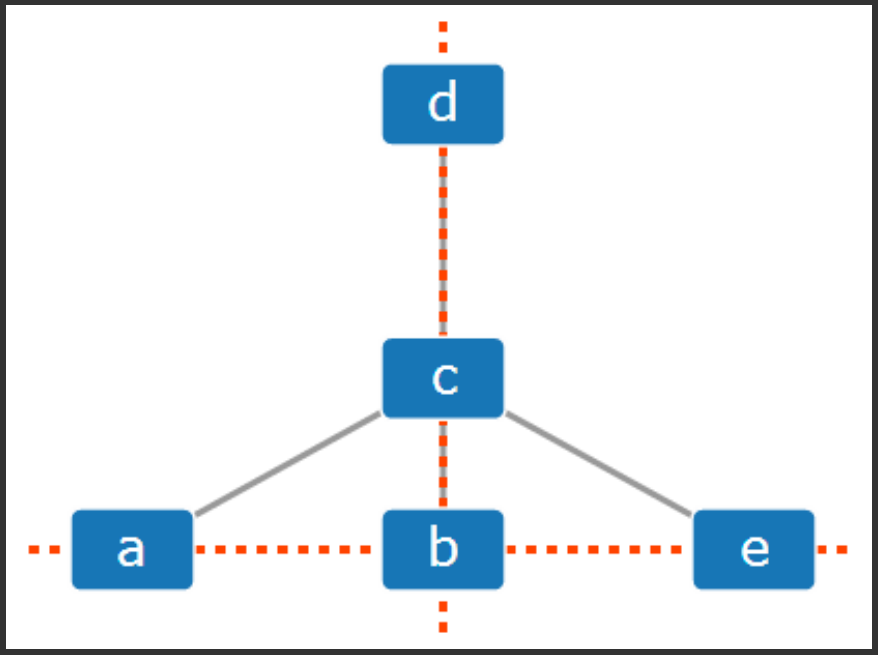
Constraint-Based Layout

Constraint-Based Layout

Treat layout as an *optimization problem*

Define layout using an *energy model* along with *constraints*: equations the layout should obey.

Use optimization algorithms to solve



Position Constraints:

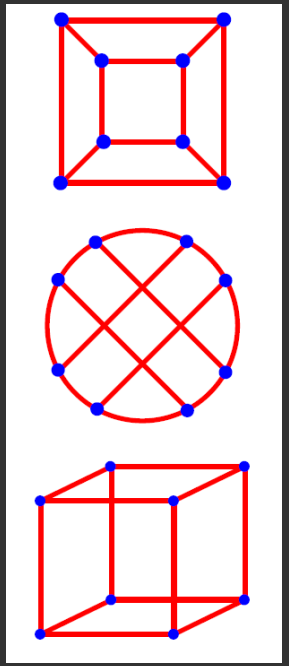
a must be to the left of b

d, c, and b must have the same x position

a, b, and e must have the same y position

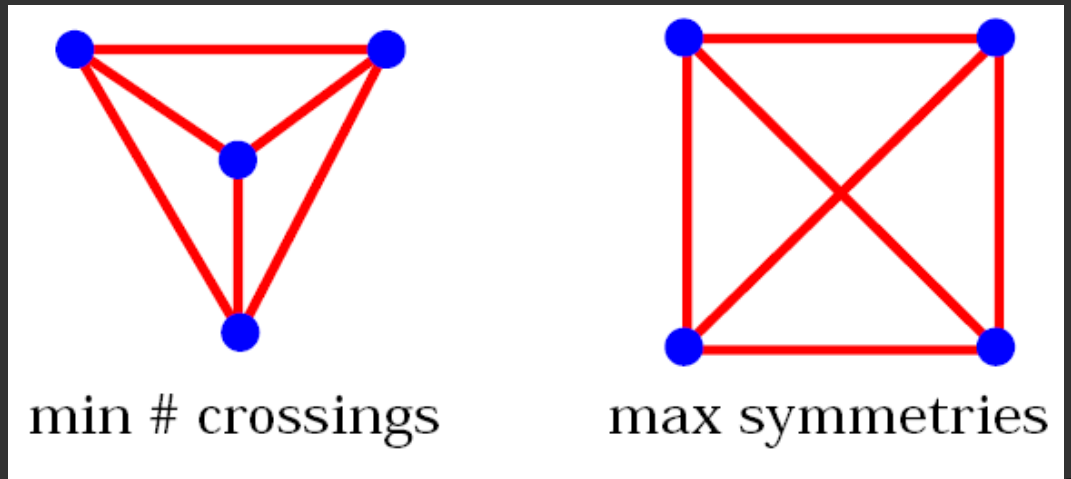
Optimizing Aesthetic Constraints

Minimize edge crossings
Minimize area
Minimize line bends
Minimize line slopes
Maximize smallest angle between edges
Maximize symmetry



but, can't do it all.

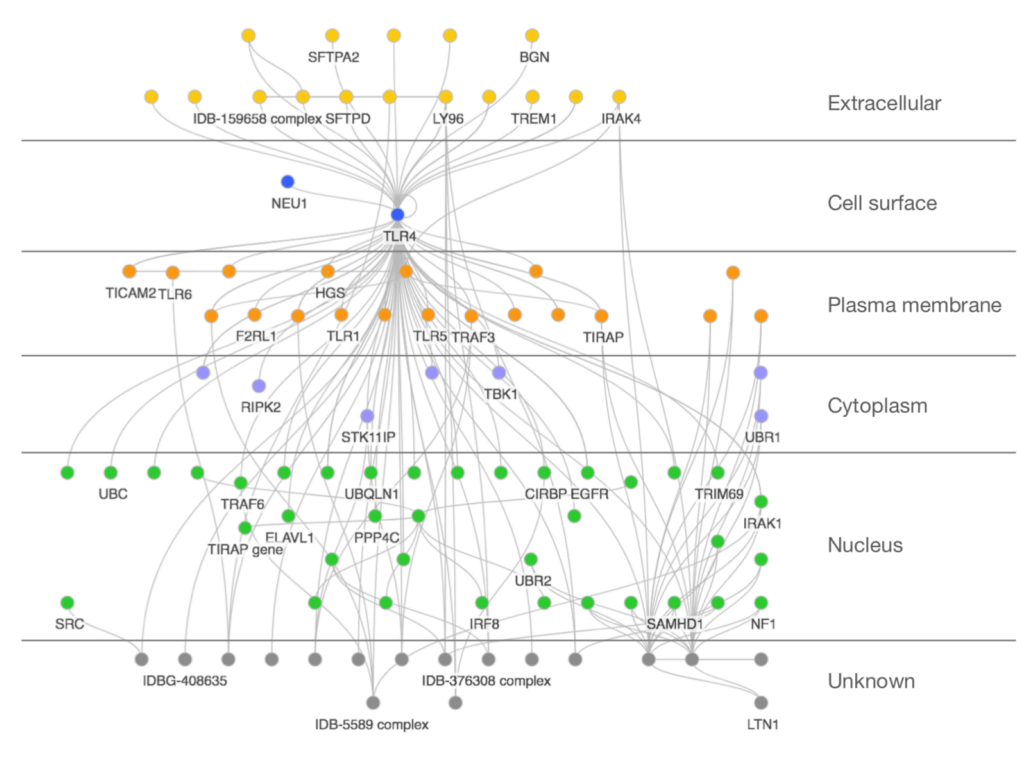
Optimizing these criteria is often NP-Hard, requiring approximations.



SetCoLa: High-Level Layout

(1) Define **sets** of nodes based on attributes.

(2) Apply **constraints** to set elements.



Layout using SetCoLa:

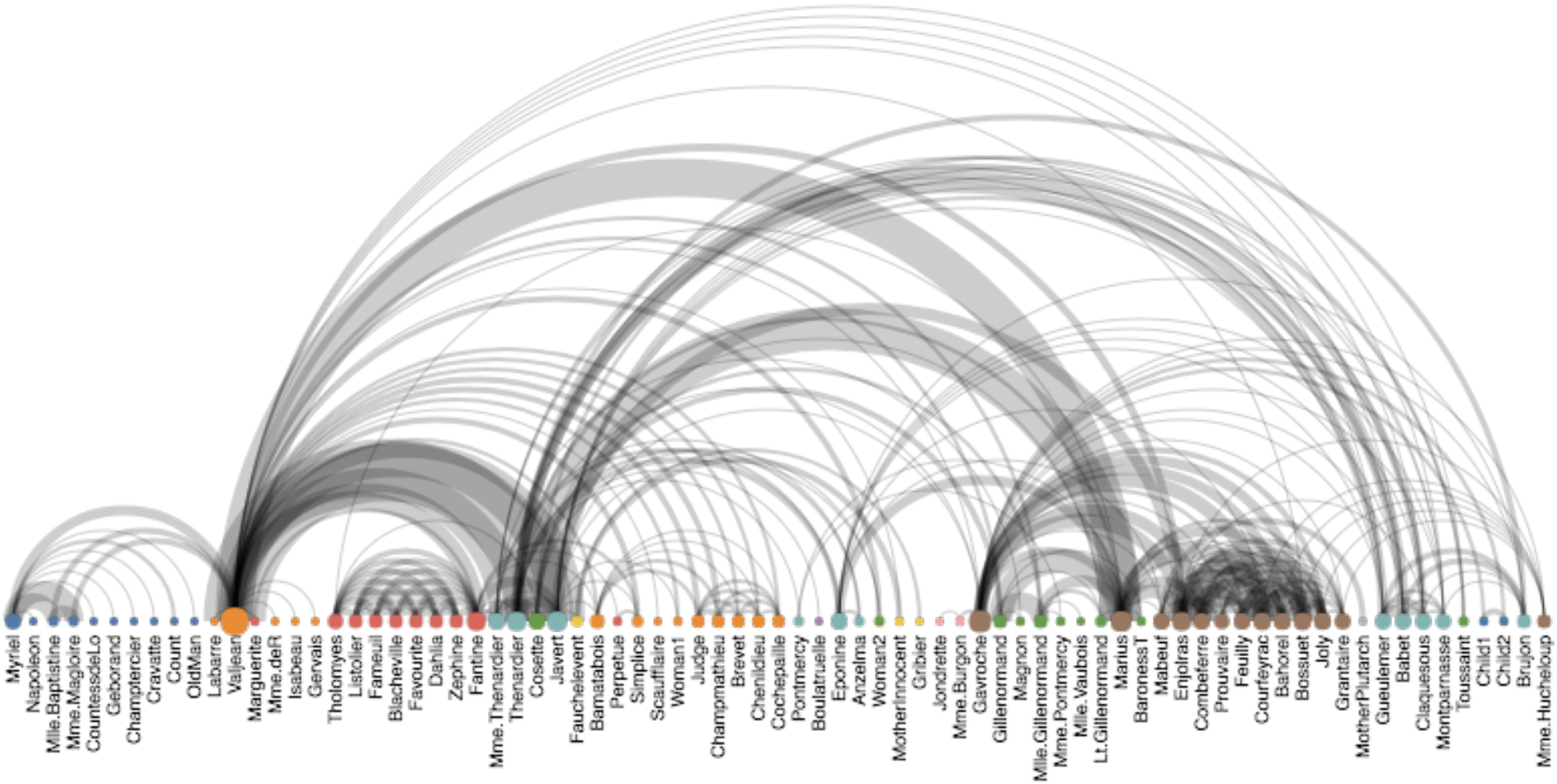
(1) ON ALL NODES
- (i) POSITION LEFT OF "RBOUND"
- (ii) POSITION RIGHT OF "LBOUND"

(2) PARTITION TYPE
- (iii) PADDING 18

(3) COMPOSE SET FROM TYPES
- (iv) ORDER BY TYPE

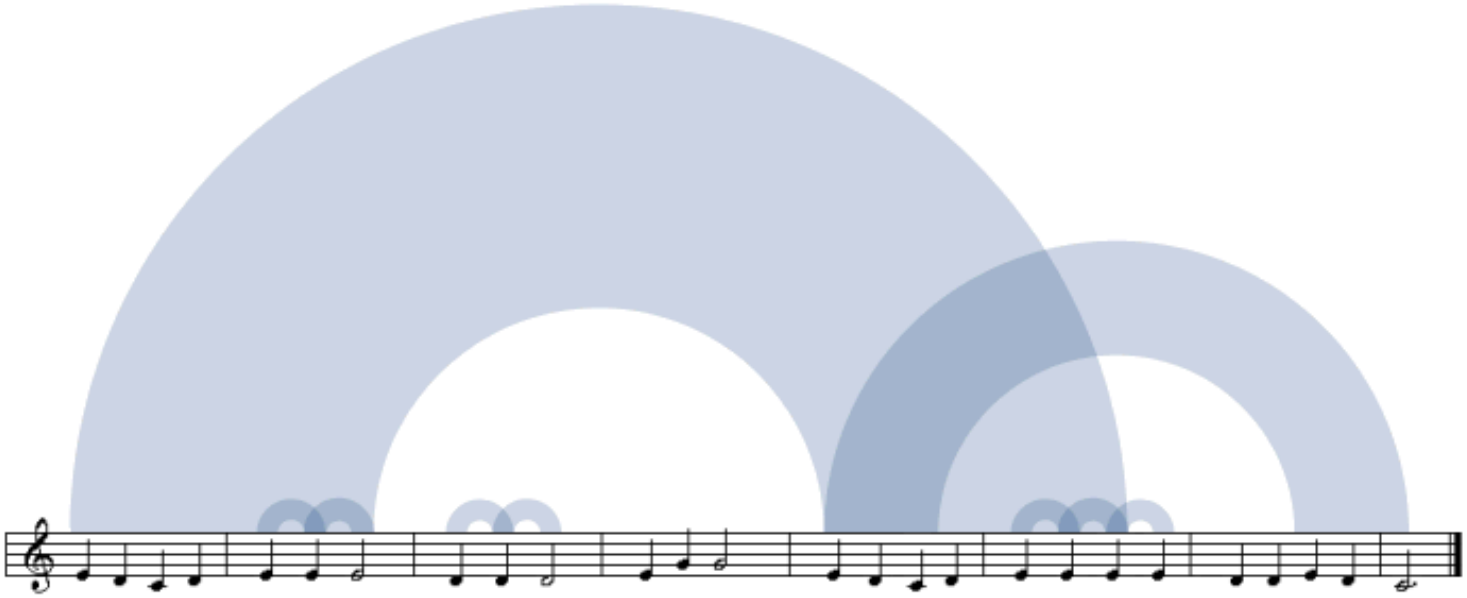
[Hoffswell '18]

Arc Diagrams



Linear node layout, circular arcs show connections.

Layout quality sensitive to node ordering!



For example, the picture above was built from the first line of a very simple piece: *Mary Had a Little Lamb*. Each arch connects two identical passages. To clarify the connection between the visualization and the song, in this diagram the score is displayed beneath the arches.

The Shape of Song

[Wattenberg '01]

This diagram visualizes the refrain from the folk song *Clementine*. As you would expect, the refrain consists of multiple repetitions of the same passage--and that is exactly what the diagram shows. The score isn't shown in this diagram since the notes would be too small to read.

Task Analysis

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout - arranged by depth

Force-Directed Layout - physical simulation

Attribute-Driven Layout - arranged by value

Constraint-Based Layout - optimization

Arc Diagrams - aligned layout

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

The Good: *Structured-based analysis of hierarchical relationships*
The Bad: *Browsing and path following due to long edges*

Force-Directed Layout

Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

Force-Directed Layout

Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

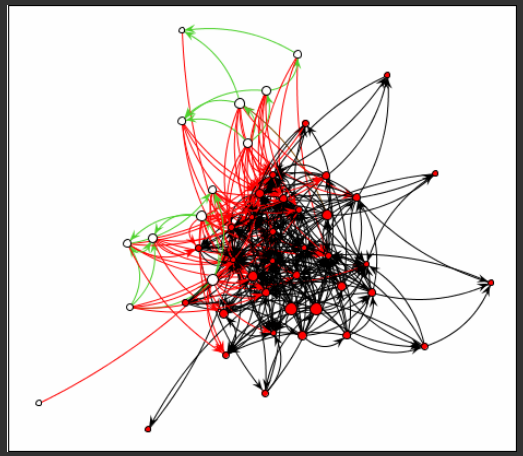
Force-Directed Layout

The Good: *Structured-based analysis of closely related elements*
The Bad: *Browsing and summarization of dense networks*

Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams



Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

Force-Directed Layout

Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

Force-Directed Layout

Attribute-Driven Layout

The Good: *Attribute-based analysis tasks*
The Bad (Difficult): *Designing layouts appropriately*

Constraint-Based Layout

Arc Diagrams

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

Force-Directed Layout

Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

Force-Directed Layout

Attribute-Driven Layout

Constraint-Based Layout

The Good: *Graph layout based on structural/aesthetic properties*
The Bad (Difficult): *Selecting constraints appropriately*

Arc Diagrams

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

Force-Directed Layout

Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams

Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

Force-Directed Layout

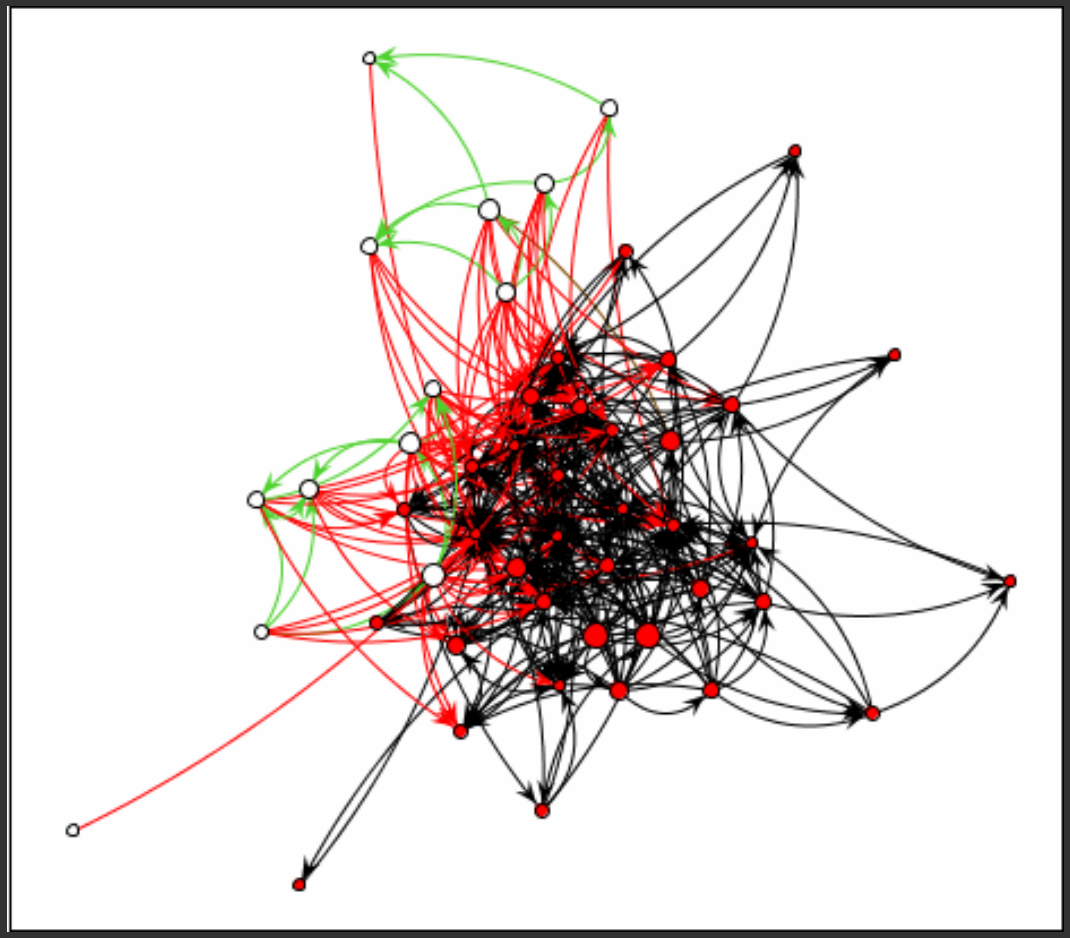
Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams

The Good: *Summarization and comparison of overall structure*
The Bad: *Order matters for node layout; Structure-based and path following*

Limitations of Node-Link Layouts



Edge-crossings and occlusion! Poor scalability….

Administrivia

Final Project

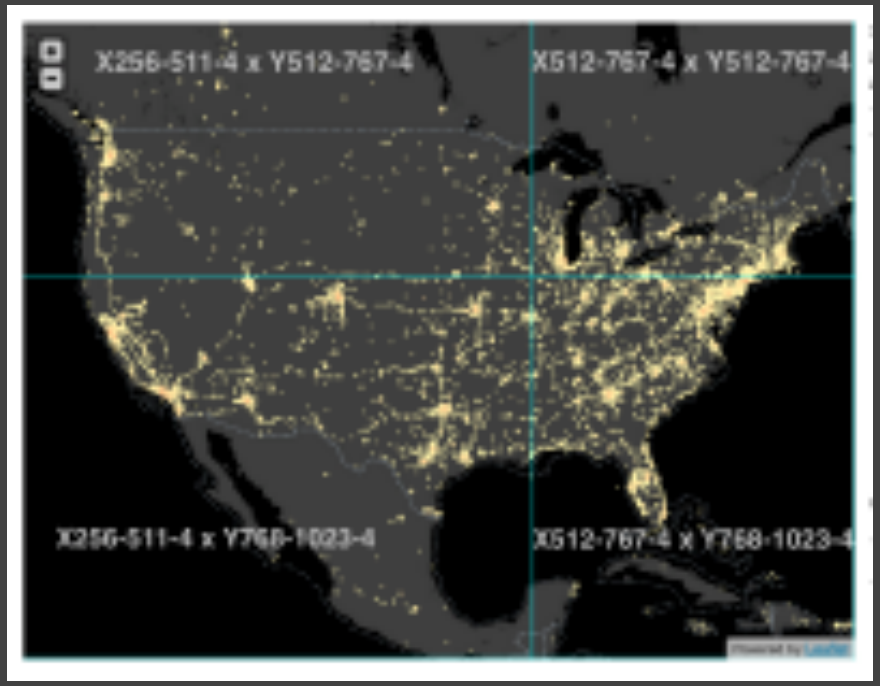
Initial Project Prototype due **this Friday May 21st**
Prototype Deliverables: must **submit link on Canvas**

Prototype Expectations:
Outline of the overall project structure
Rough prototypes of visualizations and interactions
Basic descriptive (narrative) text
Discussion of any concerns or plans for next steps

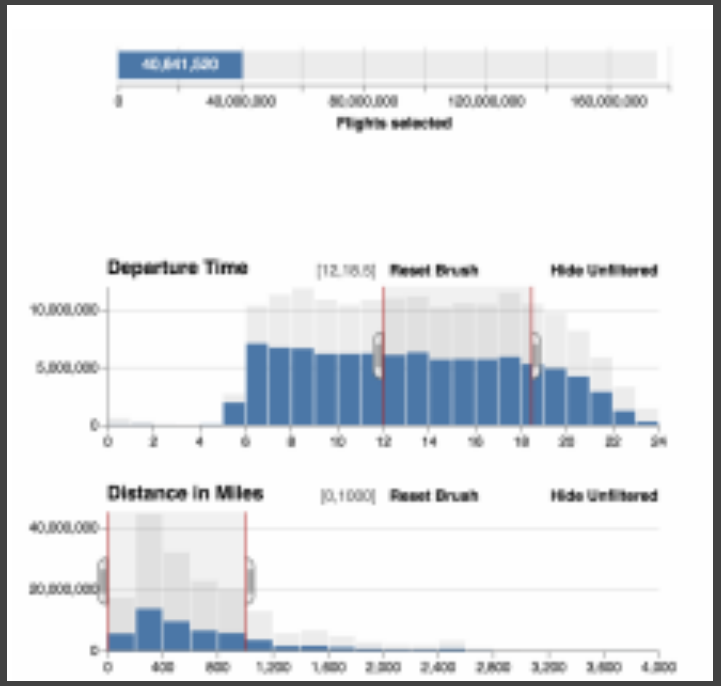
The more content you have on your page, the more specific feedback we can give to refine your project.

Zoom Poll:
Final Project Check-In

Required Reading for Fri 5/21

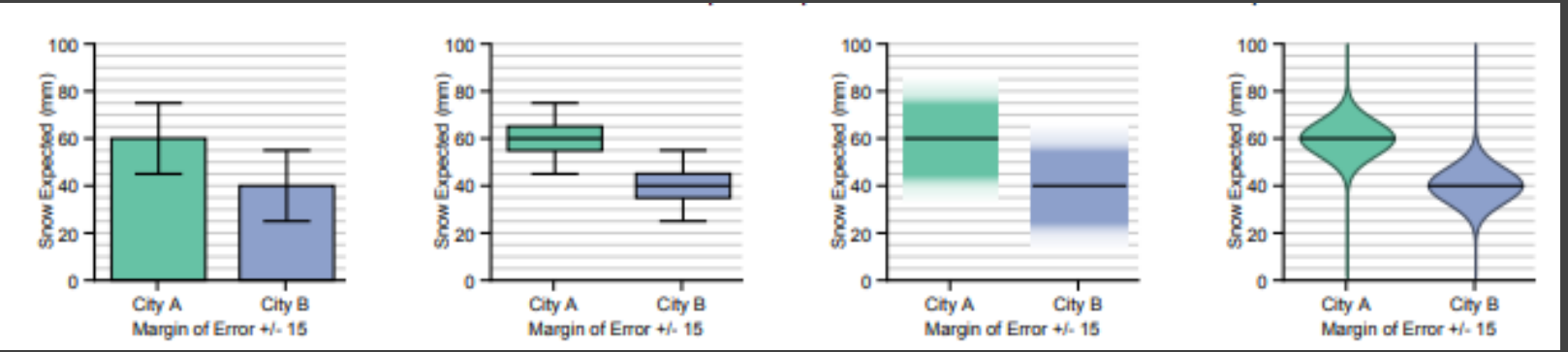


imMens: Real-time Visual Querying of Big Data. Zhicheng Liu, Biye Jiang, and Jeffrey Heer. EuroVis 2013.



Falcon: Balancing Interactive Latency and Resolution Sensitivity for Scalable Linked Visualizations. Dominik Moritz, Bill Howe, Jeffrey Heer. CHI 2019.

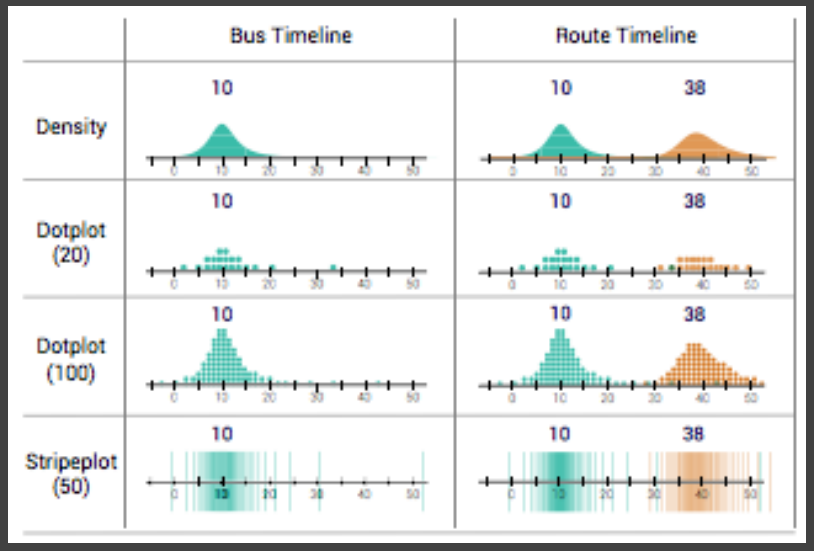
Required Reading for Mon 5/24



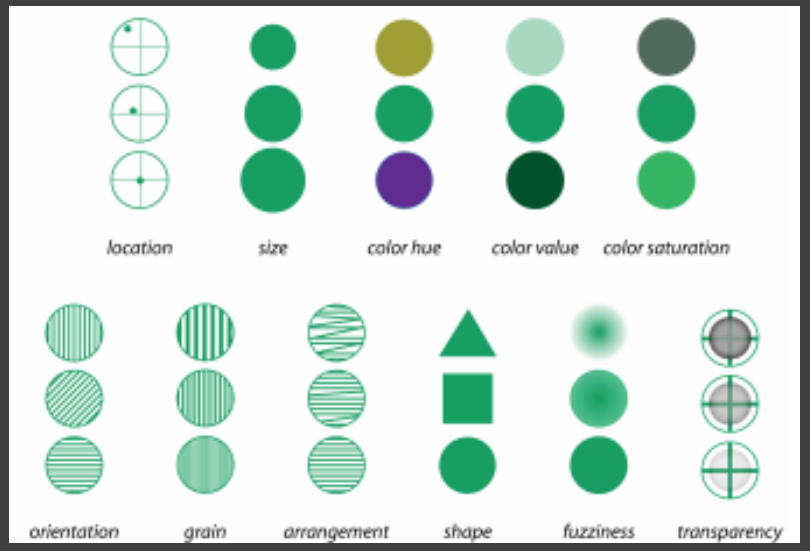
Error Bars Considered Harmful: Exploring Alternate Encodings for Mean and Error. Michael Correll and Michael Gleicher. IEEE InfoVis. 2014.

The Visual Uncertainty Experience. Jessica Hullman. OpenVis Conf. 2016.

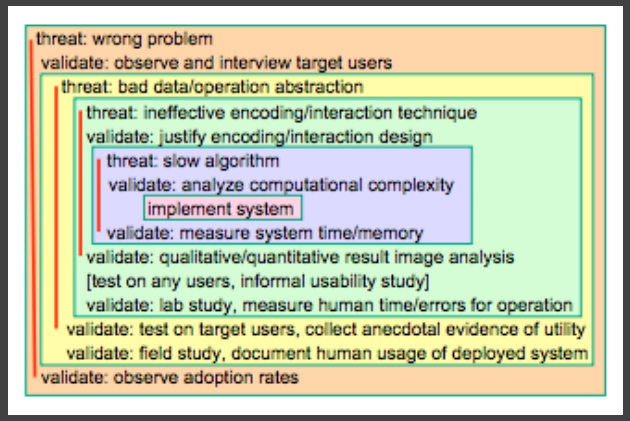
Optional Readings for Week 9



When(ish) is My Bus? User-centered Visualizations of Uncertainty in Everyday, Mobile Predictive Systems

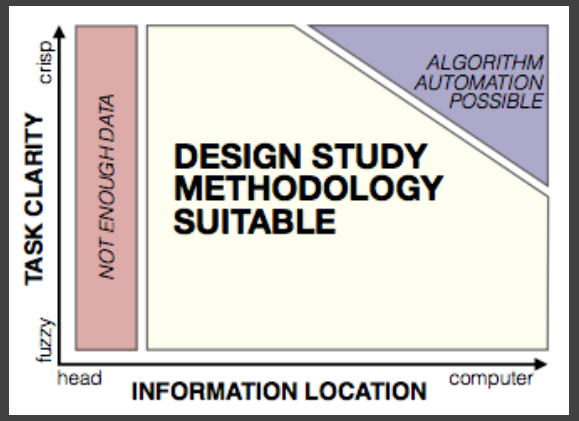


Visual Semiotics & Uncertainty Visualization: An Empirical Study



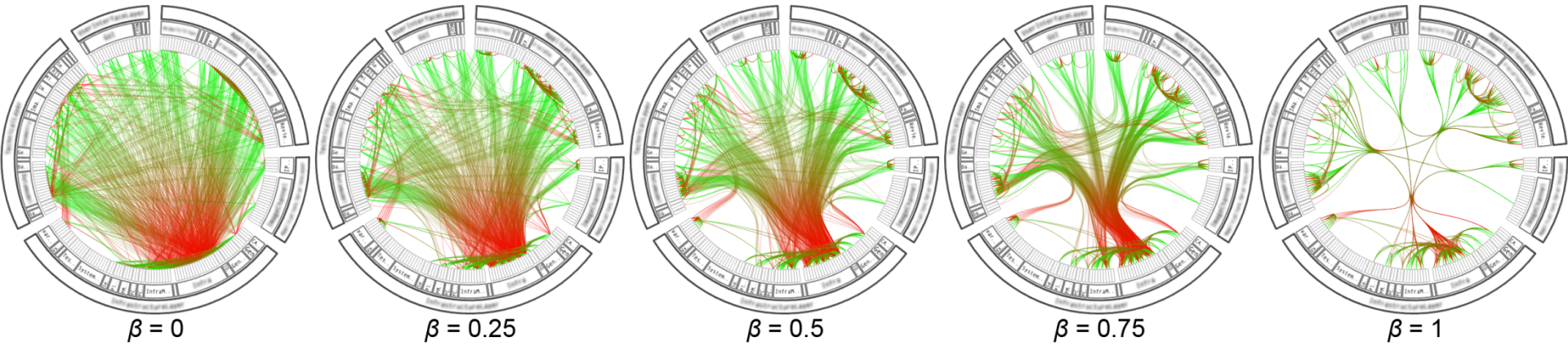
A Nested Model for Visualization Design and Validation

Design Study Methodology: Reflections from the Trenches and the Stacks



Hierarchical Edge Bundling

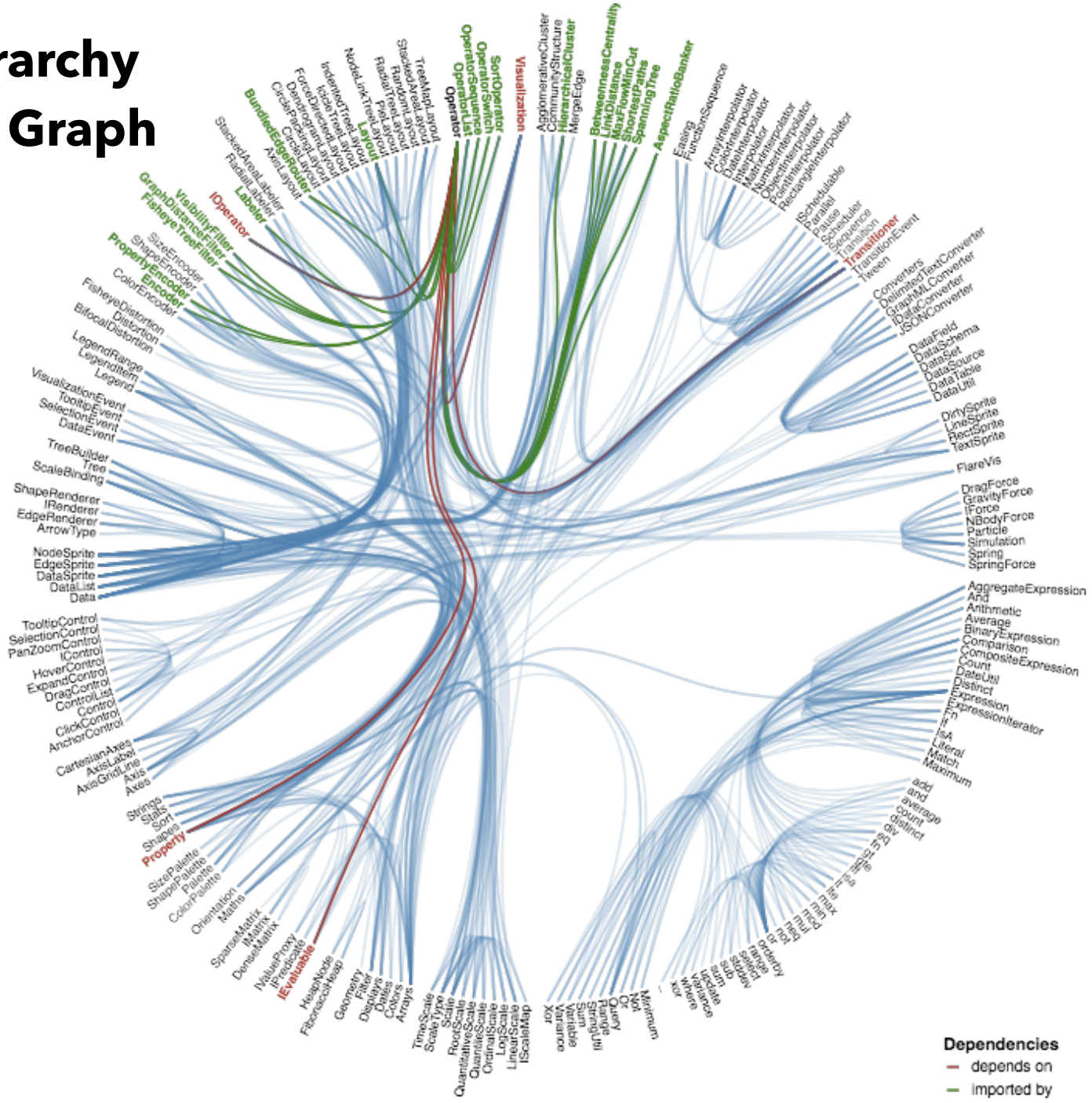
Hierarchical Edge Bundling



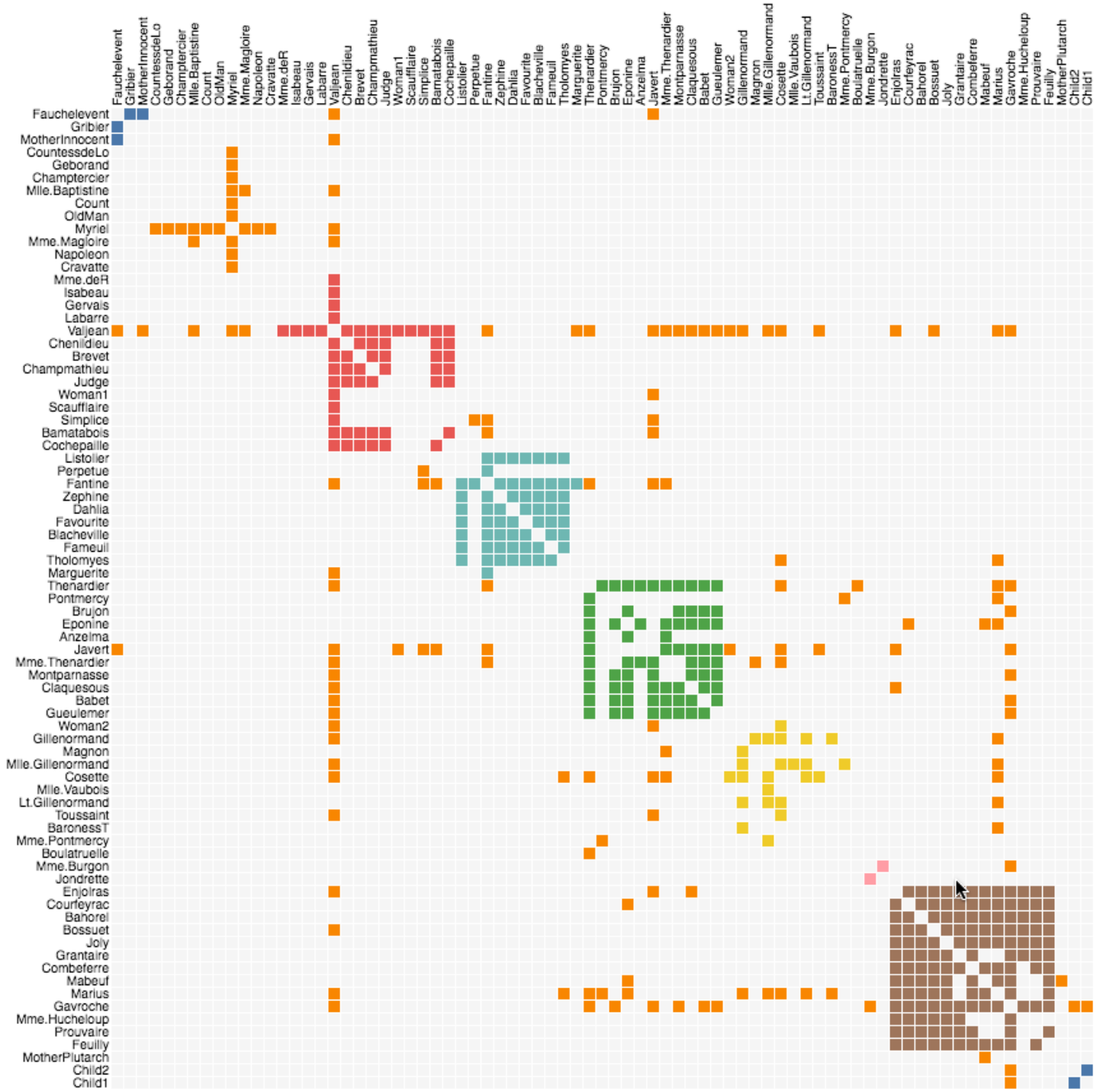
Bundle edges with varying amounts of tension

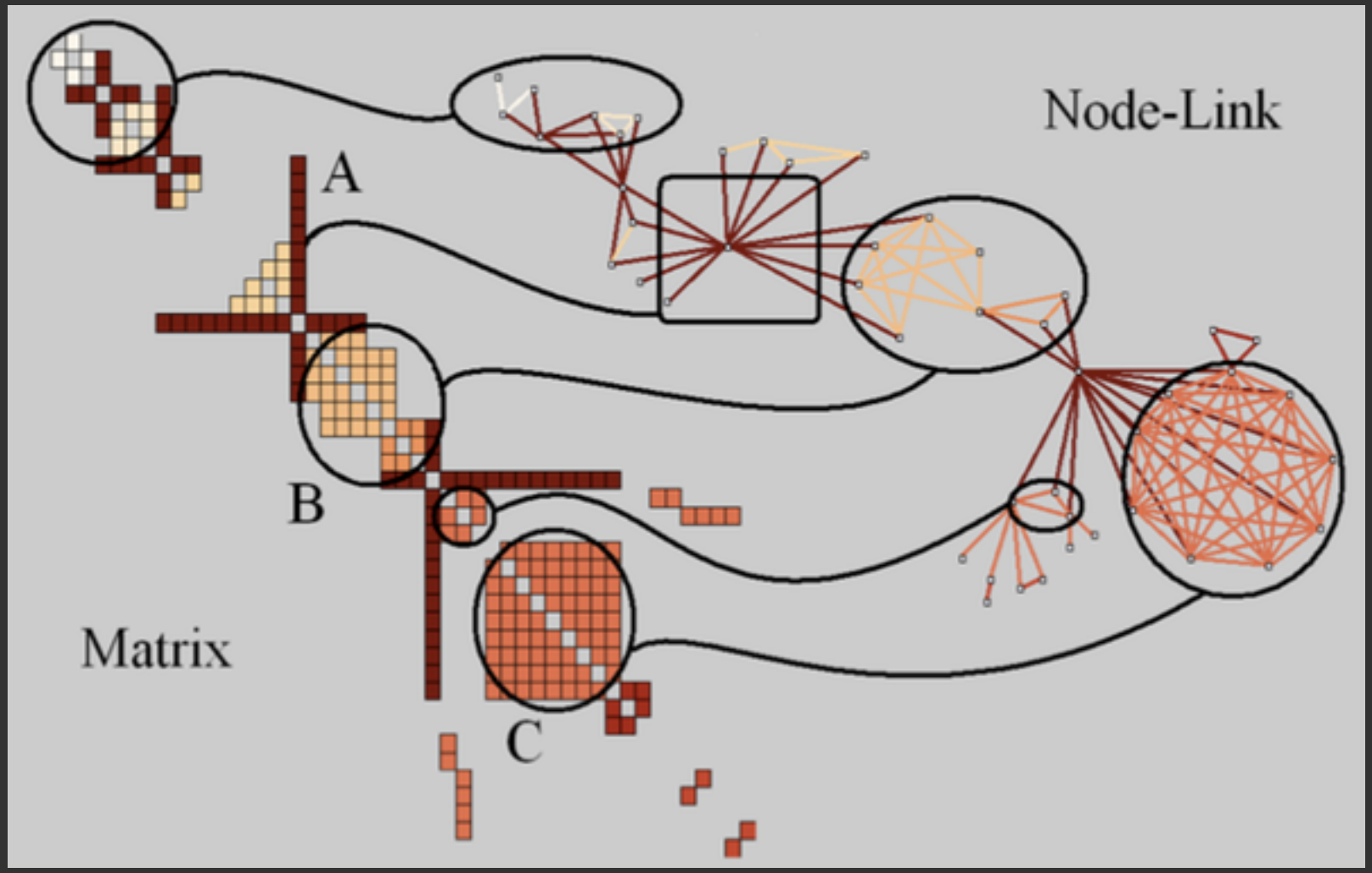
Low-level vs. high-level information

Flare Class Hierarchy & Dependency Graph



Matrix Diagrams


Fauchelevent
Gribier
MotherInnocent
CountessdeLo
Geborand
Champtercier
Mlle.Baptistine
Count
OldMan
Myriel
Mme.Magloire
Napoleon
Cravatte
Mme.deR
Isabeau
Gervais
Labarre
Valjean
Chenildieu
Brevet
Champmathieu
Judge
Woman1
Scaufflaire
Simplice
Bamatabois
Cochepaille
Listolier
Perpetue
Fantine
Zephine
Dahlia
Favourite
Blacheville
Fameuil
Tholomyes
Marguerite
Thenardier
Pontmercy
Brujon
Eponine
Anzelma
Javert
Mme.Thenardier
Montparnasse
Claquesous
Babet
Gueulemer
Woman2
Gillenormand
Magnon
Mlle.Gillenormand
Cosette
Mlle.Vaubois
Lt.Gillenormand
Toussaint
BaronessT
Mme.Pontmercy
Boulatruelle
Mme.Burgon
Jondrette
Enjolras
Courfeyrac
Bahorel
Bossuet
Joly
Grantaire
Combeferre
Mabeuf
Marius
Gavroche
Mme.Hucheloup
Prouvaire
Feuilly
MotherPlutarch
Child2
Child1



Adjacency Matrices

Graph Viewer

Graph Viewer

Roll-up by:

All

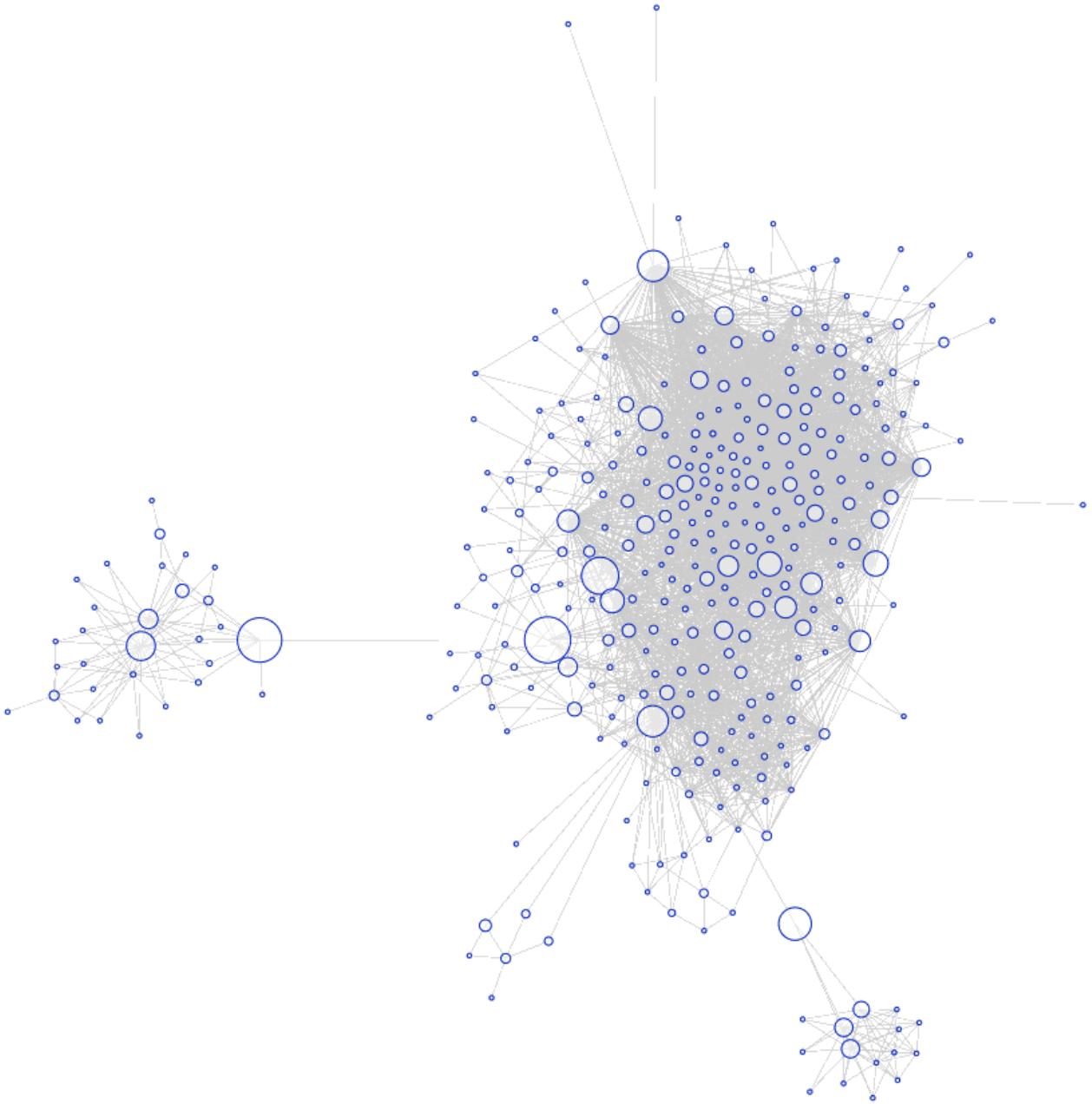
Visualization:

Node-Link

Sort by:

None

Edge centrality filters:



Images

Animate

Graph Viewer

Graph Viewer

Roll-up by:

All

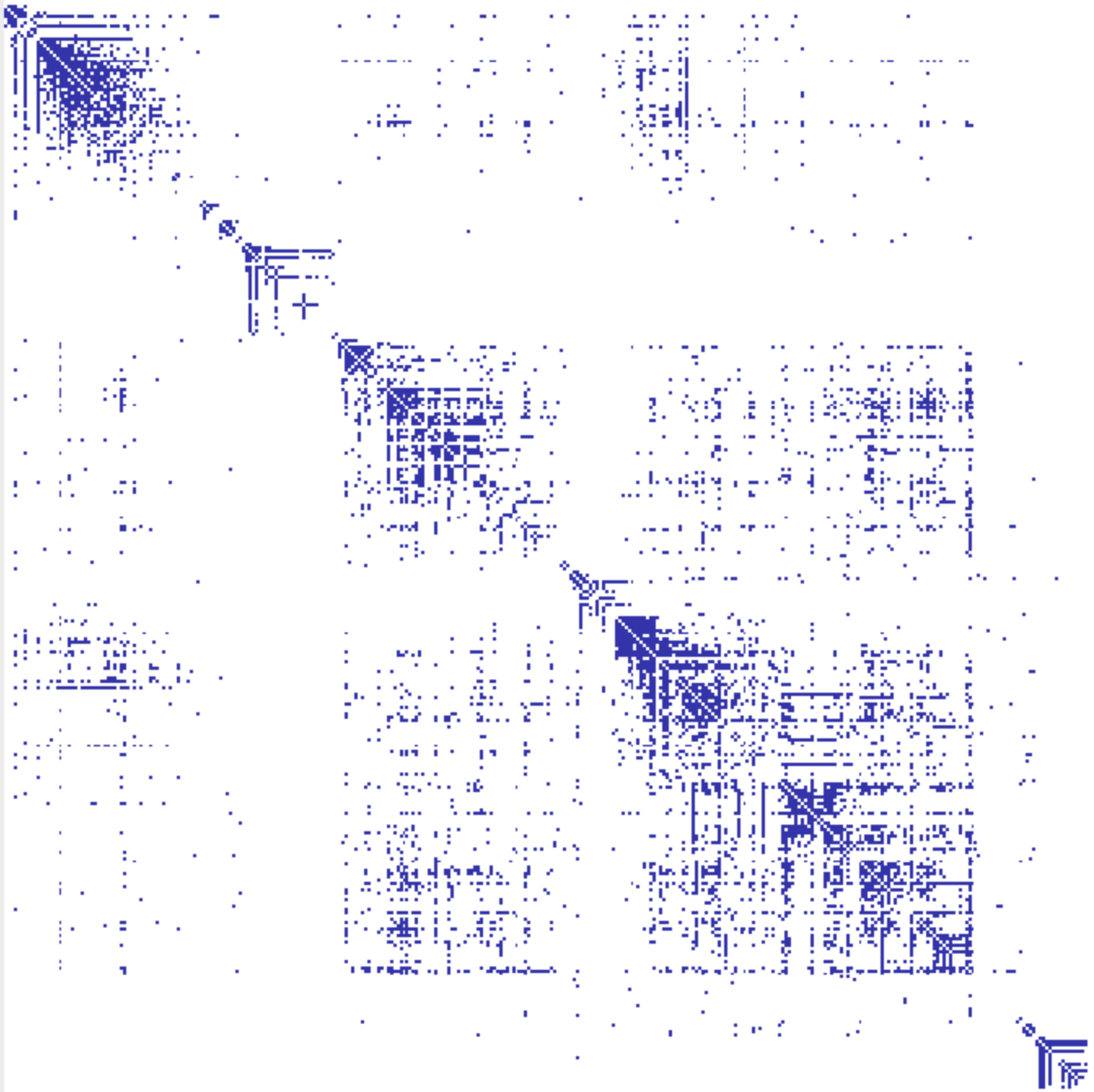
Visualization:

Matrix

Sort by:

Linkage

Edge centrality filters:



Graph Viewer

Graph Viewer

Roll-up by:

All

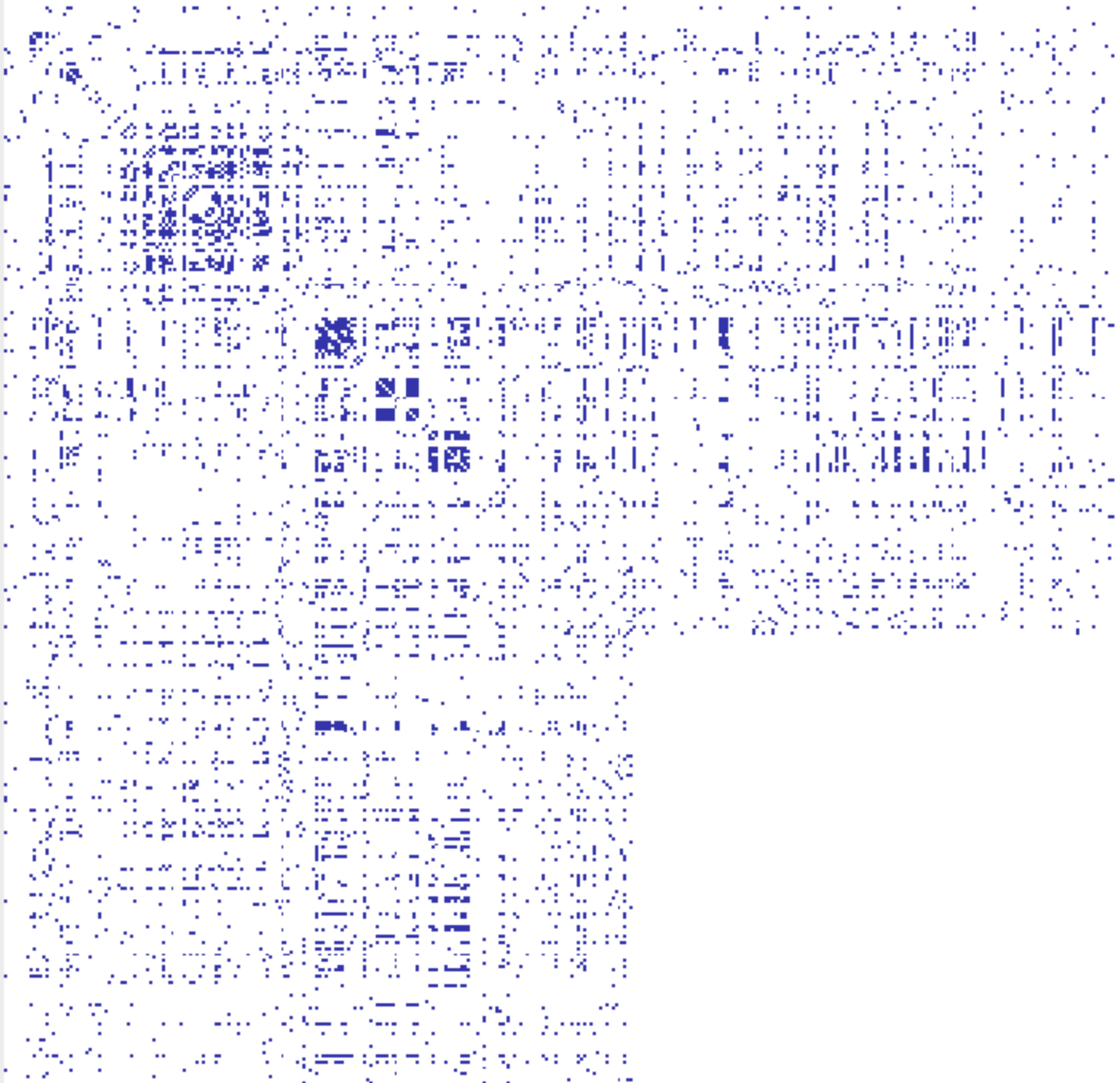
Visualization:

Matrix

Sort by:

None

Edge centrality filters:



Summary: Hierarchies & Networks

Tree Layout

Indented / Node-Link / Enclosure / Layers

Focus+Context techniques for scale

Graph Layout

“Sugiyama” Layout

Force-Directed Layout

Attribute-Driven Layout

Constraint Layout

Arc Diagrams

Matrix Diagrams

Quiz Section: Project Check In

Tomorrow, Thursday May 20th

Final Project Check In
Check in with TAs on project progress
Extra chance to ask questions / get help

Up Next: Jane's Office Hour (link on Canvas)