Cody Dunne
Northeastern University

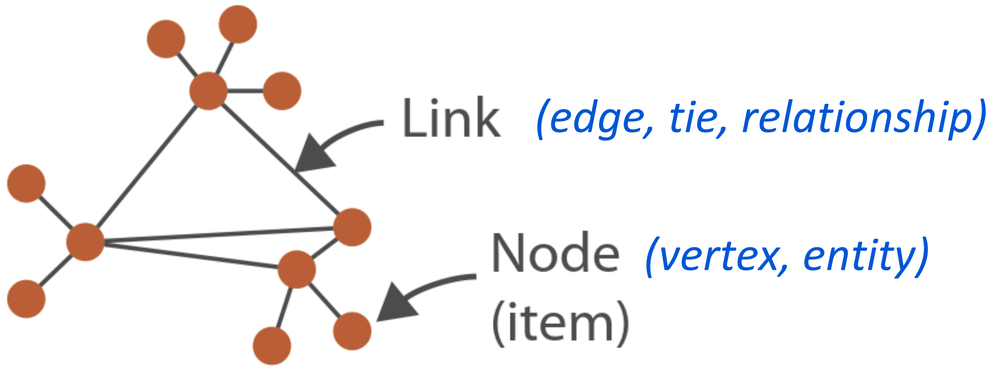
Trees & Networks

Goals for Today

- Learn the definition of a network (including node, edge)
- Learn the definition of a tree
- Learn common visual encoding techniques for network data (i.e., node-link diagram, adjacency matrix), and the advantages of each one.

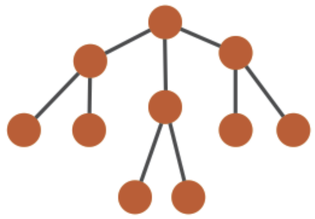
Networks

➔ Networks *(graphs)*



Network = entities and relationships between them

➔ *Trees*

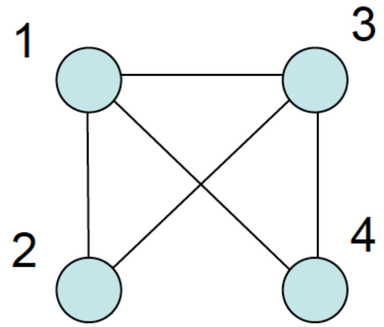


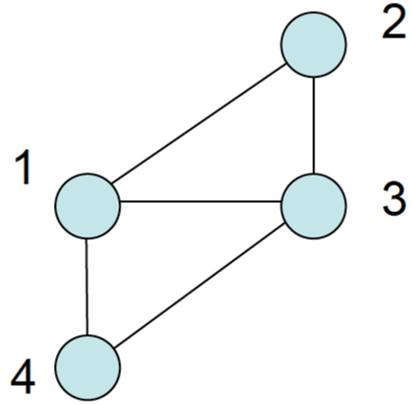
Tree = *undirected*, *connected*, *acyclic* network

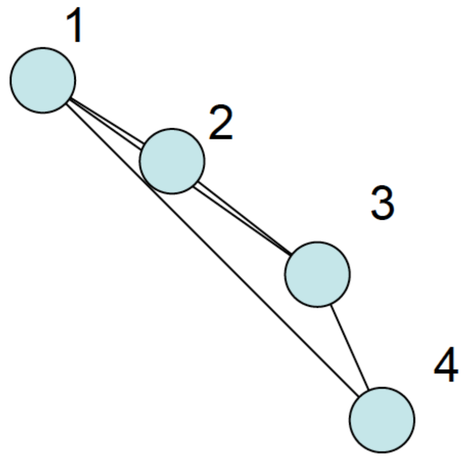
Networks

- A network *G* consists of a set of nodes *N* and a set of edges *E*
- An edge $e_{n1,n2} \in E$ connects two nodes *n1*, *n2* ∈ *N*
- E.g., *G* = {1,2,3,4}, *E* = {(*1*,*2*),(*1*,*3*), (*2*,*3*),(*3*,*4*),(*4*,*1*)}

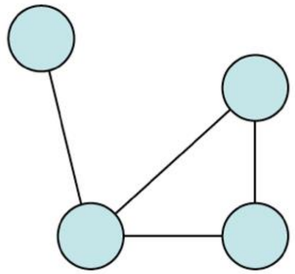
Note all the same network, just different layouts!



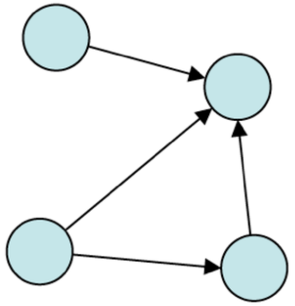




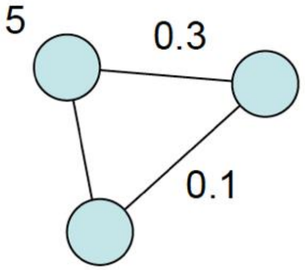
A bunch of definitions



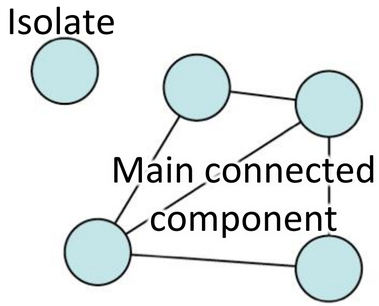
An undirected graph



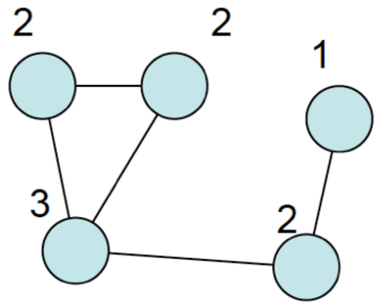
A directed graph



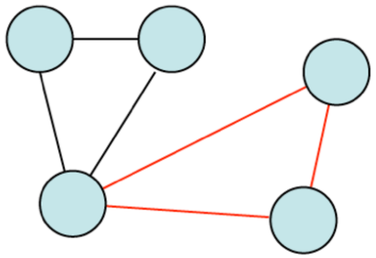
Weighted



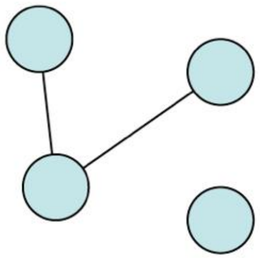
Unconnected



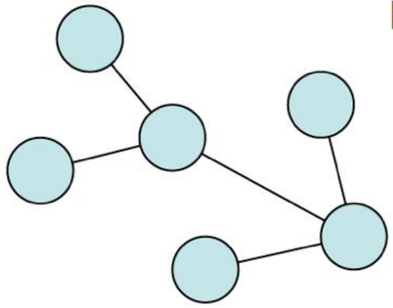
Node degrees



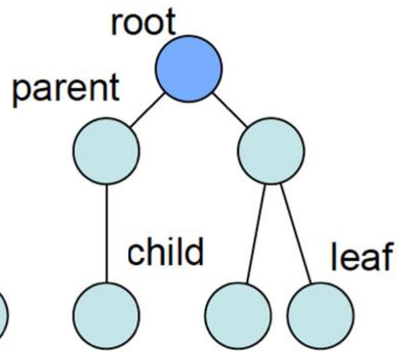
A cycle



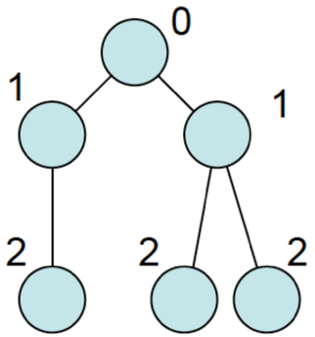
An acyclic graph



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



A rooted tree or hierarchy



Node depths

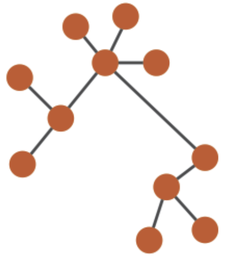
Modified from slide by Frank van Ham

Arrange Networks and Trees

Node–Link Diagrams

Connection Marks

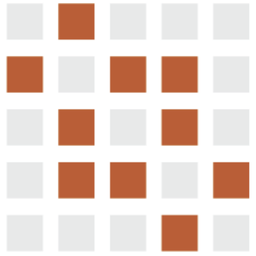
✔ NETWORKS ✔ TREES



Adjacency Matrix

Derived Table

✔ NETWORKS ✔ TREES



Enclosure

Containment Marks

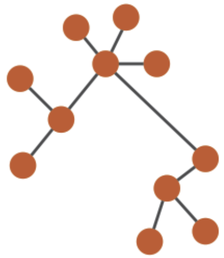
✘ NETWORKS ✔ TREES

"Treemap"

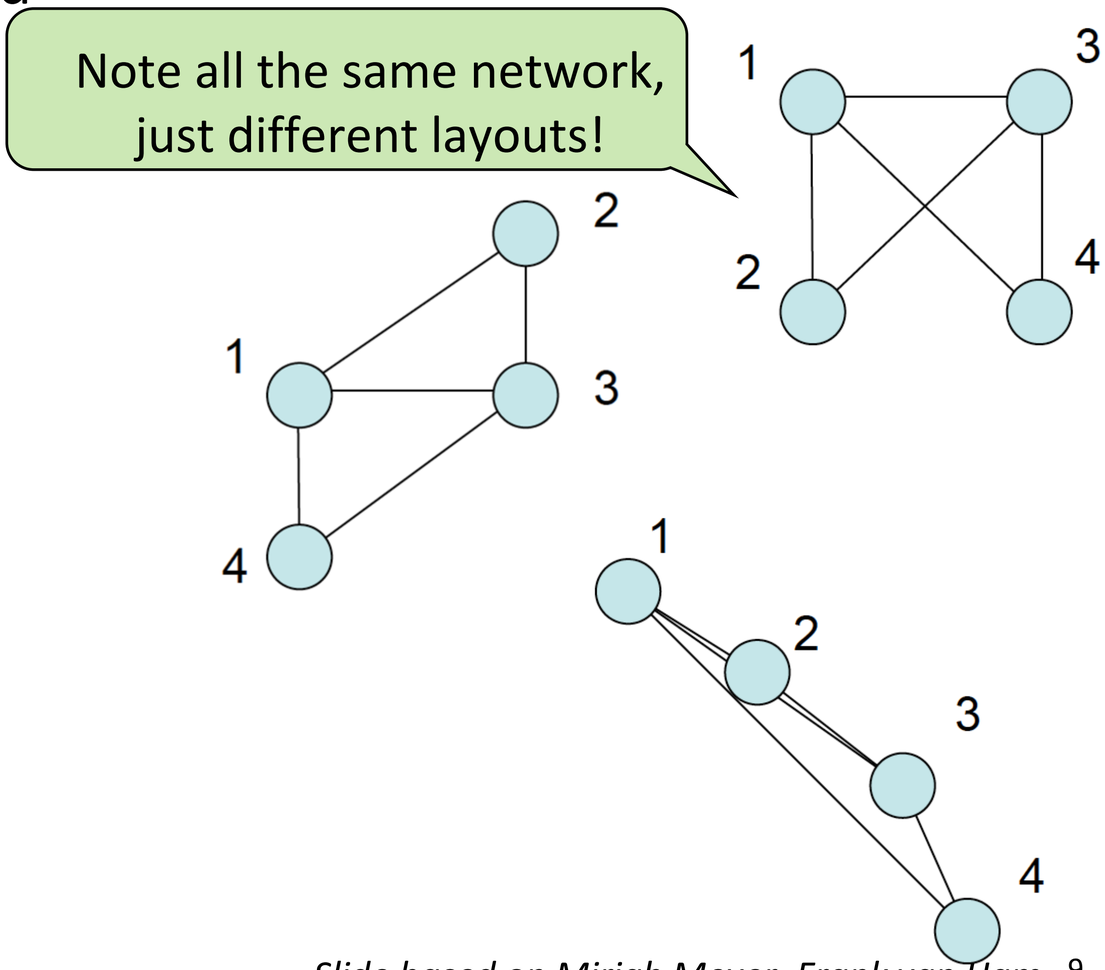
Node–Link Diagrams

Connection Marks

✔ NETWORKS ✔ TREES



- Primary concern is the *spatial layout* of nodes and edges, a.k.a. *graph drawing*
- The goal is often to effectively depict the graph structure for *topology-based tasks*:
  - connectivity, path-following
  - network distance
  - clustering
  - ordering (e.g., hierarchy level)
- But not always topology-based tasks. E.g., understanding attributes, statistics, metrics

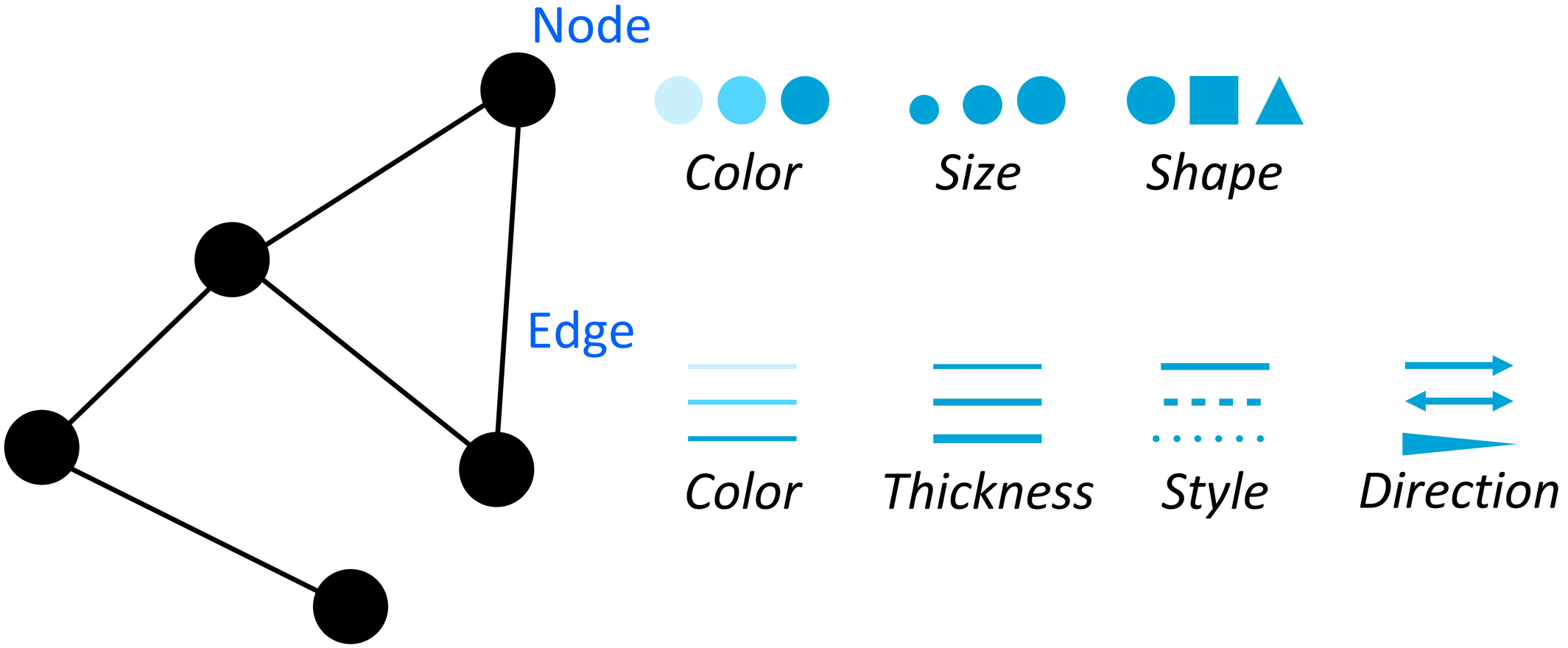


Slide based on Miriah Meyer, Frank van Ham

In-Class Algorithms—Planarity

~16 min

Marks & Channels



Hall of Fame?

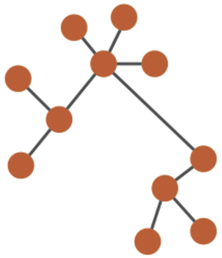
or

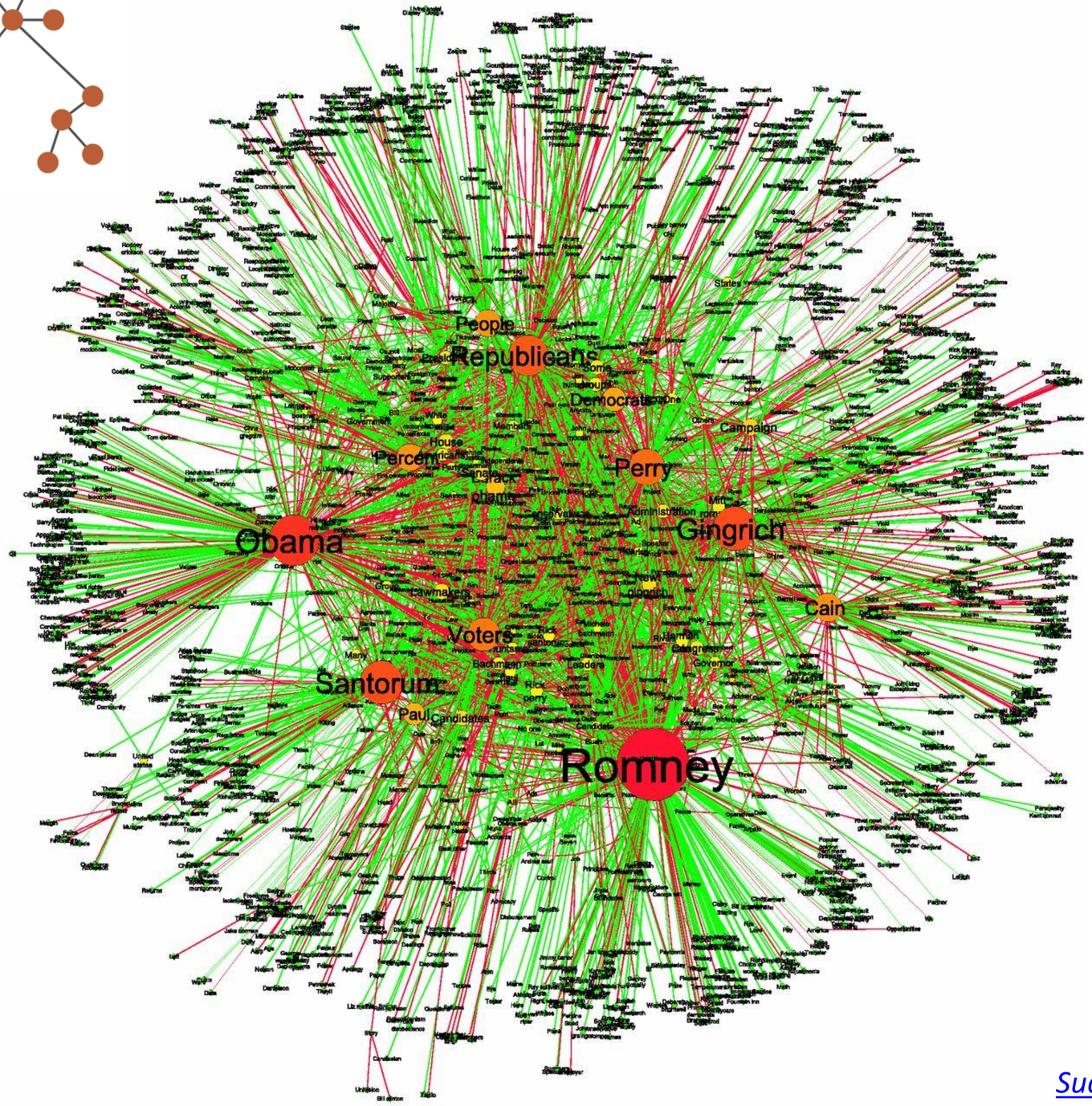
Hall of Shame?

Node–Link Diagrams

Connection Marks

✔ NETWORKS ✔ TREES





US presidential election network for 2012 primaries.

- Nodes: key entities from noun phrases. Sized by degree.

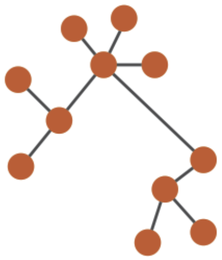
- Edges: relationships from verbs. Colored by positive (green) and negative (red) weights.

[Sudhahar et al., 2015]

Node–Link Diagrams

Connection Marks

✔ NETWORKS ✔ TREES



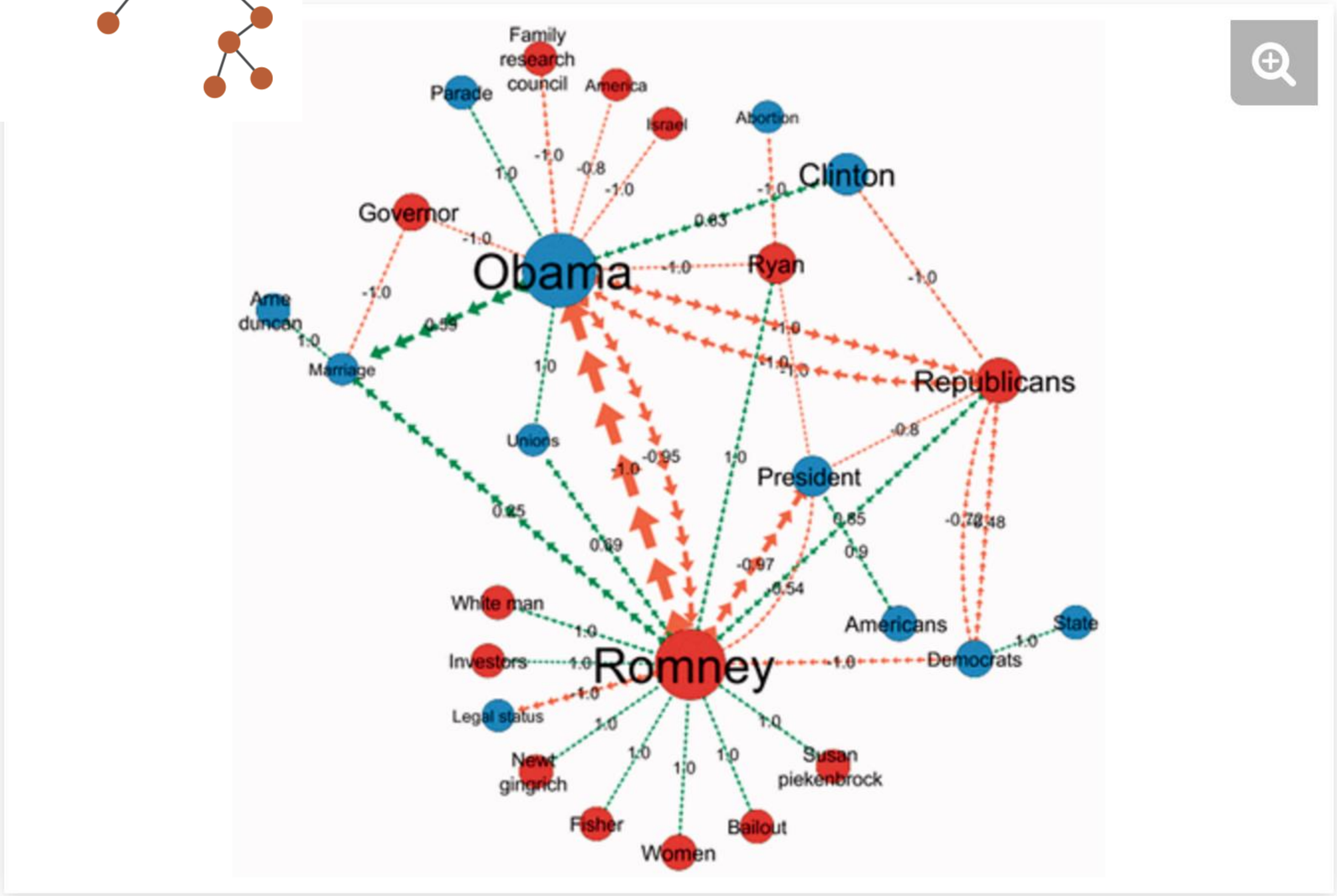


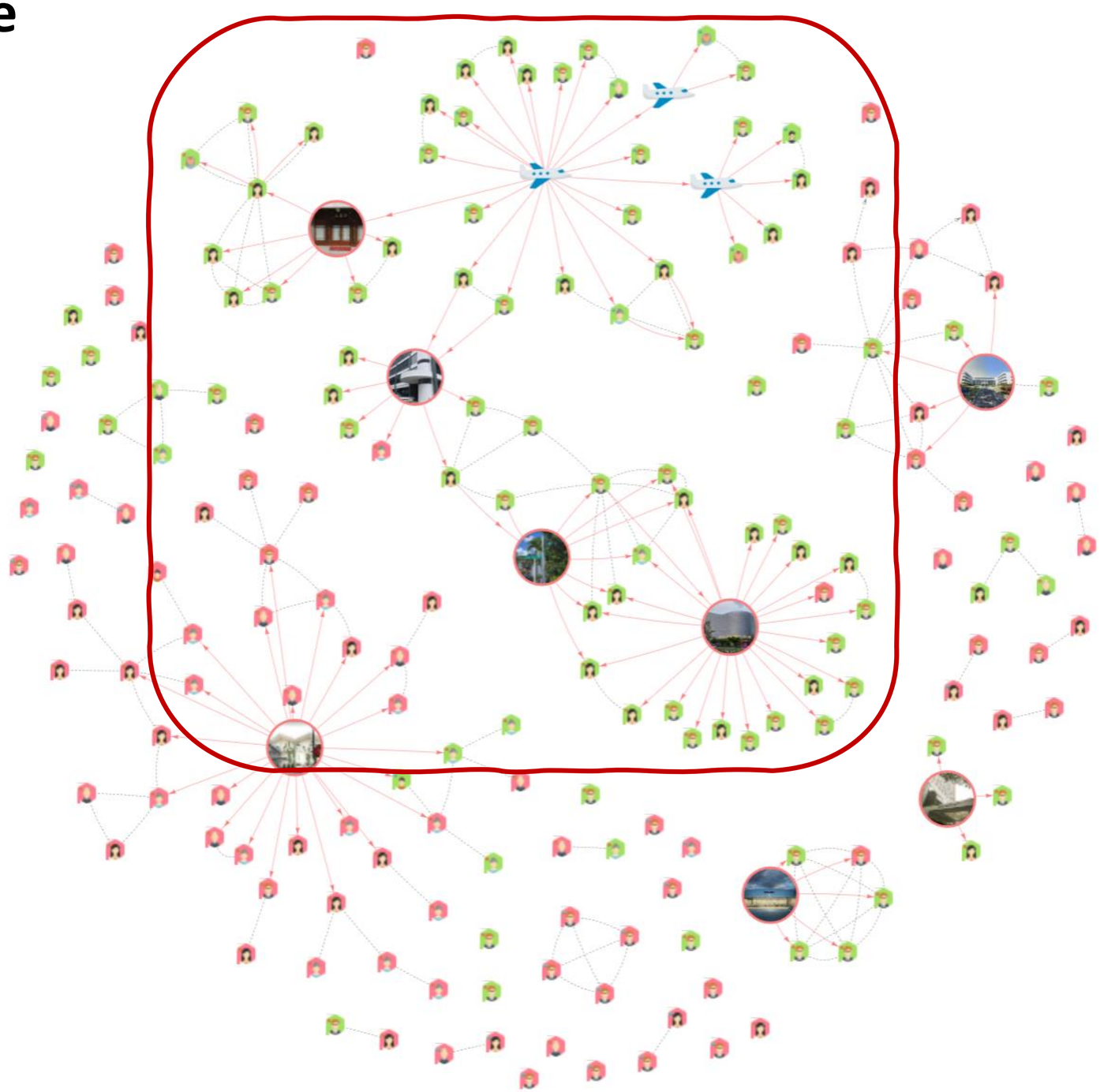
Figure 4. **Download figure** | **Open in new tab** | **Download powerpoint**

A subset of the election network, coloured by partitioning it via the first eigenvalue of the symmetrised adjacency matrix (see Appendix A8). Note that the split captures well the expected distinction between the Republican (red) and Democratic (blue) camps. The orange and green links show negative and positive relations between entities.

Sudhahar et al., 2015

Dashboard of the COVID-19 Virus Outbreak in Singapore

2020-01-21 – 03-12



[Upcode, 2020](#)

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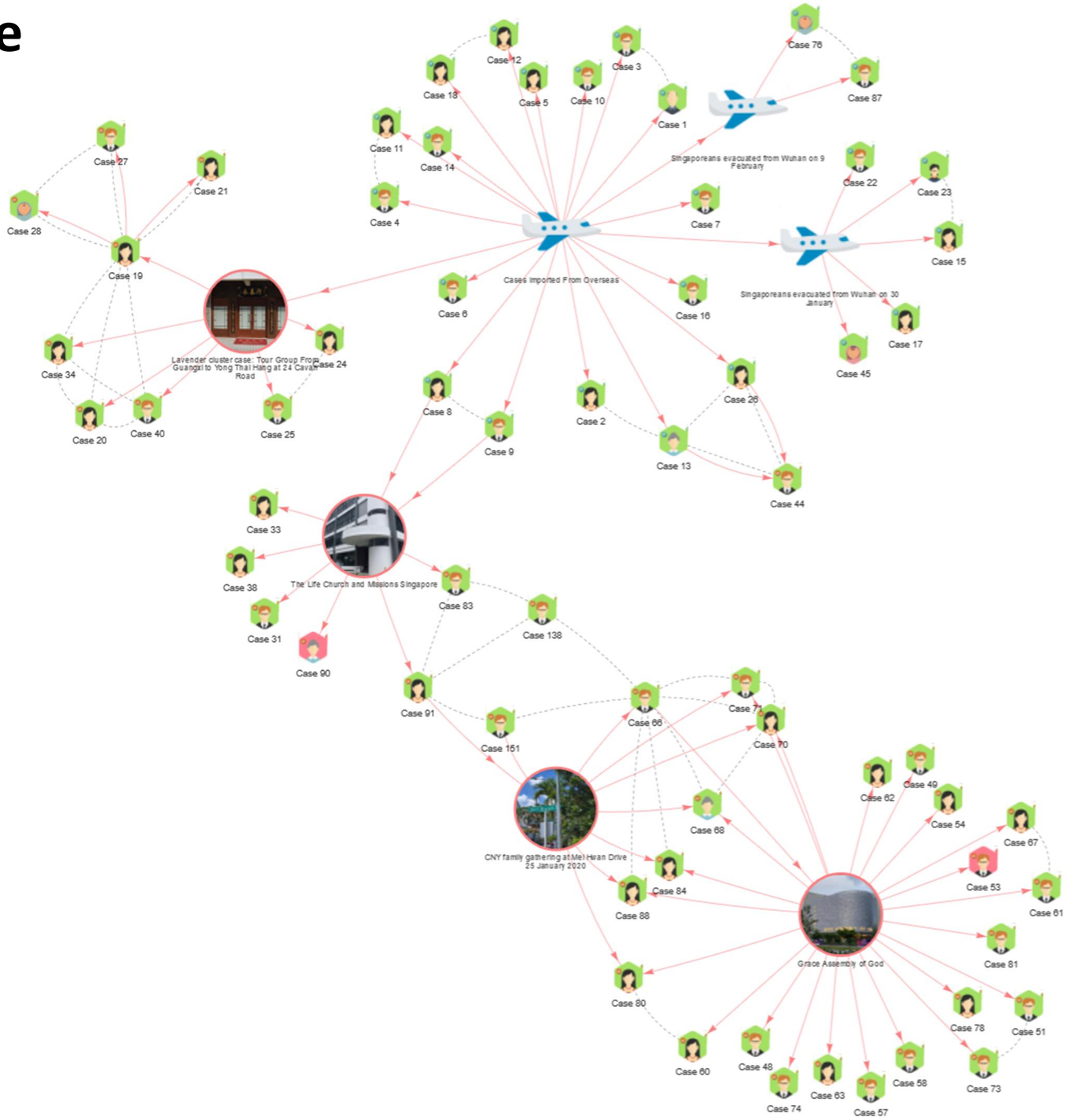
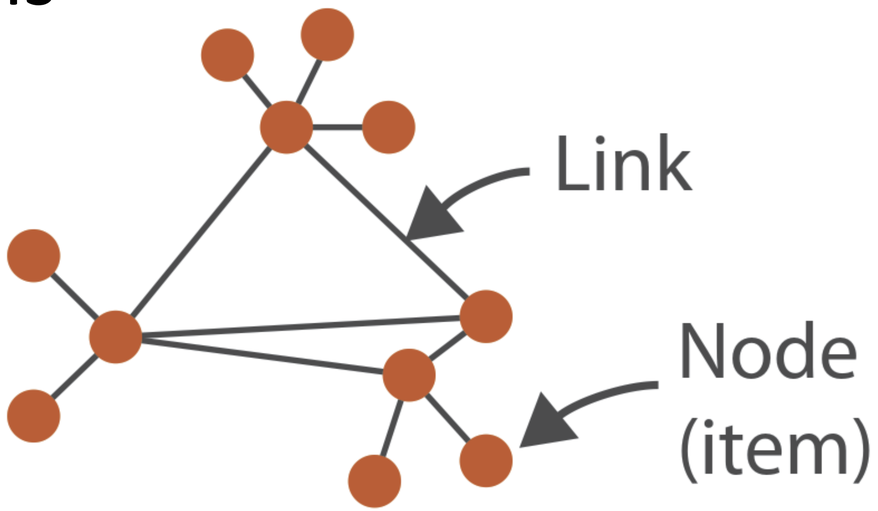


Node-Link Visualizations

Pros:

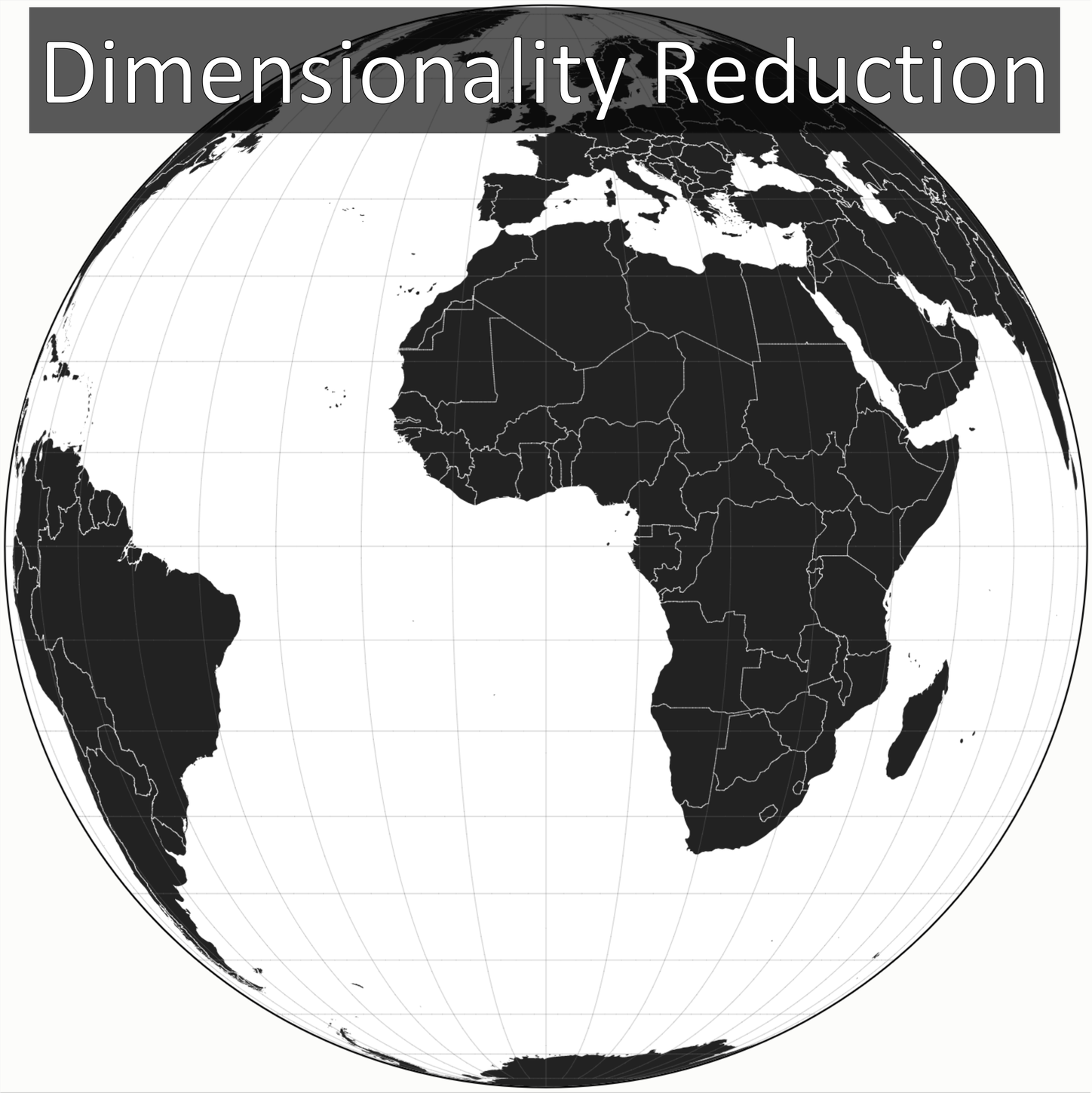
- understandable visual mapping
- can show overall structure, clusters, paths
- flexible, many variations



Cons:

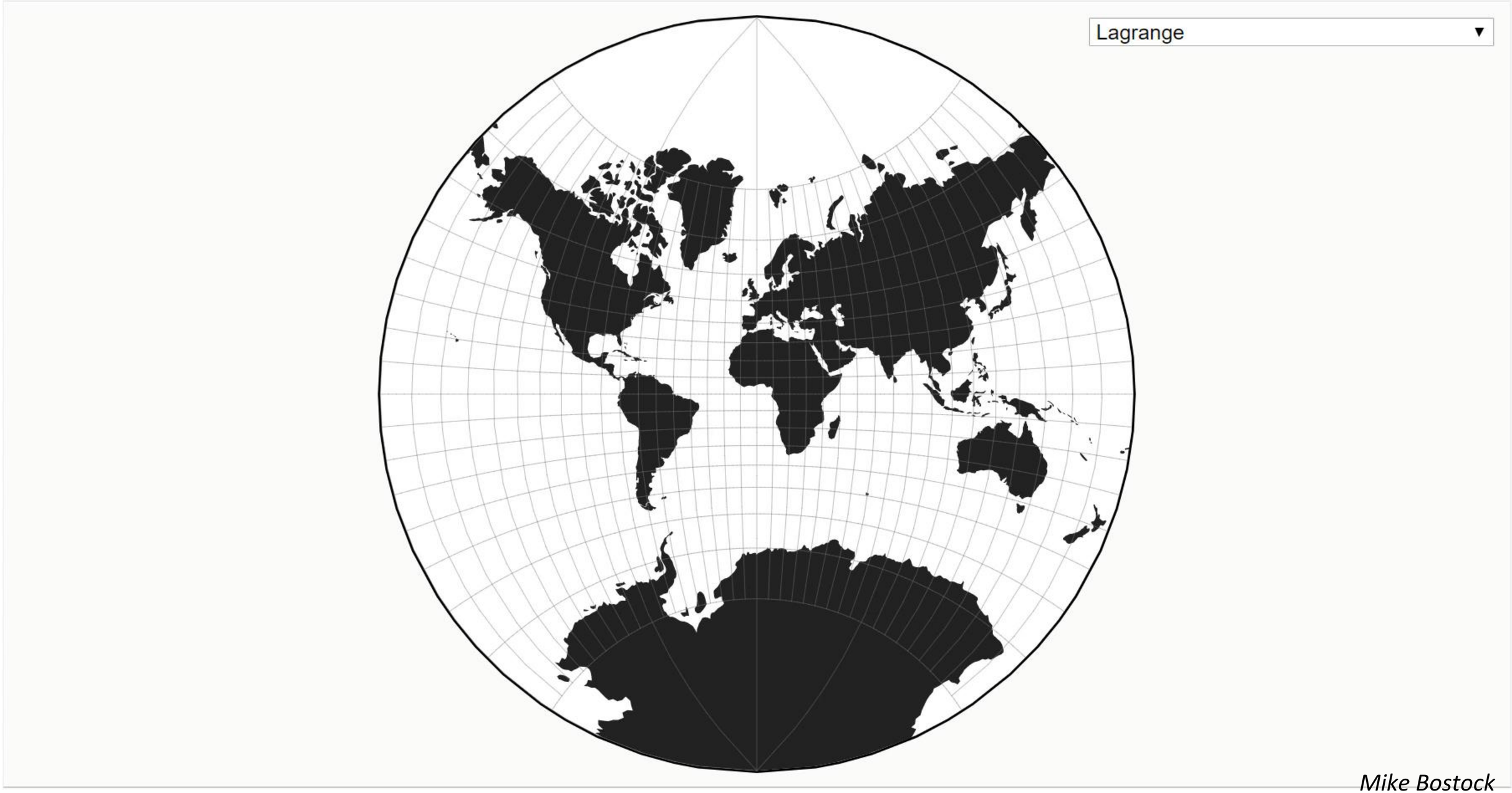
- automatic layout algorithm deficiencies
  - -time consuming to run
  - -non-deterministic results
  - -heuristics with sometimes poor results
- not good for dense graphs - hairball problem!

Dimensionality Reduction



Mike Bostock

Projection Transitions

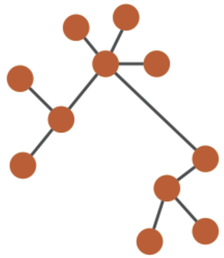


Mike Bostock

Node–Link Diagrams

Connection Marks

✔ NETWORKS ✔ TREES



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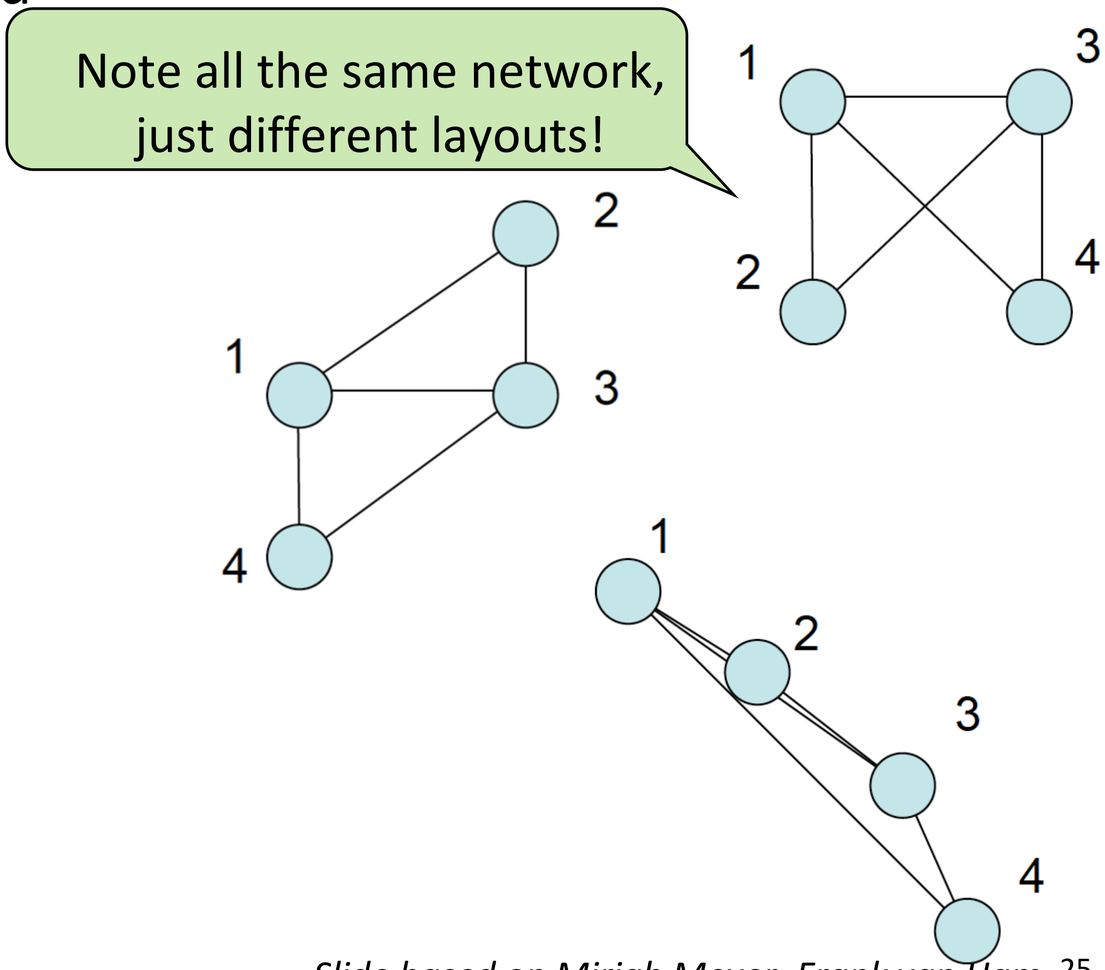
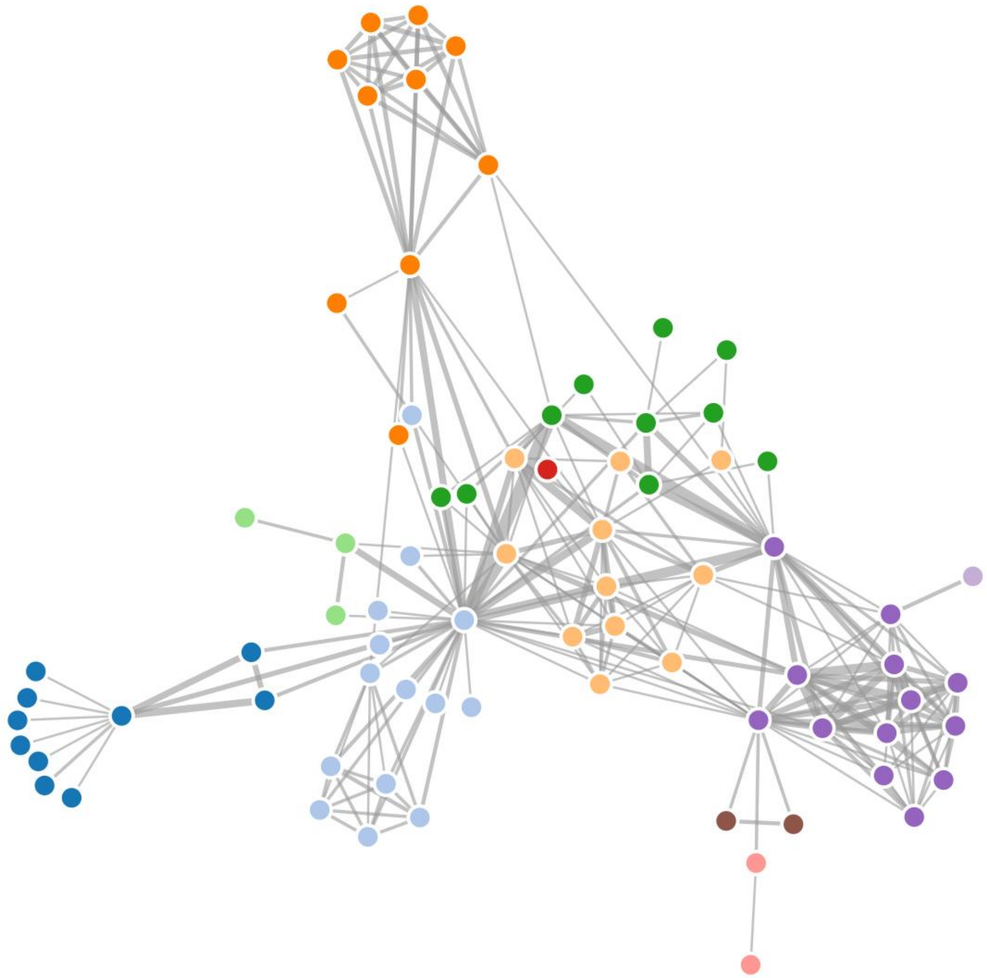


D3 Force-Directed Layout



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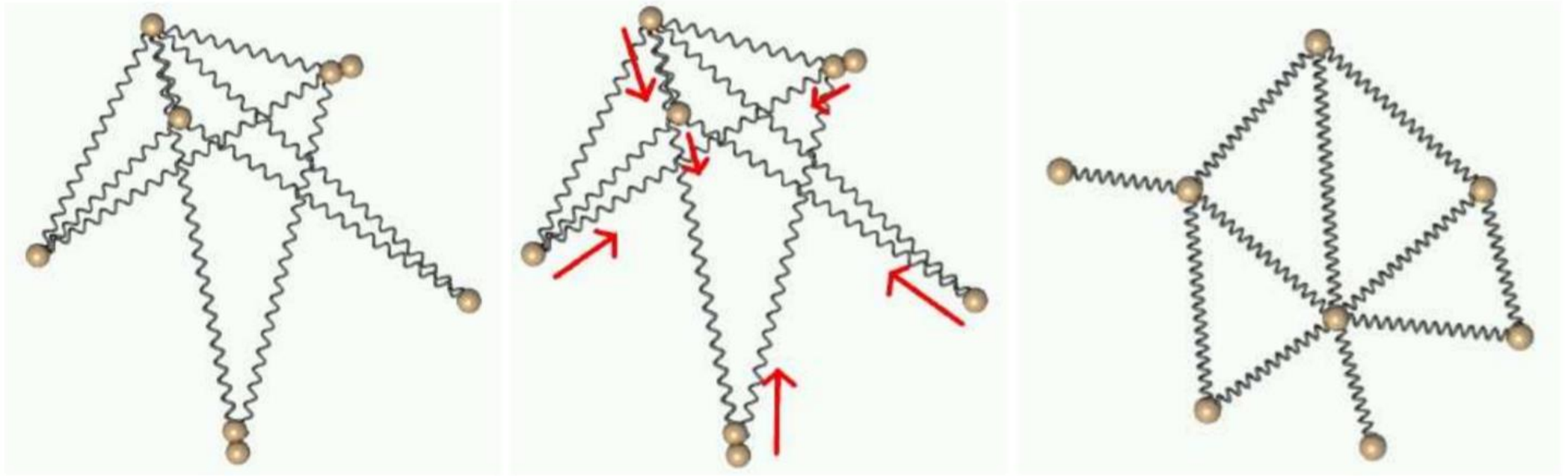
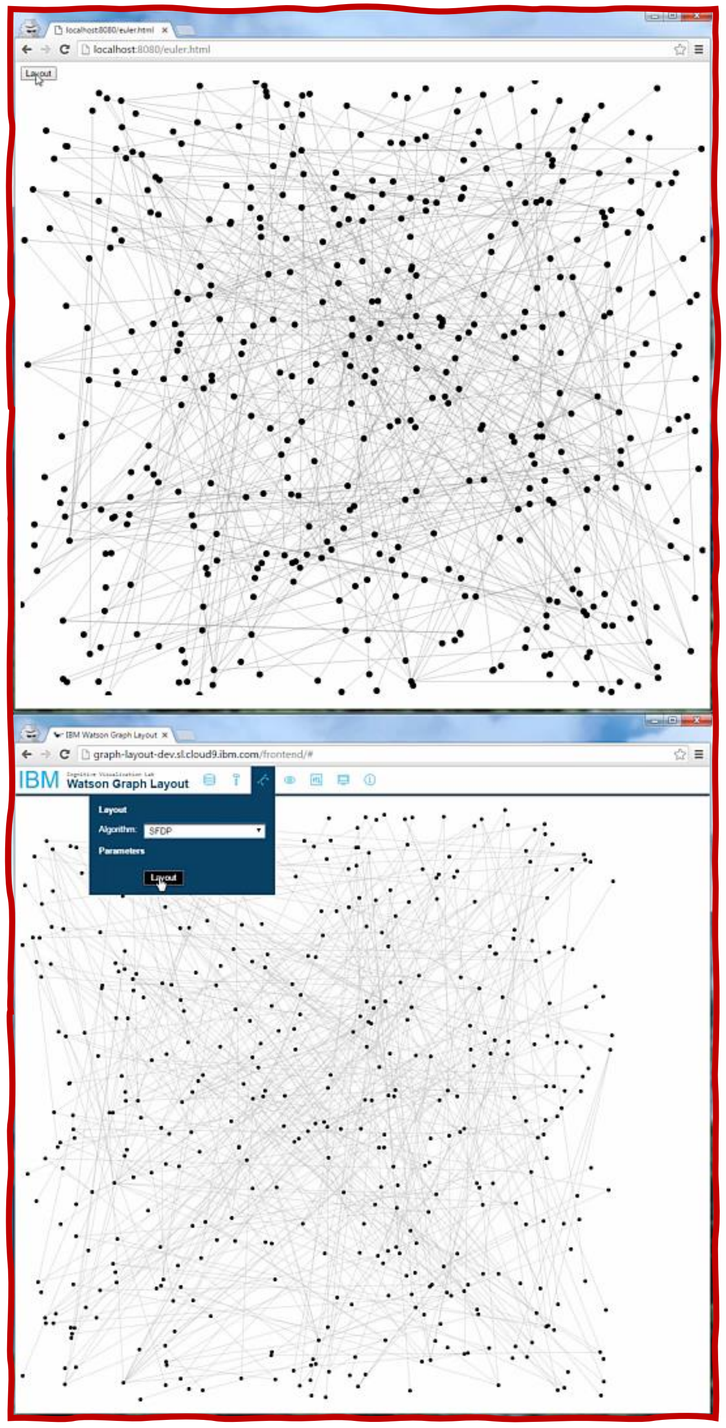
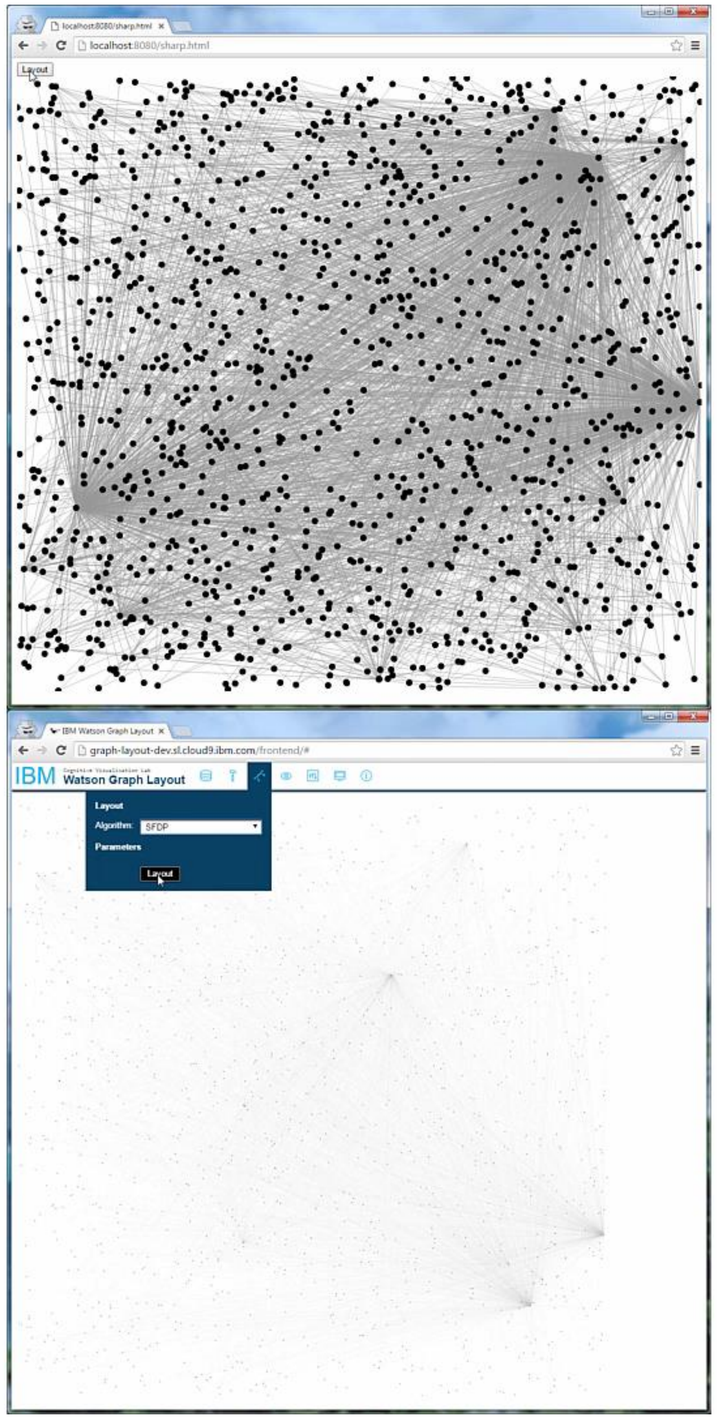
Force-Directed Algorithms



[Kobourov, 2012]


localhost:8080/euler.html
localhost:8080/euler.html
Layout
IBM Watson Graph Layout
graph-layout-dev.sl.cloud9.ibm.com/frontend/#
IBM
Cognitive Visualization Lab
Watson Graph Layout
Layout
Algorithm:
SFDP
Parameters
Layout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IBM
Cognitive Visualization Lab
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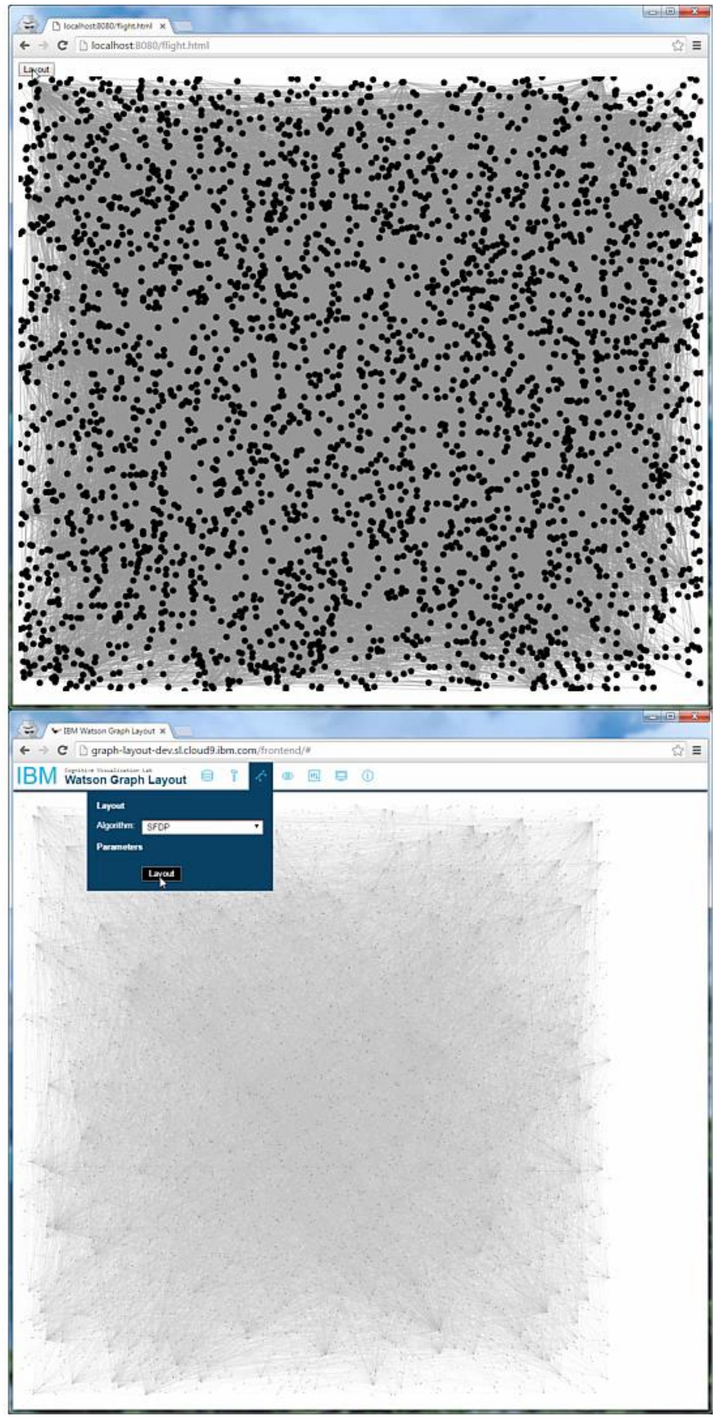
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IBM Watson Graph Layout
graph-layout-dev.sl.cloud9.ibm.com/frontend/#
IBM
Cognitive Visualization Lab
Watson Graph Layout
Layout
Algorithm:
SFDP
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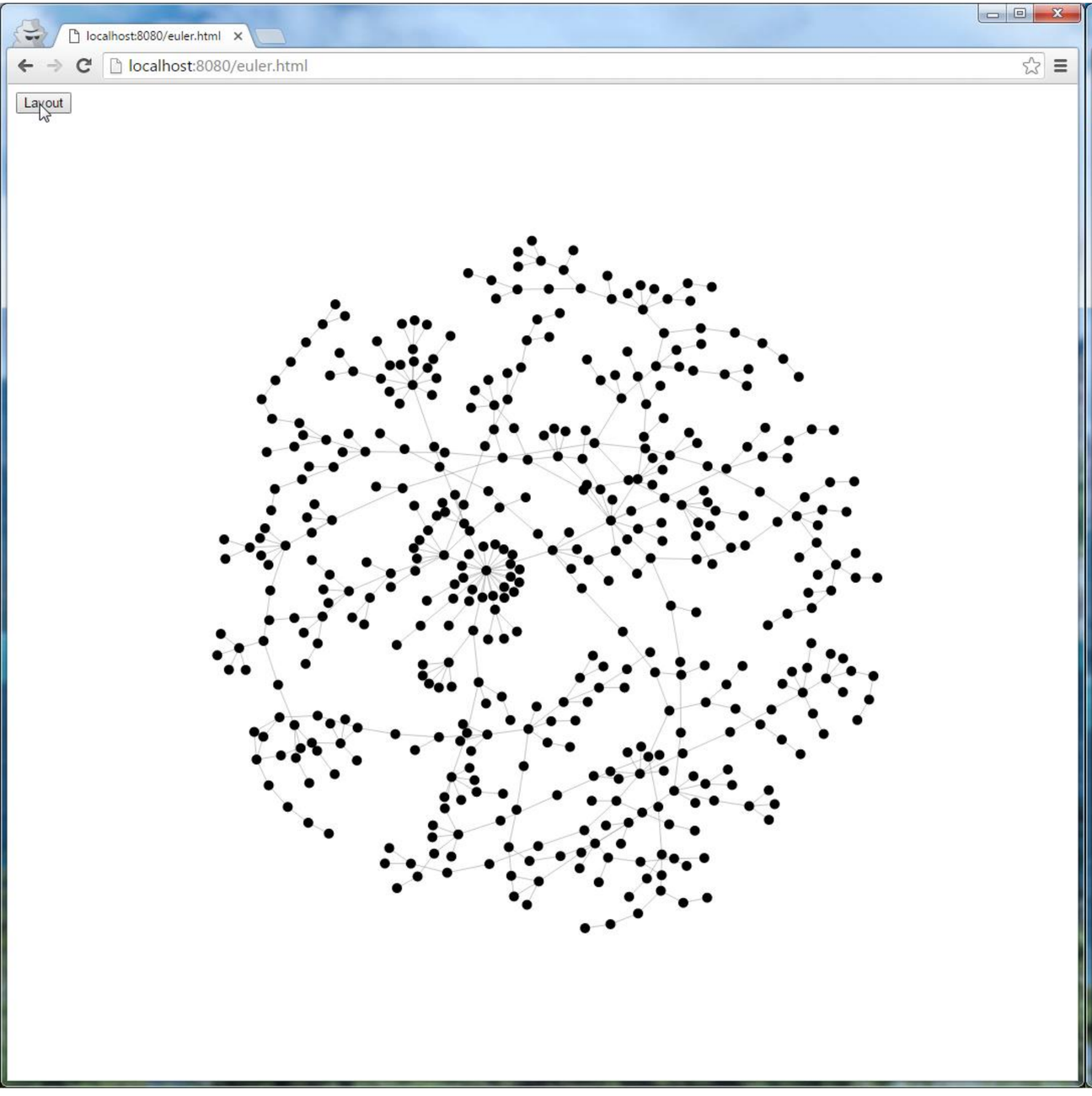
Layout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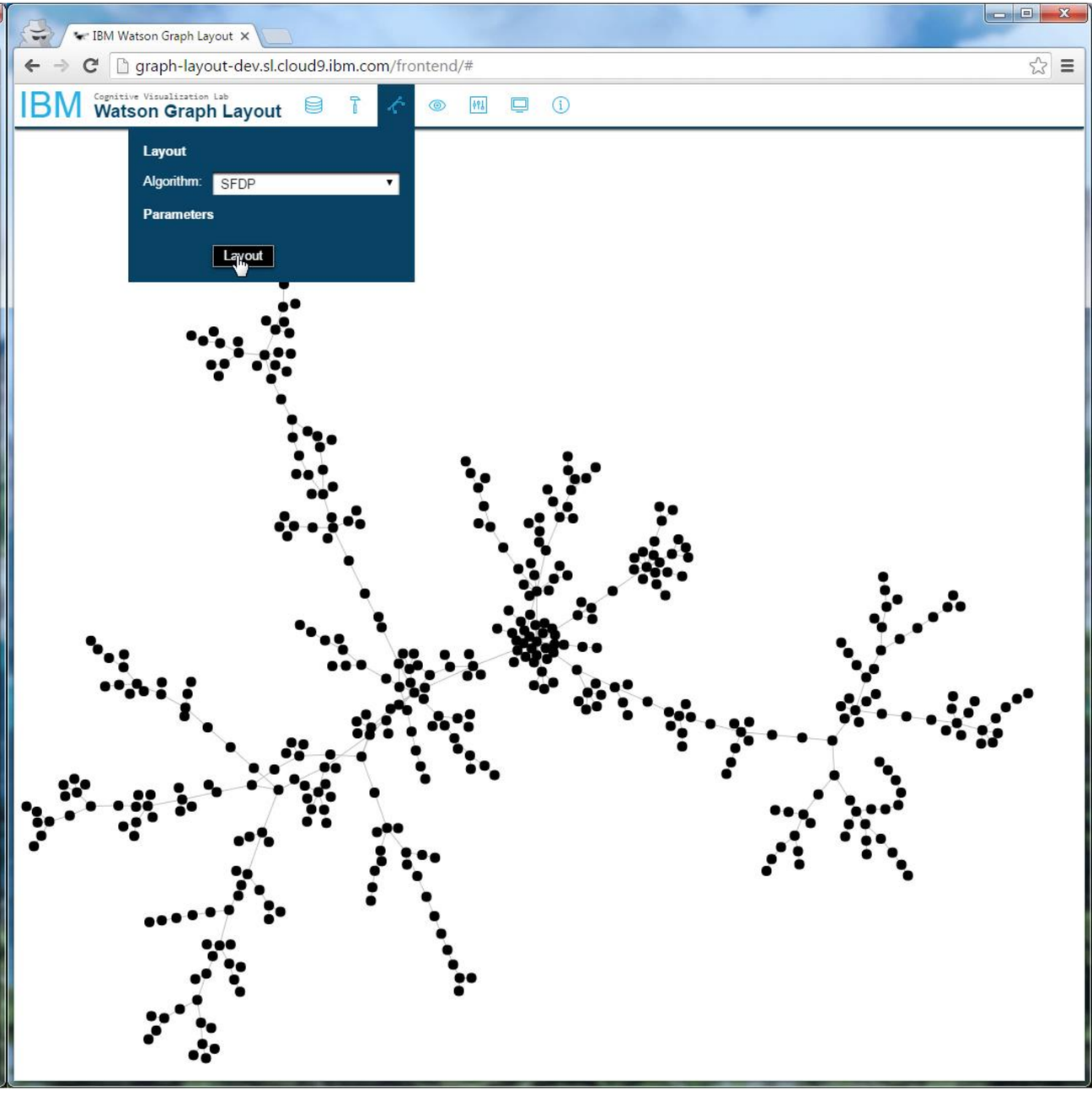
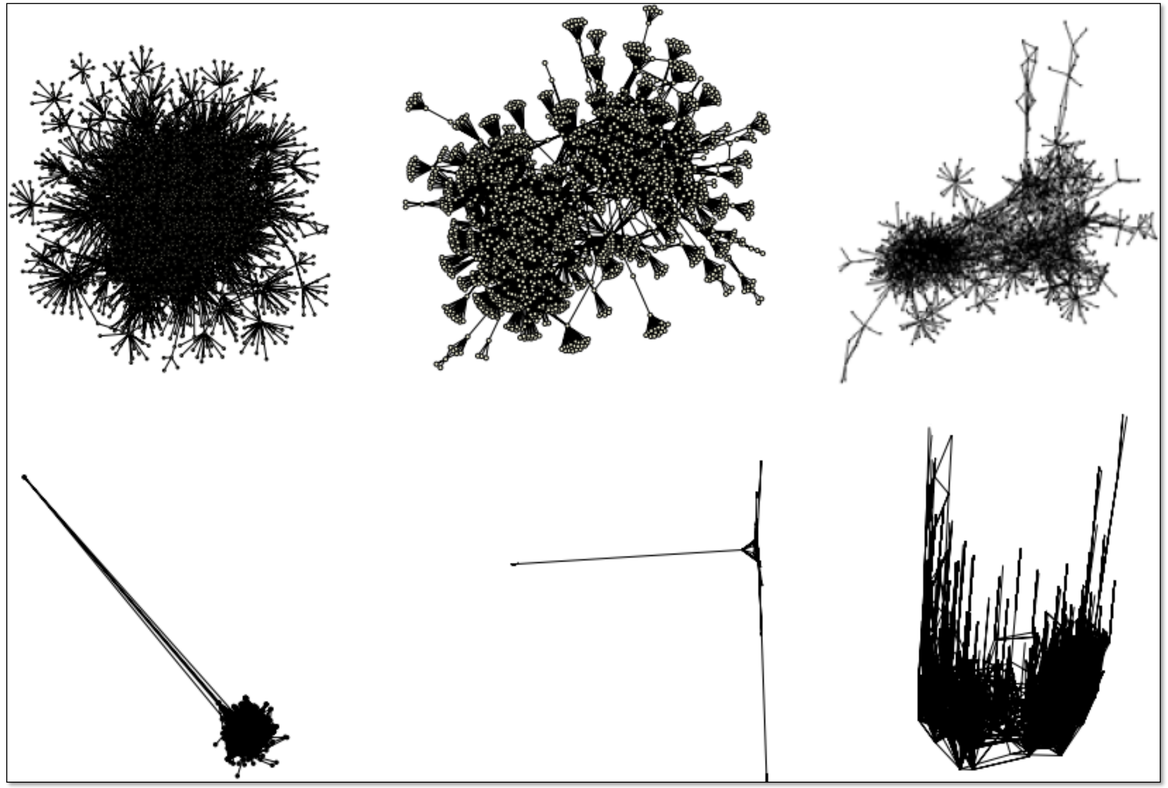
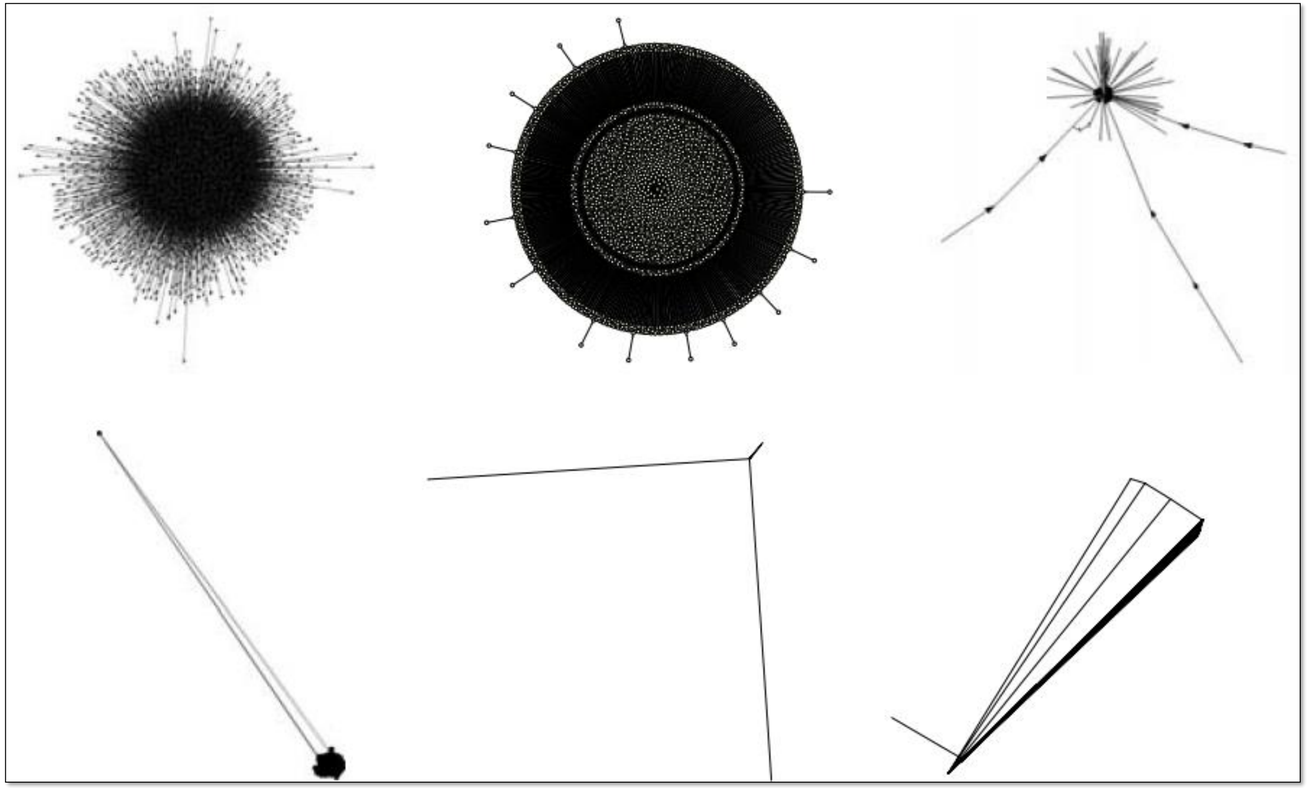

IBM Watson Graph Layout
graph-layout-dev.sl.cloud9.ibm.com/frontend/#
IBM
Cognitive Visualization Lab
Watson Graph Layout
Layout
Algorithm:
SFDP
Parameters
Layout

Algorithm Comparisons

Graph A



Graph B



Hachul & Jünger, 2006

How to compare?

User performance,
controlled experiments

Huang et al., 2007, etc.

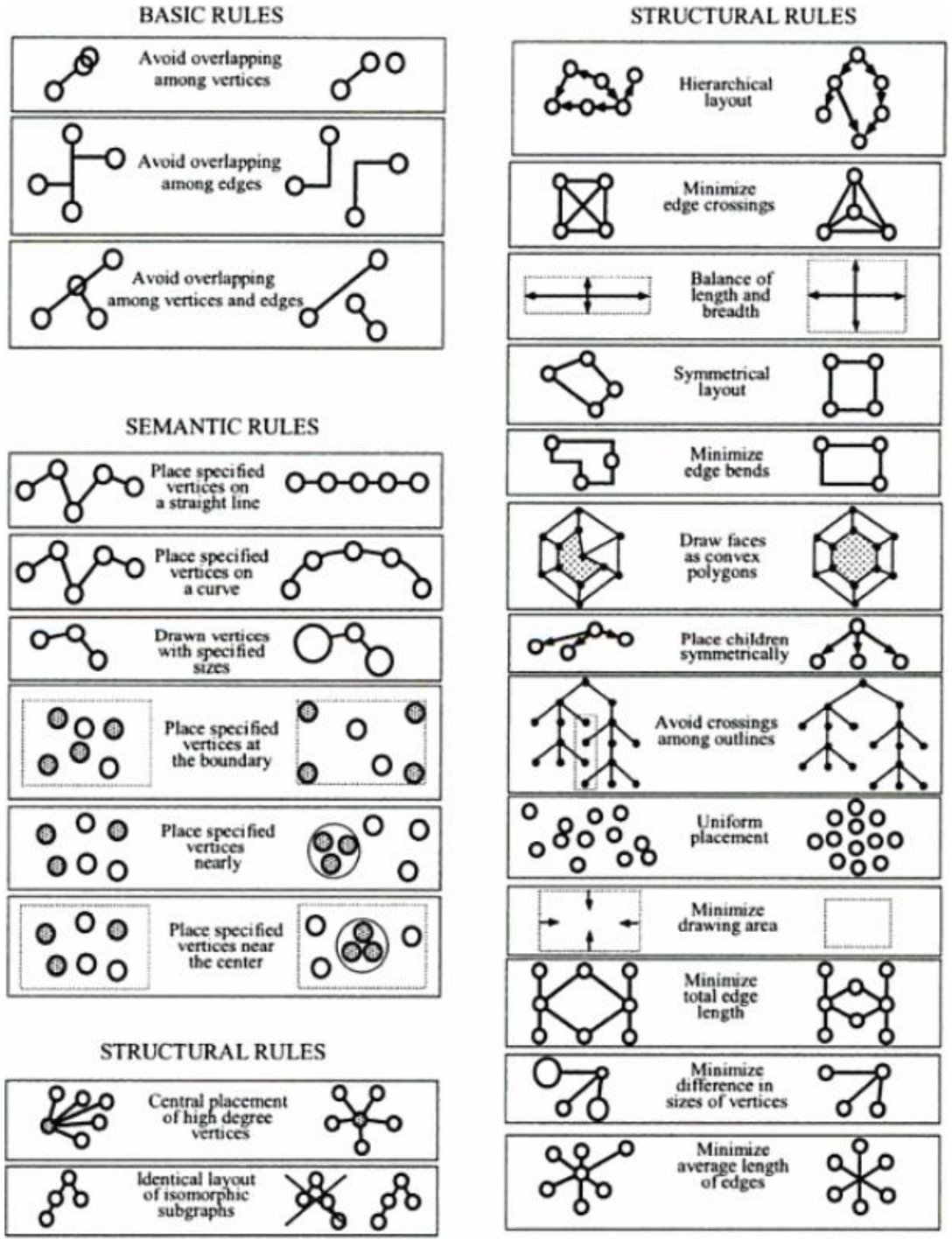
Simple rules or heuristics

Davidson & Harel, 1996

Global and local readability metrics

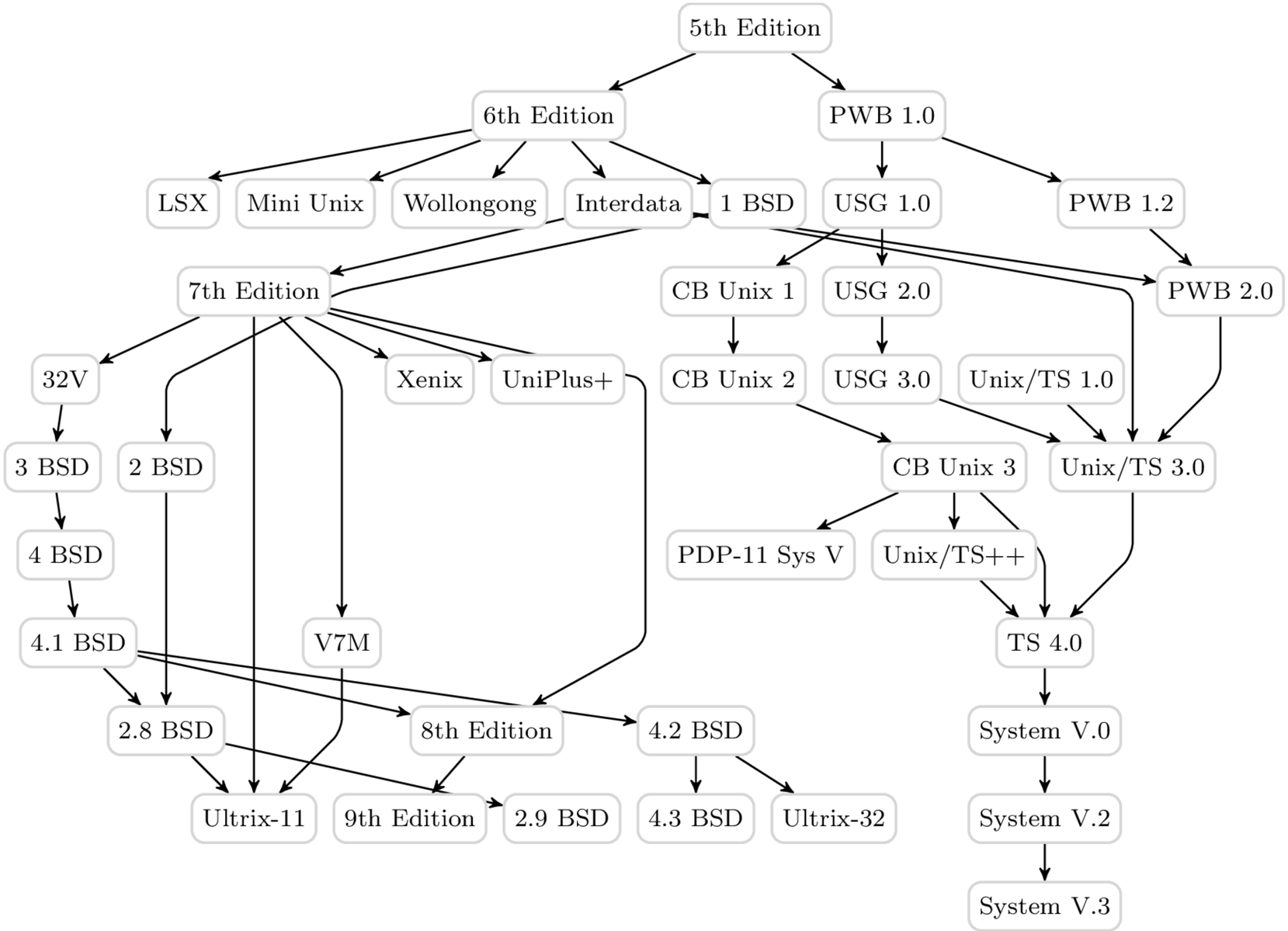
Purchase et al., 2002

Dunne et al., 2015

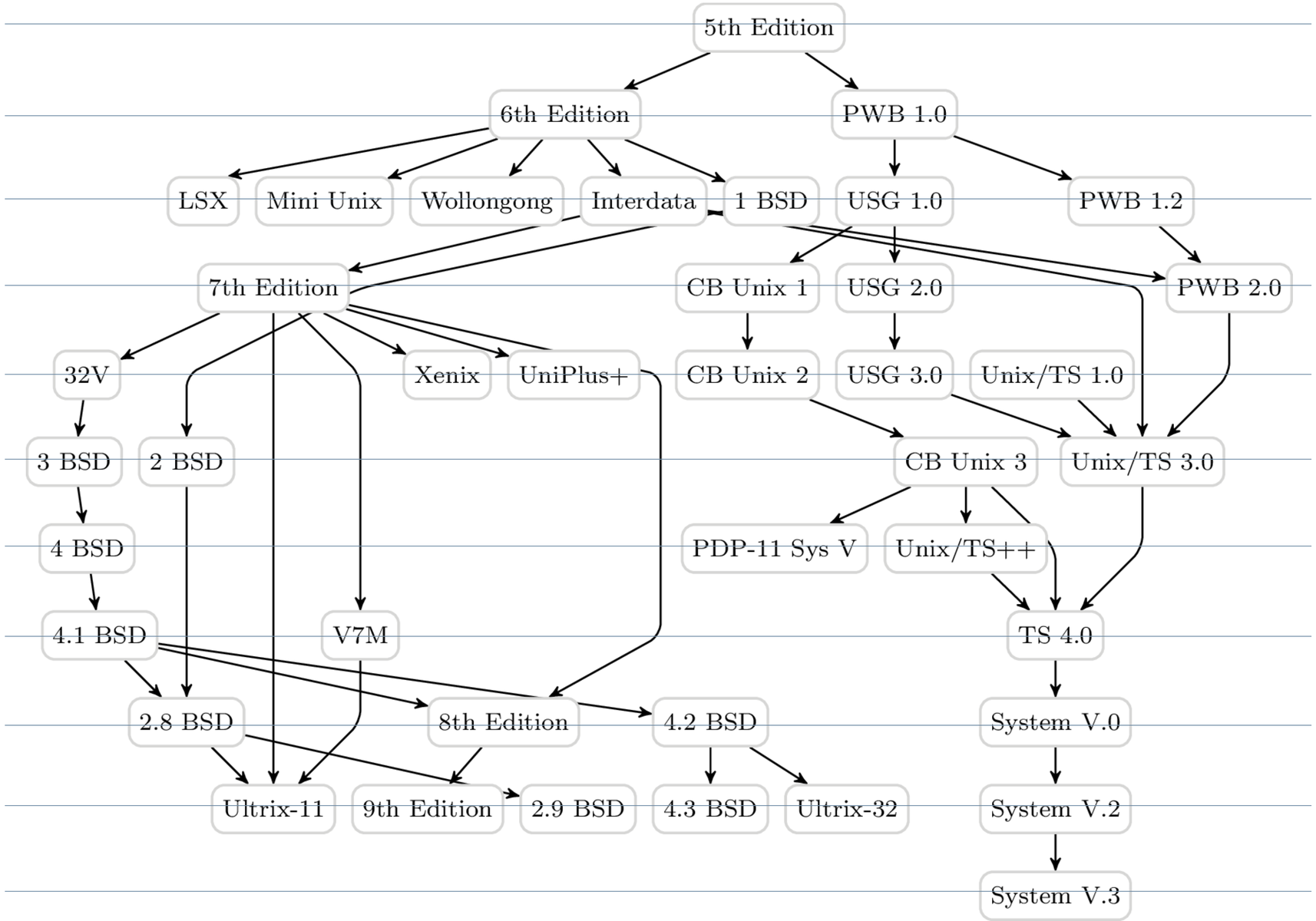


Sugiyama, 2002, p. 14

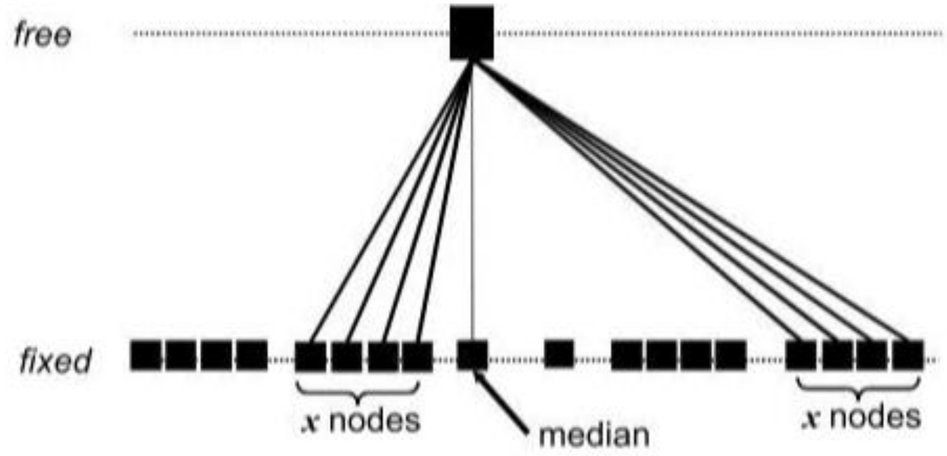
Rooted trees / layered graph drawing

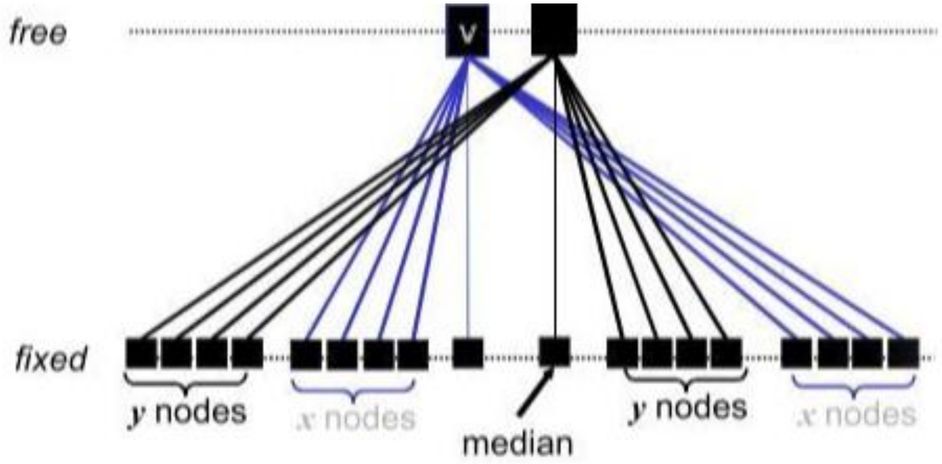


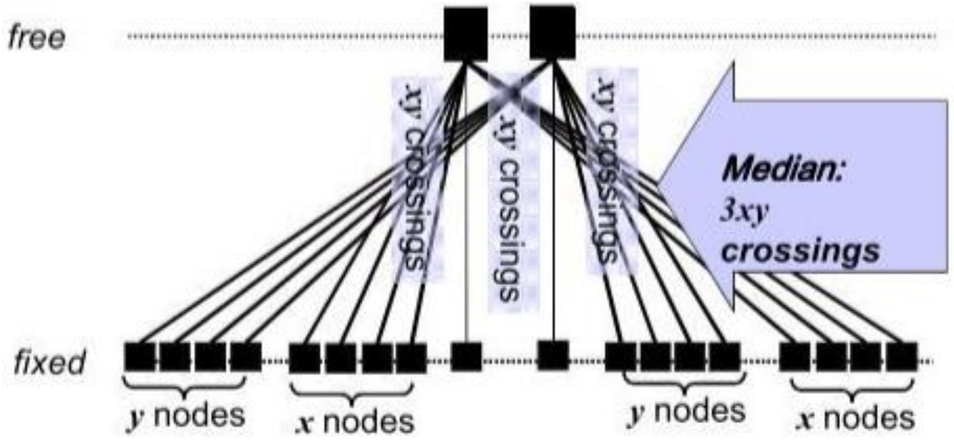
Back-and-Forth Sweeps

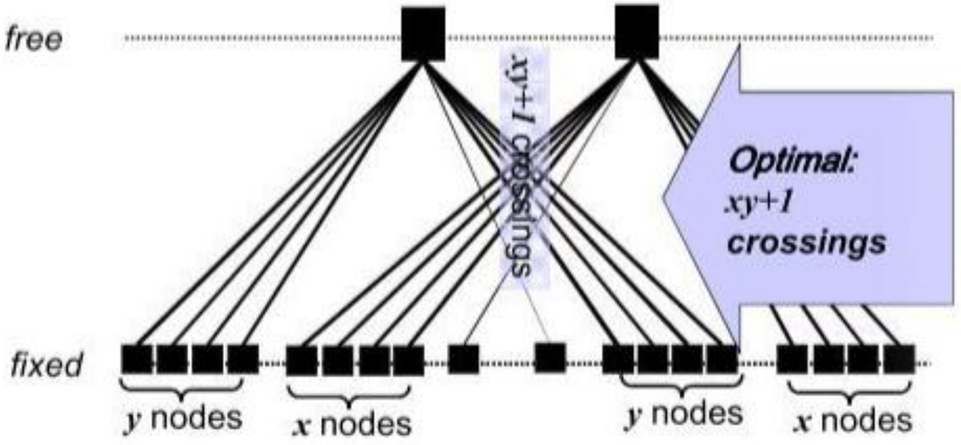


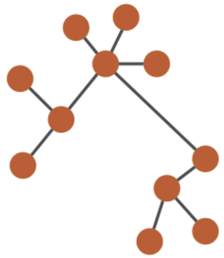
Median Heuristic











Scale Problems...

- Quickly run out of space!
- Tree breadth often grows exponentially
- Layout algorithms are slow and heuristics
- Slow rendering
- Solutions:

- scrolling or panning
- filtering or zooming
- aggregation & simplification
- faster but tricker rendering approaches

Graph Viewer Test

www.yasiv.com/graphs#HB/blckhole

Yasiv About Contact... More Visualizations... vivagraph.js Tweet

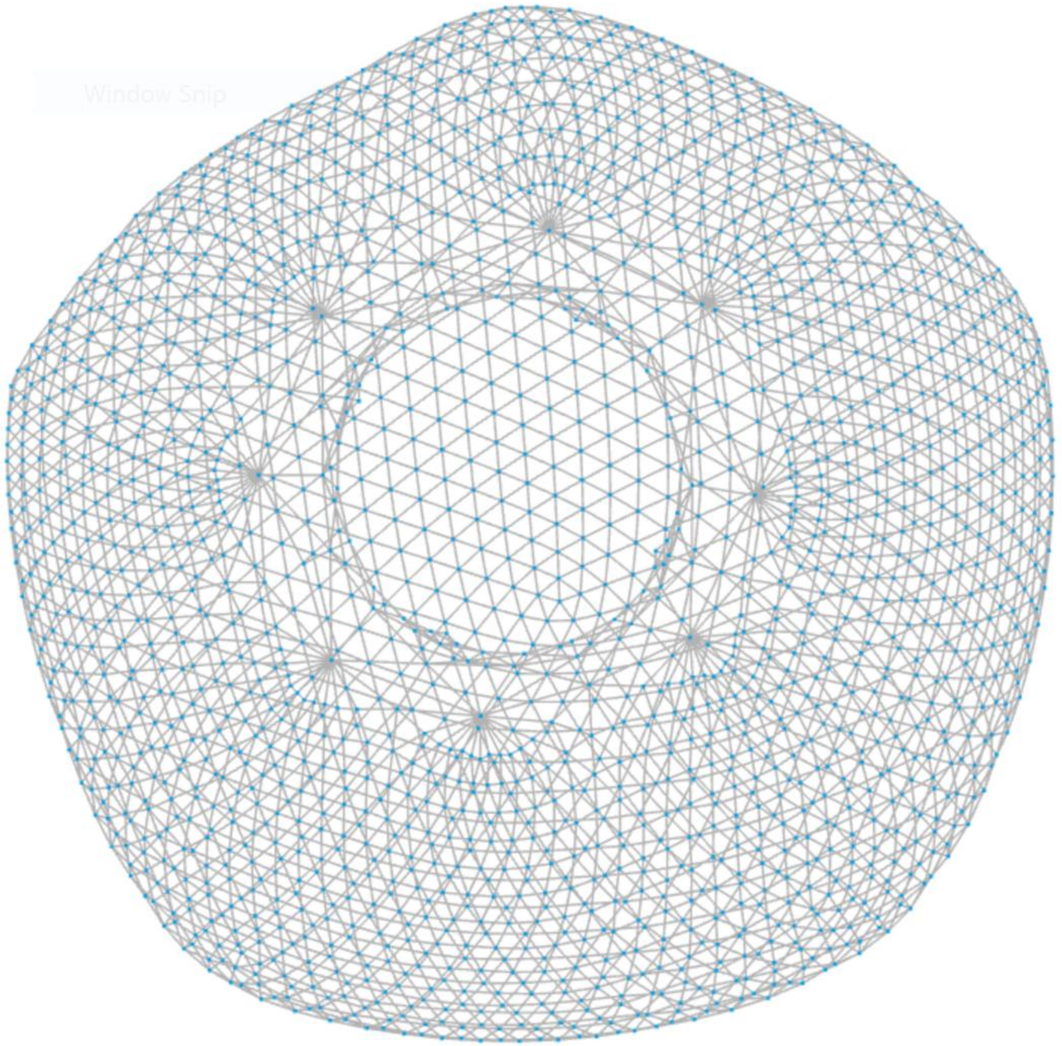
Choose Graph:

FAVORITE GRAPHS

- HB/blckhole
- Bai/rw5151
- HB/bcsstm13
- HB/jagmesh6
- HB/watt_1
- HB/lshp1882
- HB/plat1919
- HB/bcsstk26
- Bai/dw256A
- Bai/tols2000
- Bai/dw1024
- Bai/rdb2048
- Pajek/CSphd
- GHS_indef/laser

BAI

- bfwa398
- bfwa62
- bfwb398
- bfwb62
- bfwb782
- bwm200
- cdde1
- cdde2
- cdde3
- cdde4
- cdde5
- cdde6
- ck104
- ck400
- ck656



Layout Settings

Spring Coeff: 0.0008

Spring Length: 30

Gravity Coeff: -1.2

Drag Coeff: 0.009

Theta Coeff: 0.8

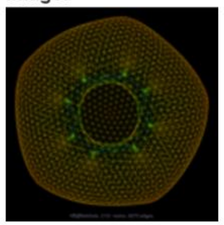
Reset to default

HB/blckhole

Nodes: 2121

Edges: 6370

Image:



Pause layout

Use mouse wheel to zoom in/zoom out

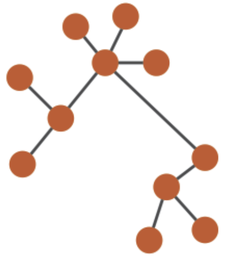
http://www.yasiv.com/graphs#HB/blckhole

Arrange Networks and Trees

Node–Link Diagrams

Connection Marks

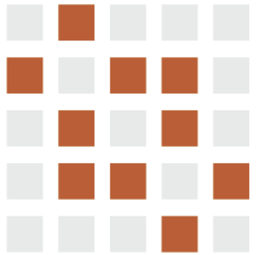
✔ NETWORKS ✔ TREES



Adjacency Matrix

Derived Table

✔ NETWORKS ✔ TREES



Enclosure

Containment Marks

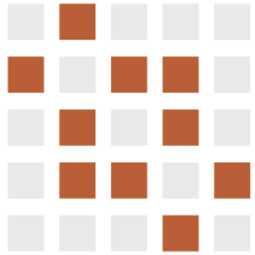
✘ NETWORKS ✔ TREES

"Treemap"

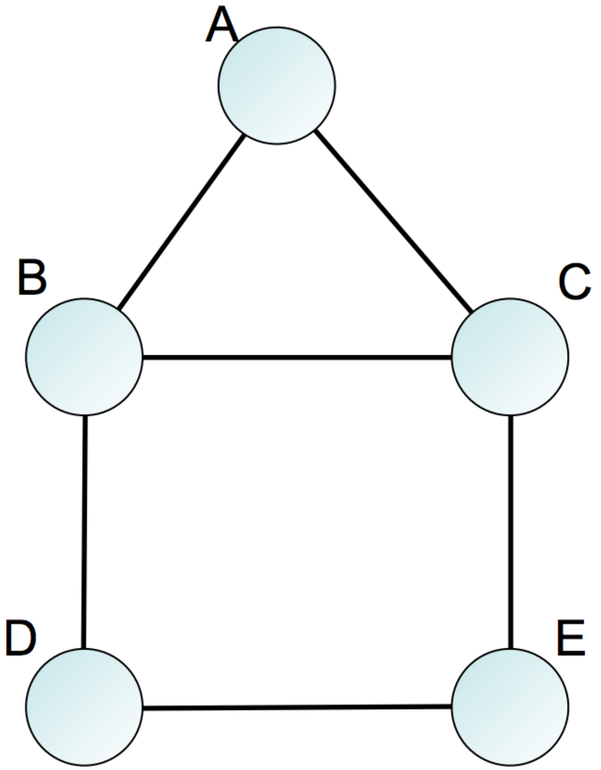
Adjacency Matrix

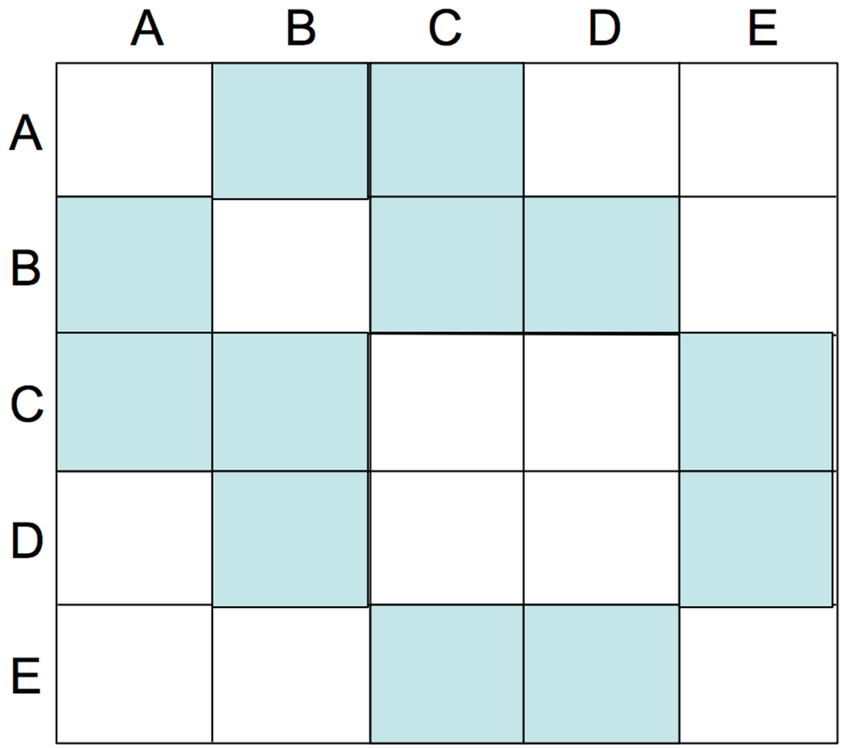
Derived Table

✔ NETWORKS ✔ TREES

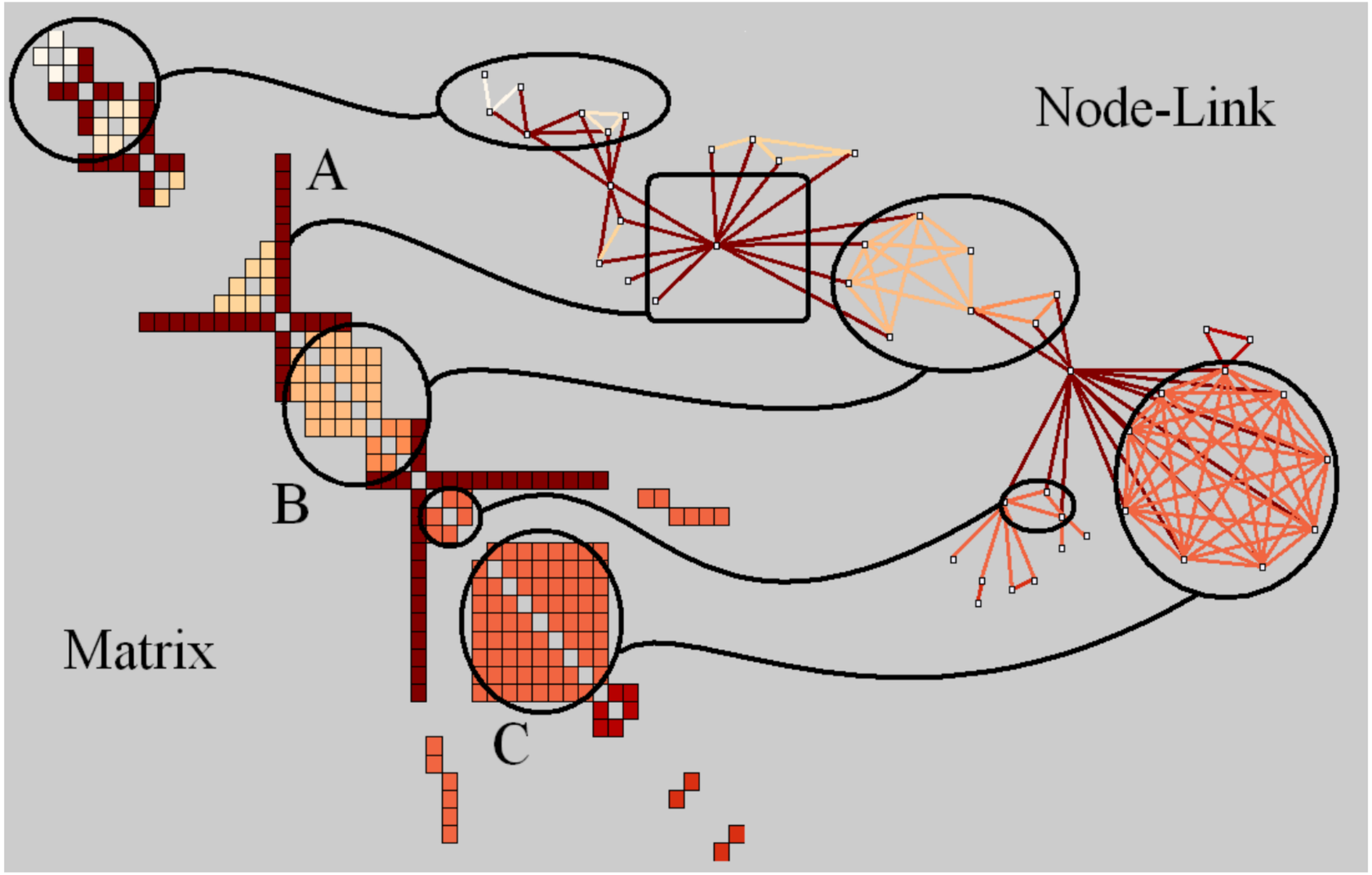


Alternate to node-link visualization for dense & weighted networks





Adjacency Matrix

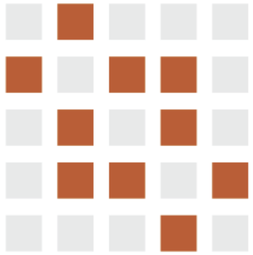


Henry & Fekete (2006)

Adjacency Matrix

Derived Table

✔ NETWORKS ✔ TREES



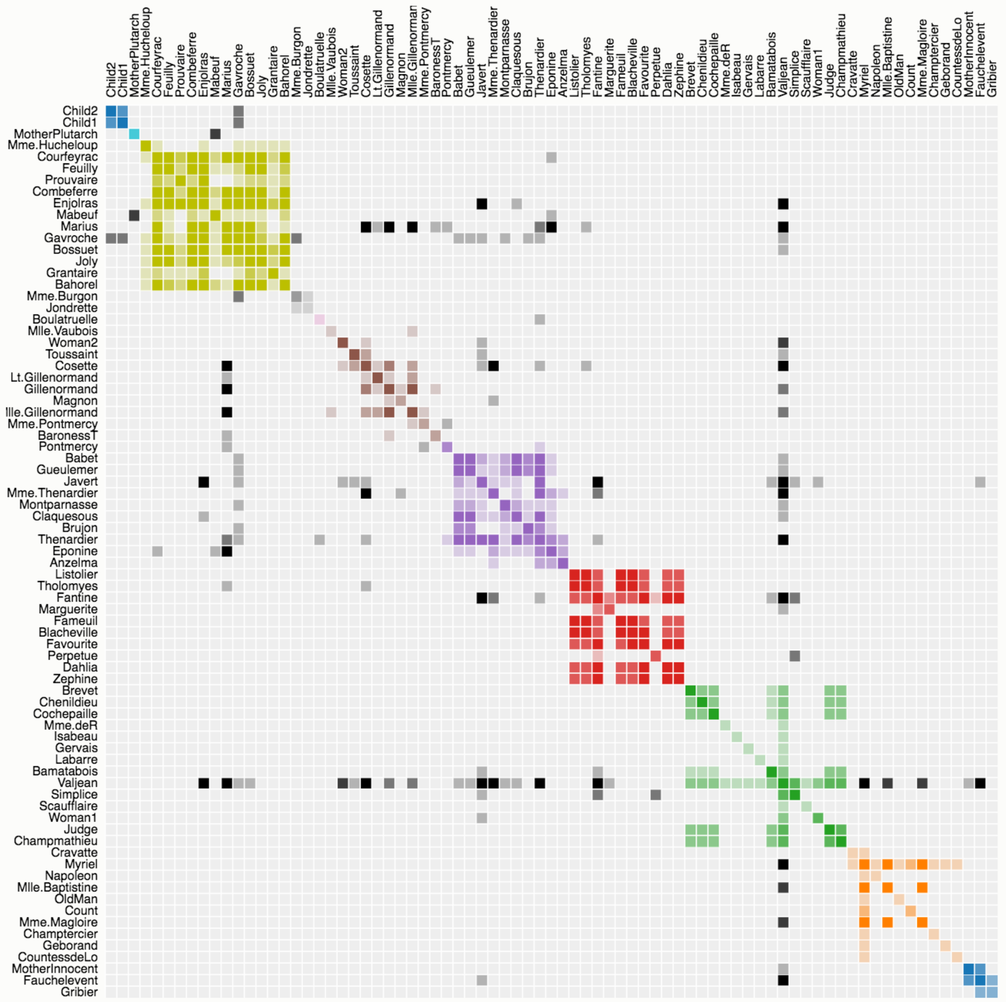
Pros:

- great for dense graphs
- visually scalable
- can spot clusters

Cons:

- **row order affects what you can see**
- abstract visualization
- hard to follow paths

Les Misérables Co-occurrence



Order: by Cluster

This matrix diagram visualizes character co-occurrences in Victor Hugo's *Les Misérables*.

Each colored cell represents two characters that appeared in the same chapter; darker cells indicate characters that co-occurred more frequently.

Use the drop-down menu to reorder the matrix and explore the data.

Built with d3.js.

Source: The Stanford GraphBase.

Previous Class

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

WDA-LS clustered co-occurrence

Use the drop-down menu to reorder the matrix and explore the data.

When ordered by cluster, rows and columns are clustered by affinity values using hierarchical agglomerative clustering.
Distance measure: Euclidean.
Linkage technique: Single.

Rows and columns are then arranged using leaf reordering using the algorithm from: Sakai, Ryo, et al. "Dendsort: modular leaf ordering methods for dendrogram representations in R." F1000Research 3 (2014).

Cell labels show count and color shows normalized affinity.

Cody Dunne and Tim Stutts, IBM Watson Health Cognitive Visualization Lab

---

Dataset: genes/genes Medline (example) ▾ Edge List

Order: by Cluster ▾

The query was for genes related to the genes SOX9, TCF7L1, SMAD4, PIK3CA, KRAS in Medline.

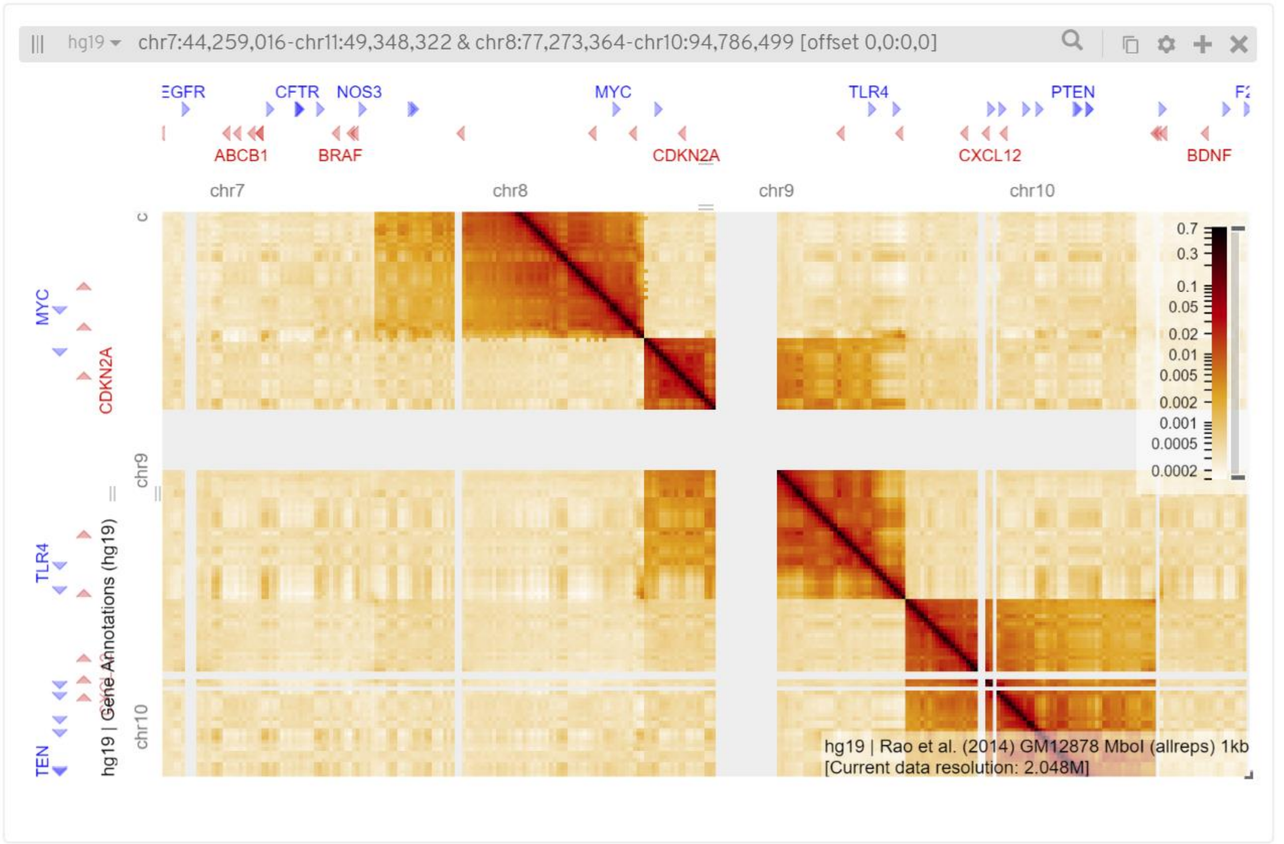
	SOX9	TCF7L1	SMAD4	KRAS	PIK3CA
tp53	33	4	406	1295	726
apc	10	1	106	255	91
kras	10	1	166	11277	926
nras	0	0	20	878	269
hras	0	0	9	659	107
f2	2	0	5	407	0
raf1	3	1	12	760	266
alk	0	0	11	339	126
ns2	0	0	0	228	0
sos1	0	0	0	286	8
hspb3	0	0	4	279	9
ptpn11	0	0	6	192	21
cd8a	4	0	7	190	25
cd4	0	0	11	152	34
ifng	0	0	14	118	12
myc	18	1	50	278	80
mlh1	0	1	34	190	50
smad4	13	1	3052	166	53
smad2	21	1	828	12	12
smad3	20	0	658	6	12
smad7	5	0	281	0	0
smad1	17	0	262	0	6
tgfb1	23	0	230	16	7
inhbe	12	0	164	0	0
tgfbr2	5	0	123	22	6
cdkn2a	13	0	222	330	150

HiGlass About Examples Docs

HiGlass is a tool for exploring genomic contact matrices and tracks. Please take a look at the examples and documentation for a description of the ways that it can be configured to explore and compare contact matrices. To load private data, HiGlass can be run locally within a Docker container. The HiC data in the examples below is from Rao et al. (2014) [2].

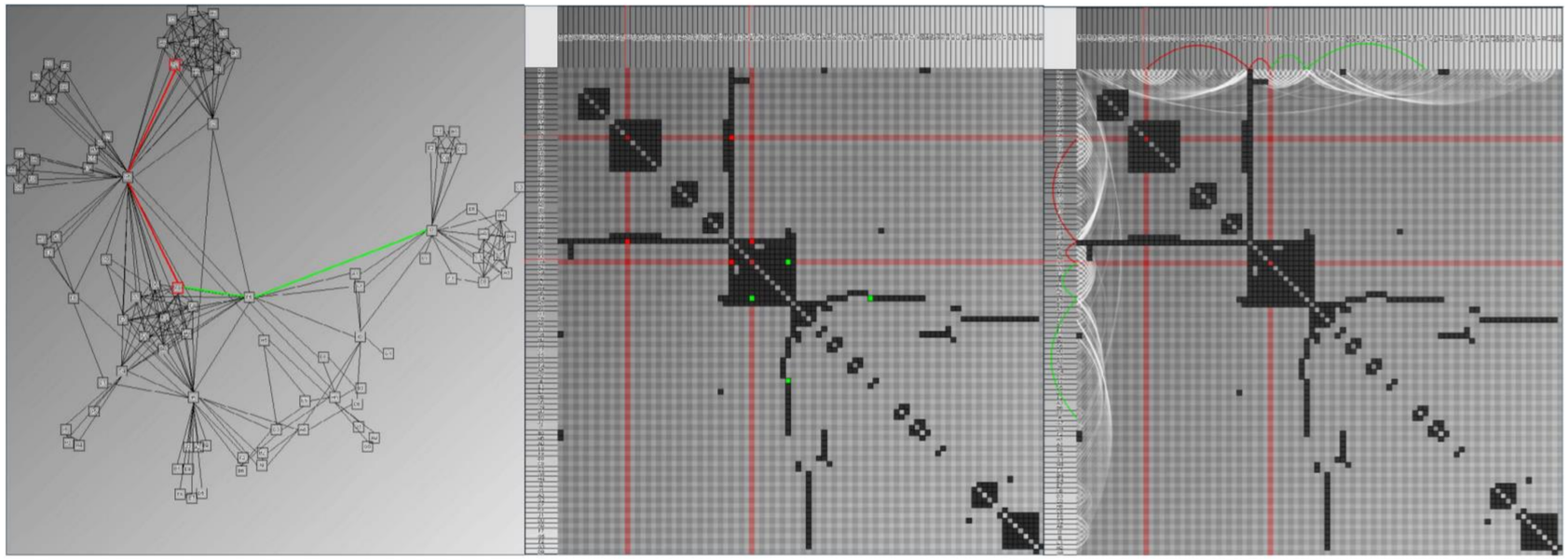
A preprint of the paper describing HiGlass is available on bioRxiv [1].

Single View

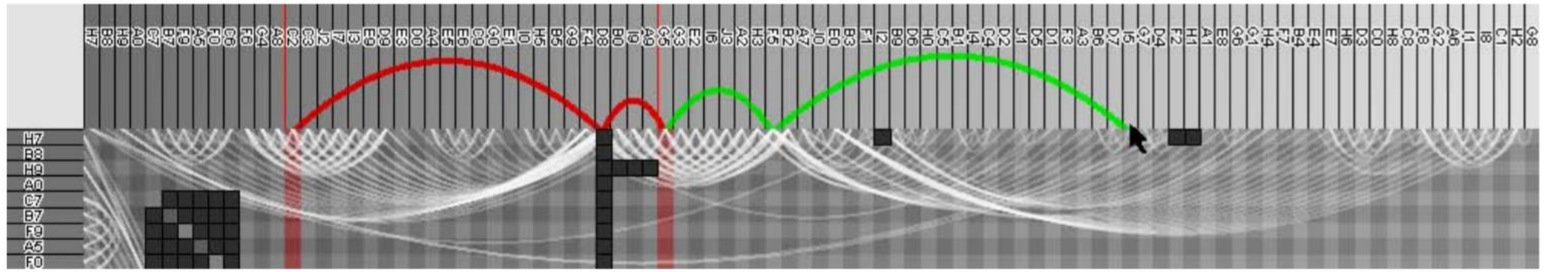


http://higlass.io/

MatLink



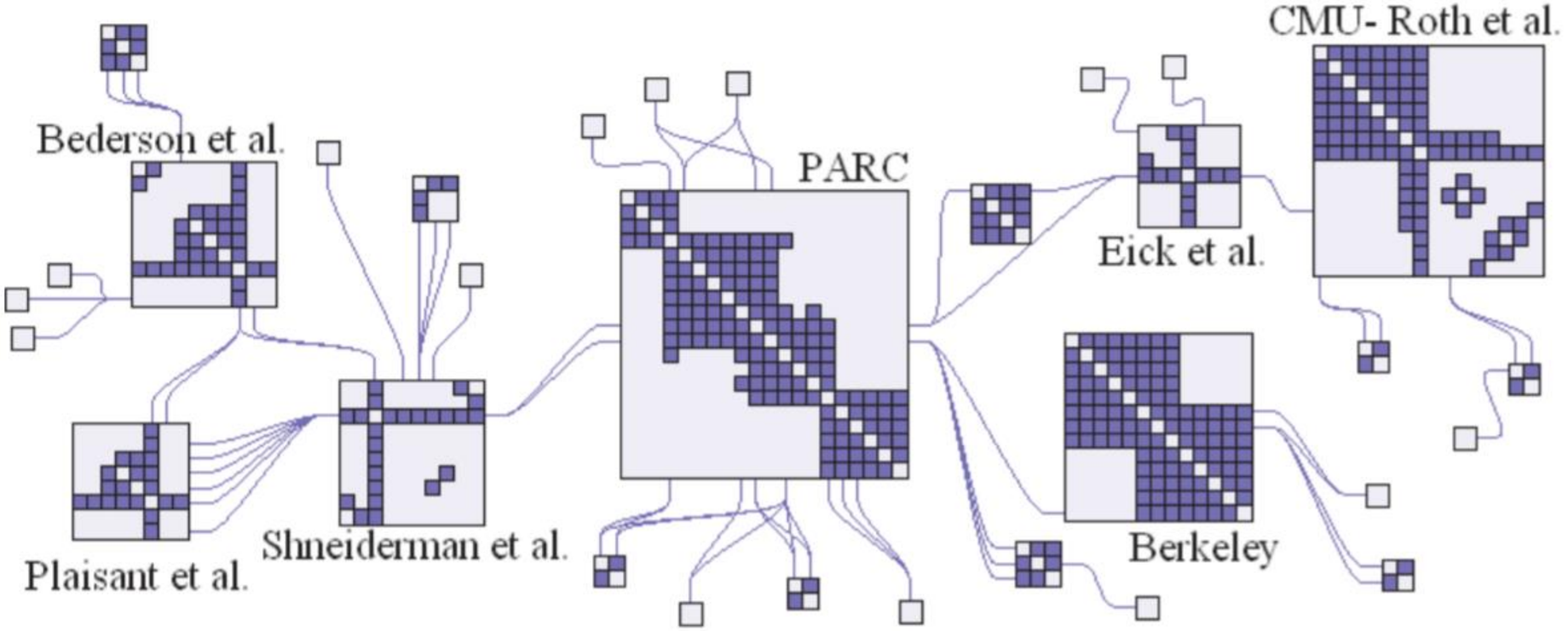
(a) Node-Link(NL) **(b)** Matrix(MAT) **(c)** MatLink



(d) Zoom on MatLink

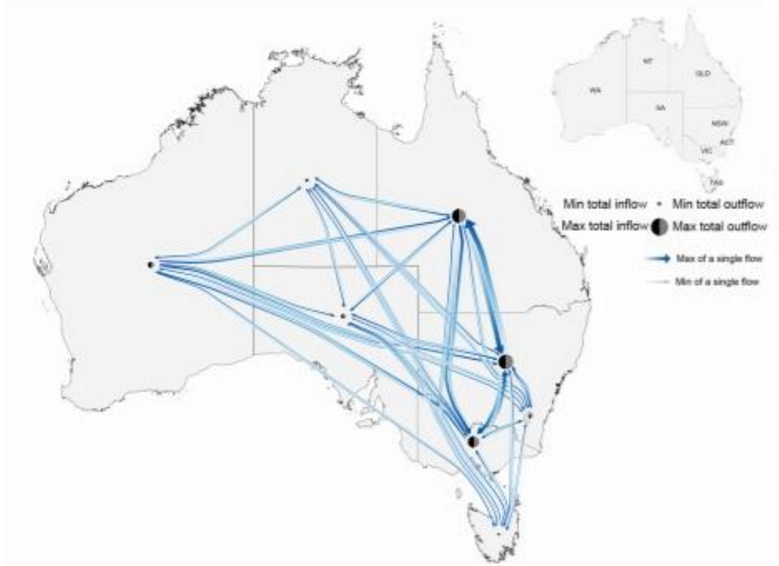
Henry & Fekete, 2007

NodeTrix

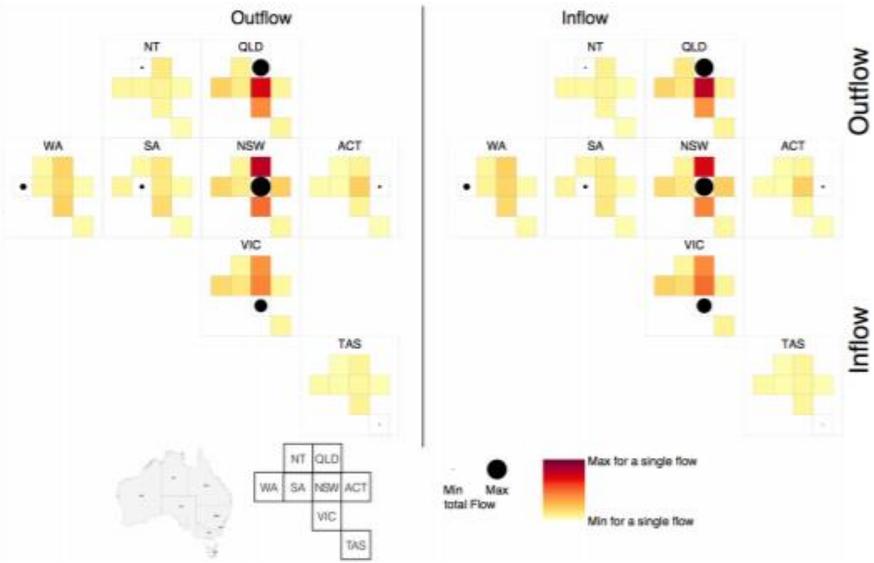


Henry et al, 2007

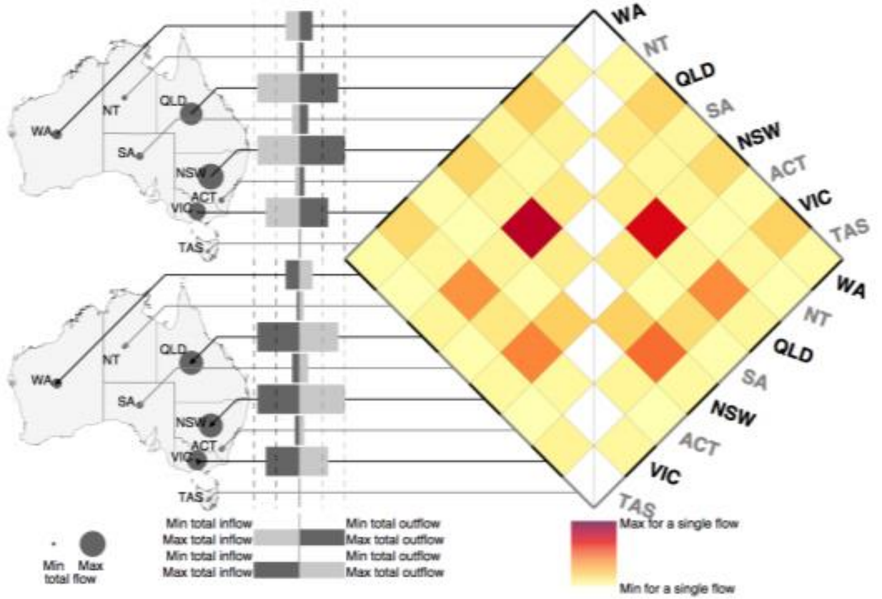
MapTrix



(a) Bundled Flow Map



(b) OD Map

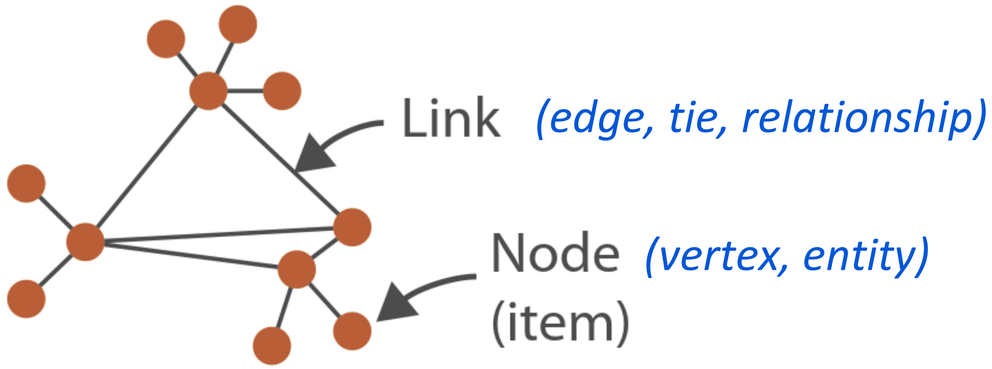


(c) MapTrix

https://vimeo.com/182970812
https://vimeo.com/278433529

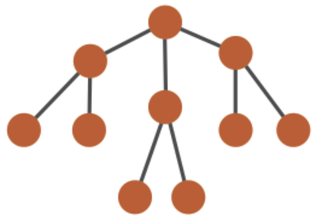
Yang et al., 2016; Demo

➔ Networks *(graphs)*



Network = entities and relationships between them

➔ *Trees*



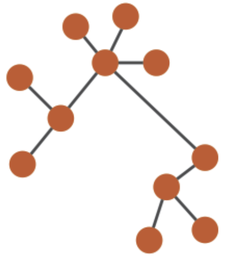
Tree = *undirected*, *connected*, *acyclic* network

Arrange Networks and Trees

Node–Link Diagrams

Connection Marks

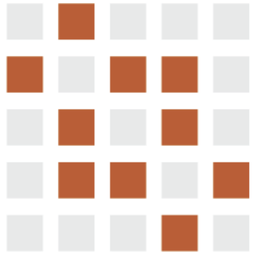
✔ NETWORKS ✔ TREES



Adjacency Matrix

Derived Table

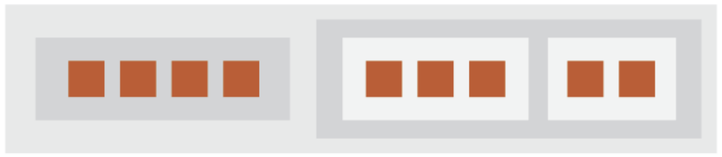
✔ NETWORKS ✔ TREES



Enclosure

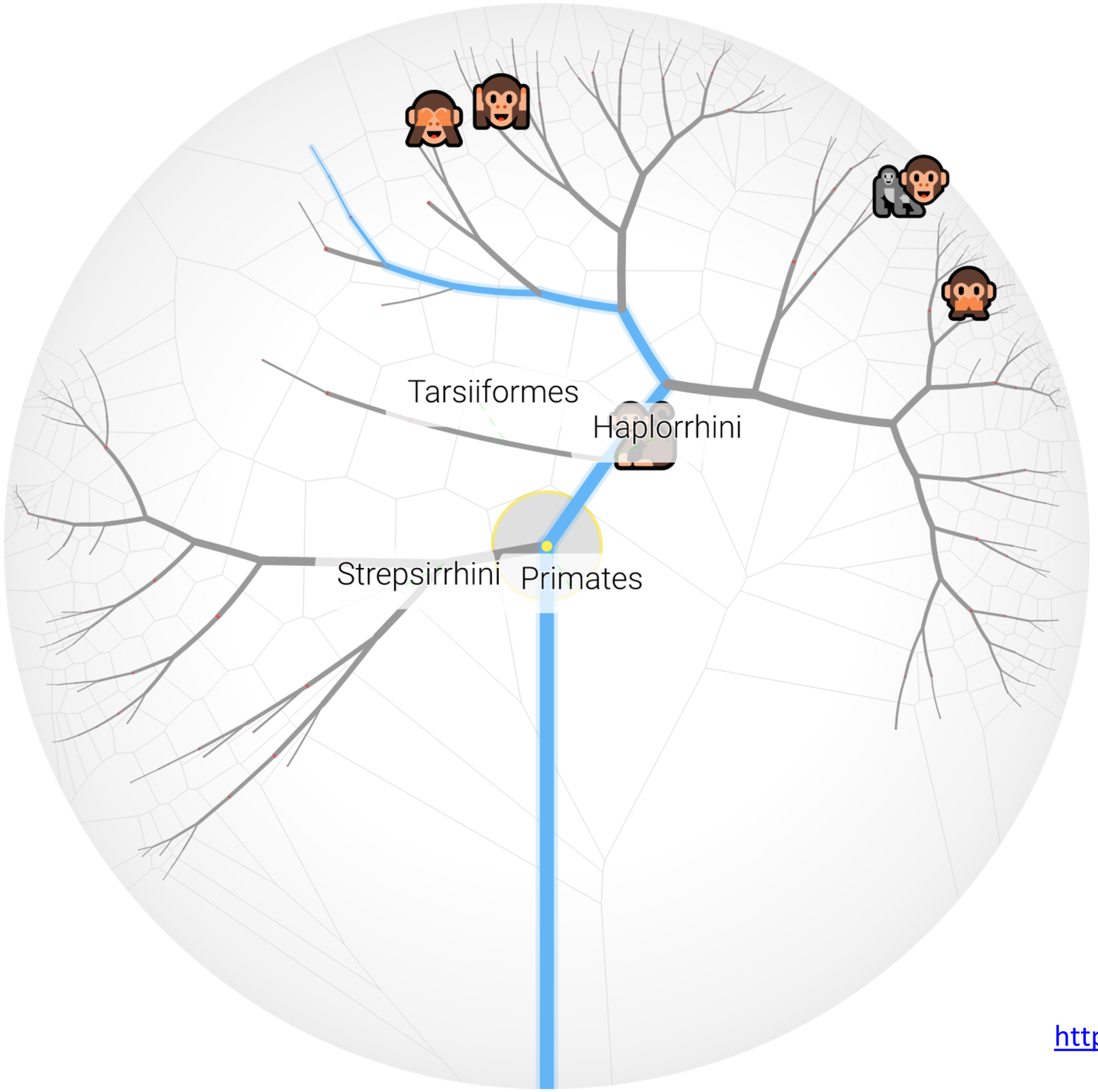
Containment Marks

✘ NETWORKS ✔ TREES

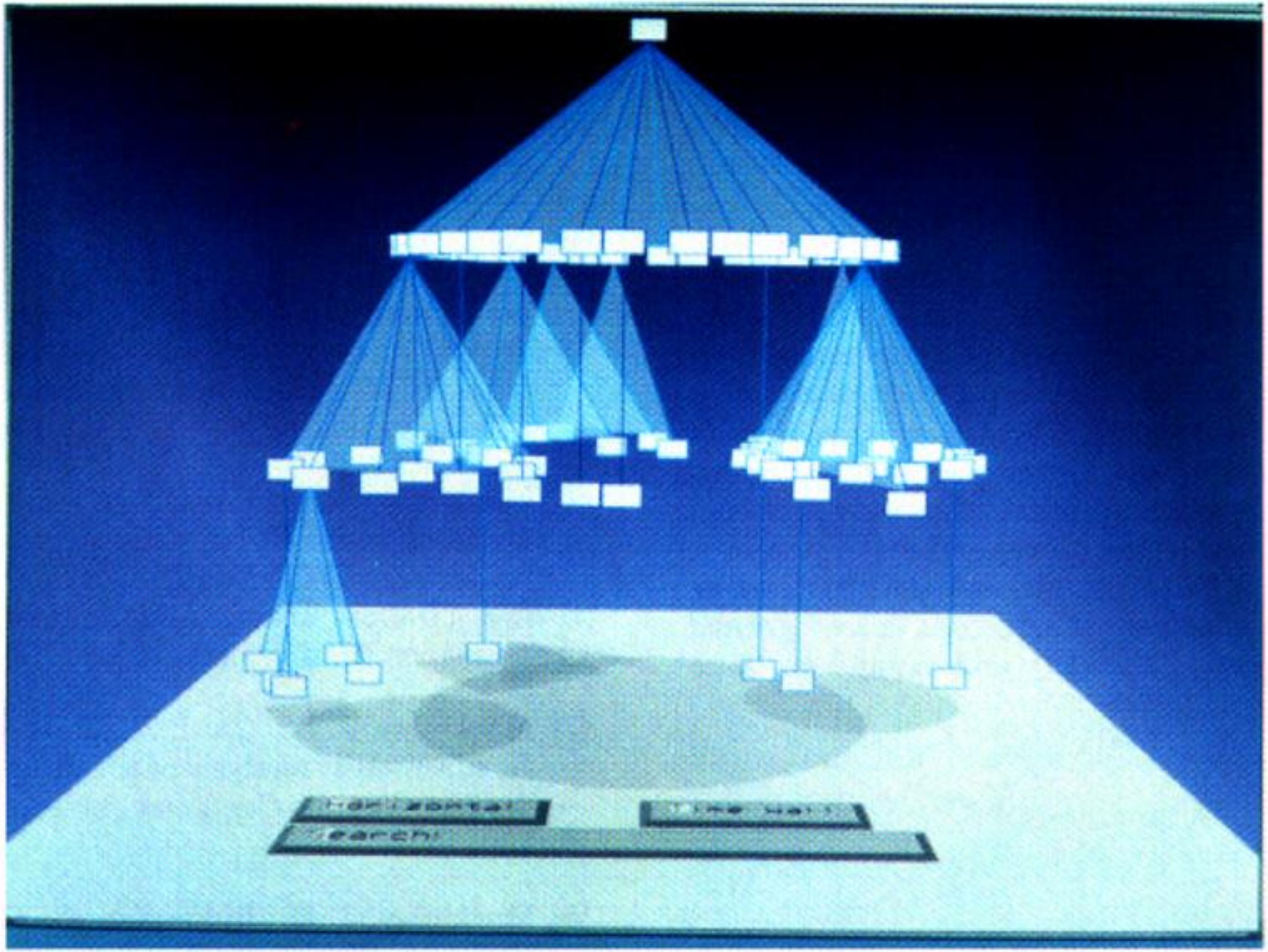


"Treemap"

Hyperbolic trees



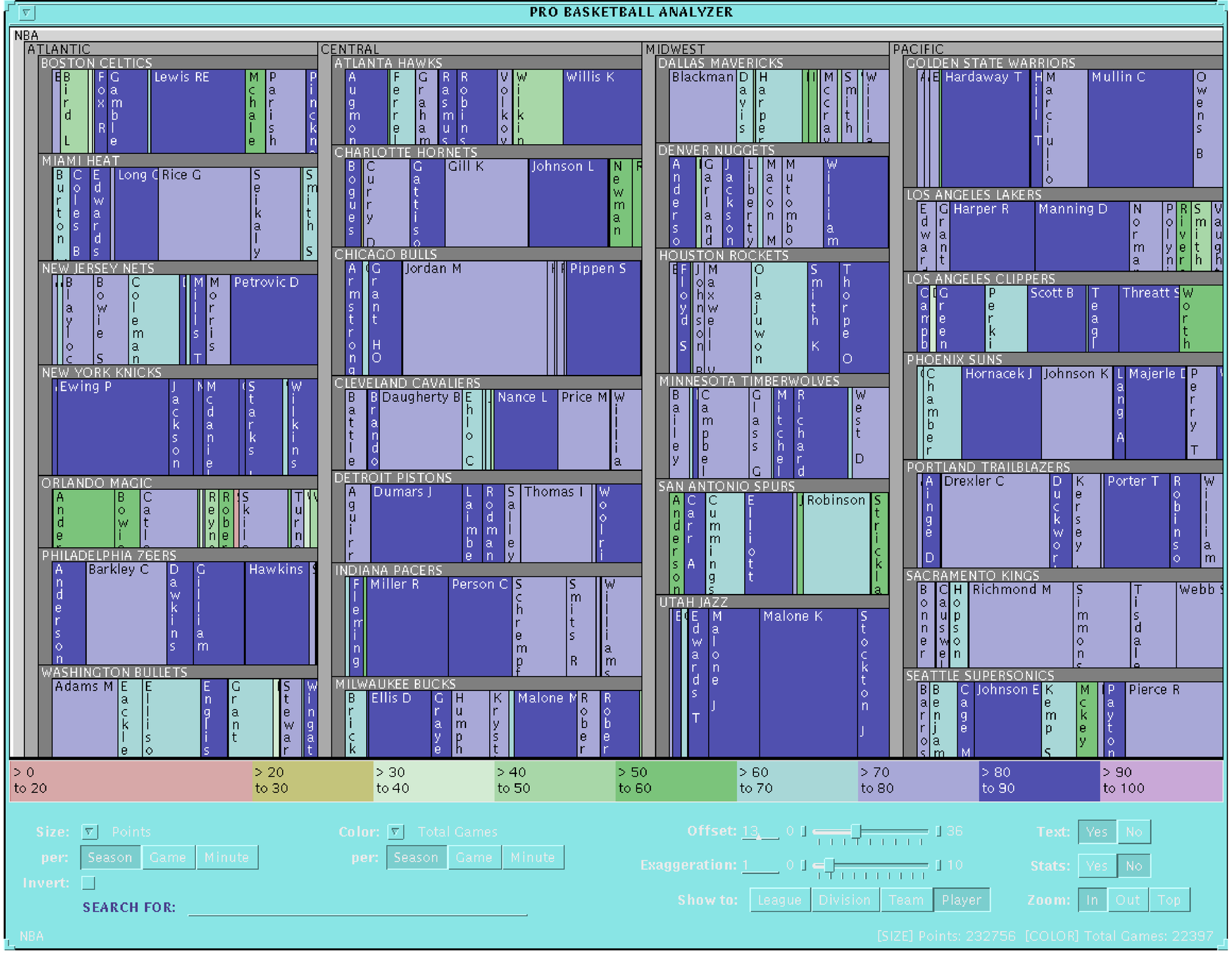
https://glouwa.github.io/d3-hypertree-examples/demo/



Cone Trees

Robertson et al., 1991

Slice and Dice Treemaps

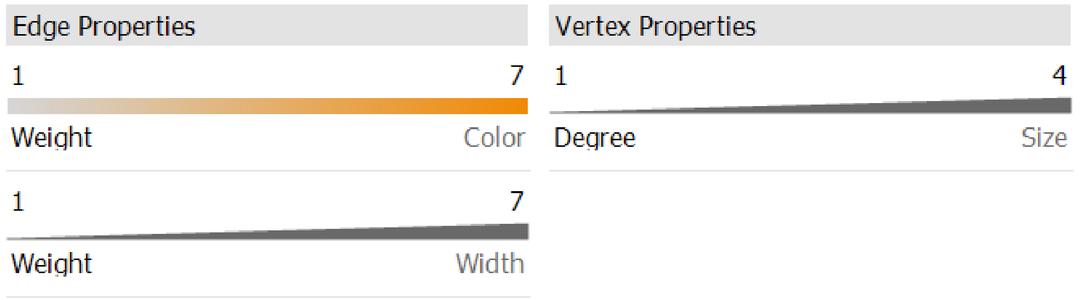


Turo & Shneiderman, 1993

Cluster / Squarified Treemaps

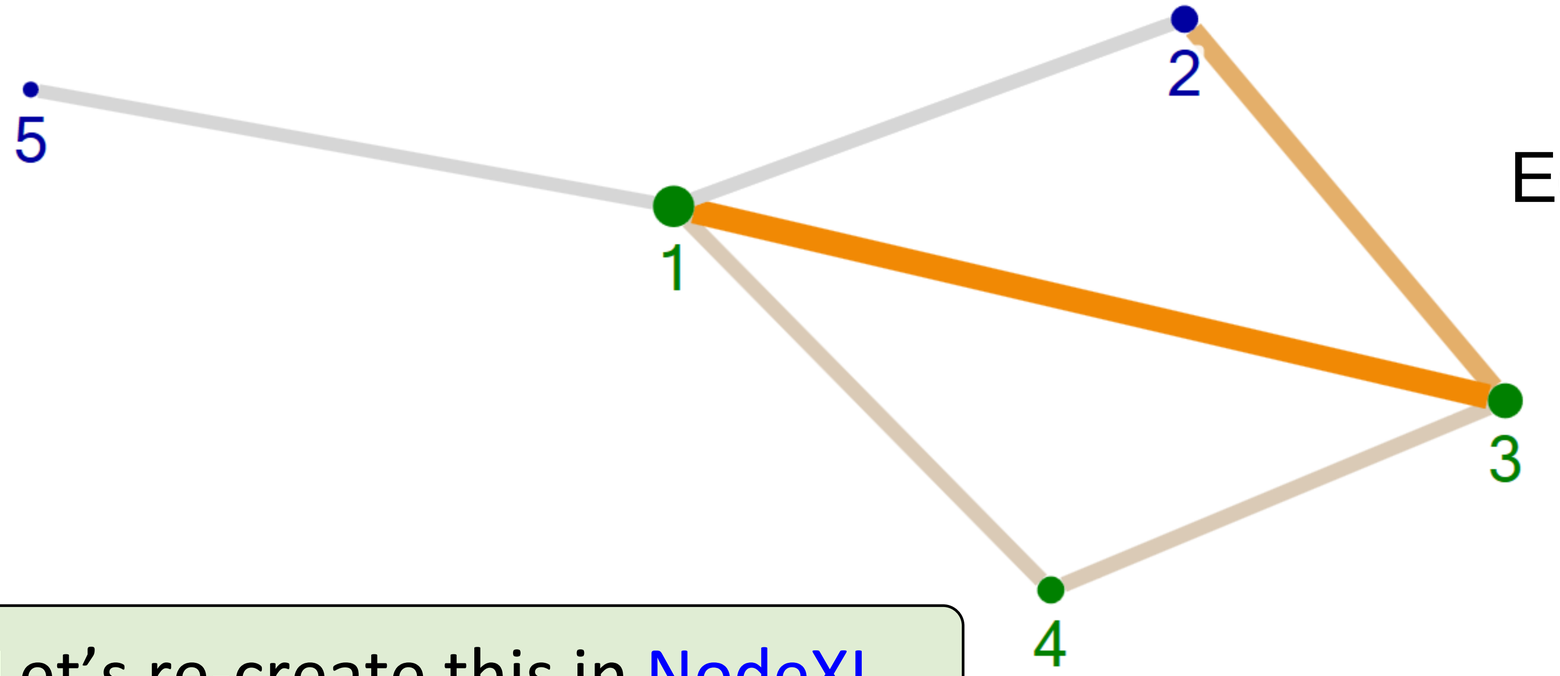
[Wattenberg, 1999](); [Bruls et al., 2000](); [finviz live site](); Snapshot: [finviz, 2020]()

In-Class Drawing: Node-Link Visualization



Nodes:

ID	Type
1	A
2	B
3	A
4	A
5	B



Edges:

Source	Target	Weight
1	2	1
1	3	7
2	3	4
3	4	2
4	1	2
5	1	1

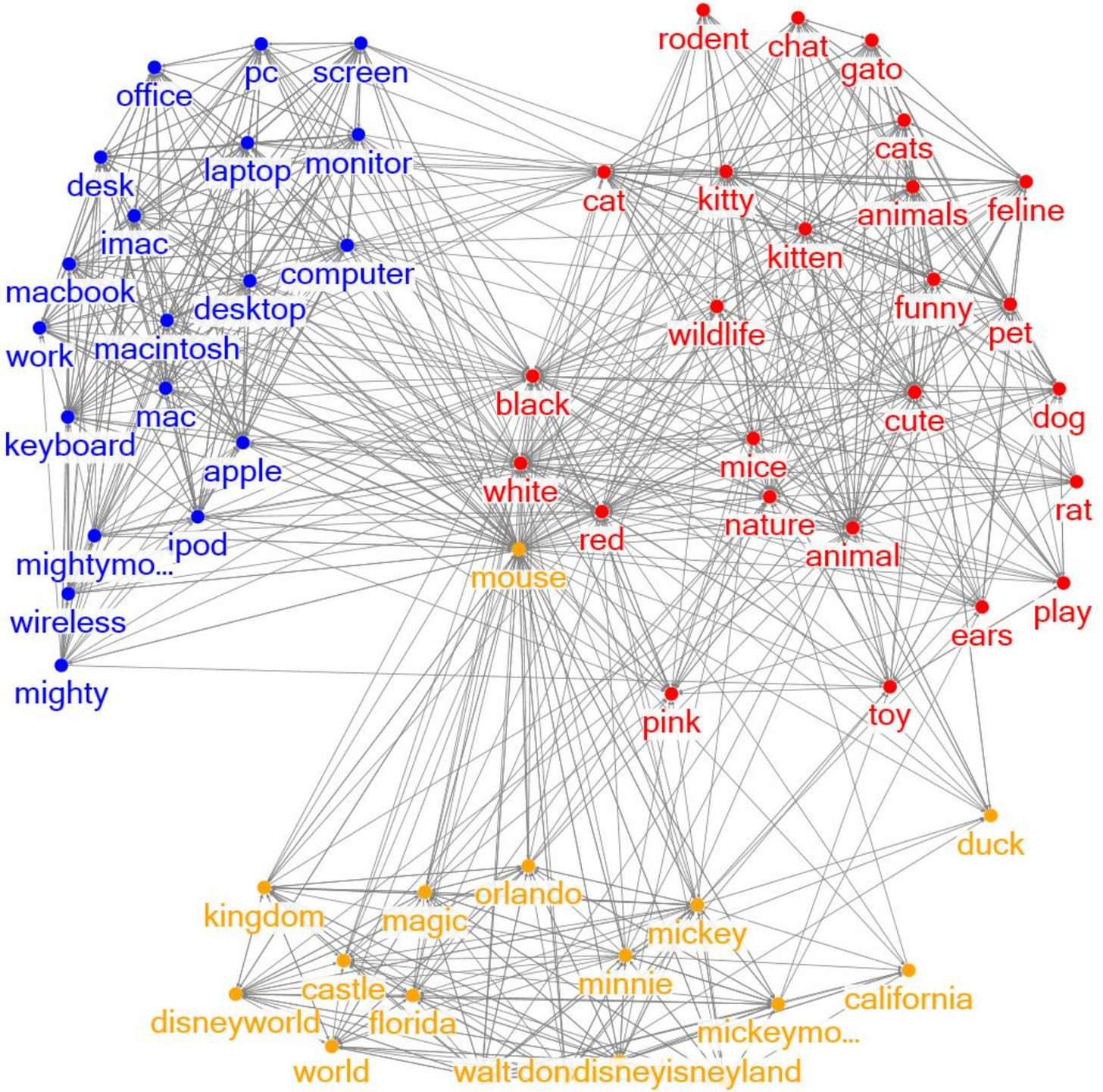
Let's re-create this in NodeXL…

Hall of Fame?

or

Hall of Shame?

Flickr Query for “Mouse”



IBM **Watson** News Explorer recent news about current events investigate advanced [+]

Details 100 articles loaded

person

Barack Hussein Obama II (US /bəˈrɑːk huːˈseɪn oʊˈbɑːmə/; born August 4, 1961) is an American politician who is the 44th and current President of the United States. He is the first African American to hold the office and the first president born outside the continental United States. Born in Honolulu, Hawaii, Obama is a graduate of Columbia University and Harvard Law School, where he was president of the

California endures more wildfires, 1 sparked by a hot car

Mass shooting at Halloween party leaves at least 4 dead in California

US role in Syria grows more complex with Trump claim to oil

What is Dia de los Muertos and when is it celebrated?

Chicago girl, 7, shot while trick-or-treating, in critical condition

News Network show/hide: companies, organizations, people

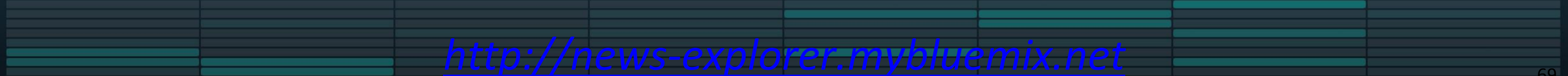
investigation stats:
articles: 100
companies: 42
organizations: 42
people: 94

Locations 41 found, view in map list

Topics People Companies Organizations

Timeline news articles across 7 days, 11 hrs, 2 min, 0 sec up to the current date: 11/1/2019

Powered By IBM Watson™



http://news-explorer.mybluemix.net

For Next Time

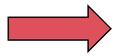
neu-ds-4200-s22.github.io/schedule

Look at the upcoming assignments and deadlines

- Textbook, Readings, & Reading Quizzes—Variable days
- In-Class Activities—If due, they are due 11:59pm the same day as class

Everyday Required Supplies:
- 5+ colors of pen/pencil
- White paper
- Laptop and charger

Use Canvas Discussions for general questions, email codydunne-and-tas@ccs.neu.edu for questions specific to you.



Week	Topics	Assignments
#1: Jan 17–21	What is visualization Design rules of thumb	A1—Setting up
#2: Jan 24–28	JS development, projects Marks & channels	A2—Encodings & xenographics
#3: Jan 31–Feb 04	Data types and tasks, Tableau D3 tutorial 1/2	P1—Pitches★
#4: Feb 07–11	In-class group formation D3 tutorial 2/2	A3—Tableau analysis P2—Proposal★
#5: Feb 14–18	Altair and JupyterLab Practice Design Study	A4—D3 basic charts
#6: Feb 21–25	Arrange Tables Color, pop-out, illusions	A5—Altair basic charts P3—Interview & tasks
#7: Feb 28–Mar 04	Interaction & animation In-class project meetings 1/2	A6—D3 event handling P4—Data and sketches
#8: Mar 07–11	In-class project meetings 2/2 Trees & networks	P5—Final sketches & plan★
Mar 14–18	*Spring Break*	
#9: Mar 21–25	Spatial, 3D, and scientific vis. TBD	A7—D3 Brushing & linking 1 P6—Implementation 1
#10: Mar 28–Apr 01	Validation & evaluation Flex day	A8—Brushing & linking 2 P7—Implementation 2
#11: Apr 04–08	Project usability testing, how to give a talk Storytelling	
#12: Apr 11–15	Project presentations 1/2 Project presentations 2/2	P8—Presentations★⧗
#13: Apr 18–22	Flex day	P9—Presentation peer review
#14: Apr 25–29	Reflecting & project work	
May 02–06		P10—Video & Final Deliverables★⧗