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Lecture 4: Heuristic Layout Algorithms, Readability

CS 7295, Fall 2021

Course Homepage on Canvas

https://c.dunne.dev/cs7295f21/

(project details + assignments to be added)

Feel free to interrupt with questions!

Plan for Today

Discuss:
- Layout Objectives & Readability
- Layout heuristics

For next time:

For W 2021-10-06:
- Project 1a — Initial Idea Pitches & Related Work (discussion post, presentation, PDF slides)

Checking In

Previously, on CS 7295…

Visualization Building Blocks

Marks :

Marks as Items/Nodes

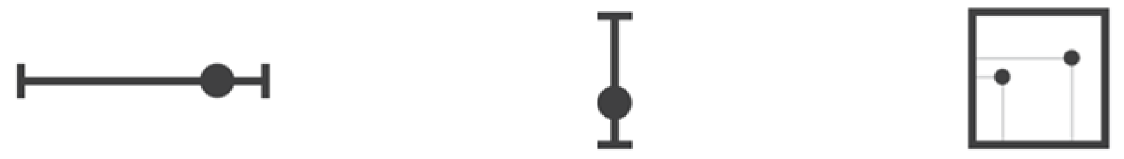
- Points
- Lines
- Areas

Marks as Links

- Containment
- Connection

Channels :

- Position
  - Horizontal
  - Vertical
  - Both

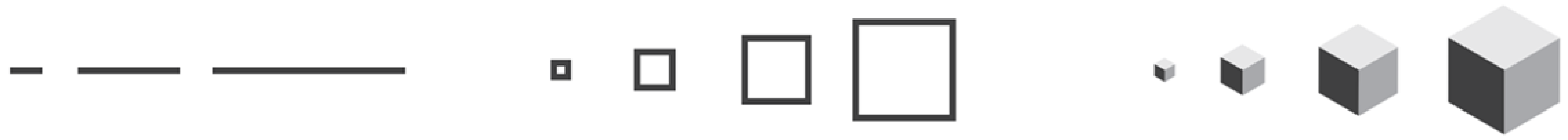


- Color

- Shape

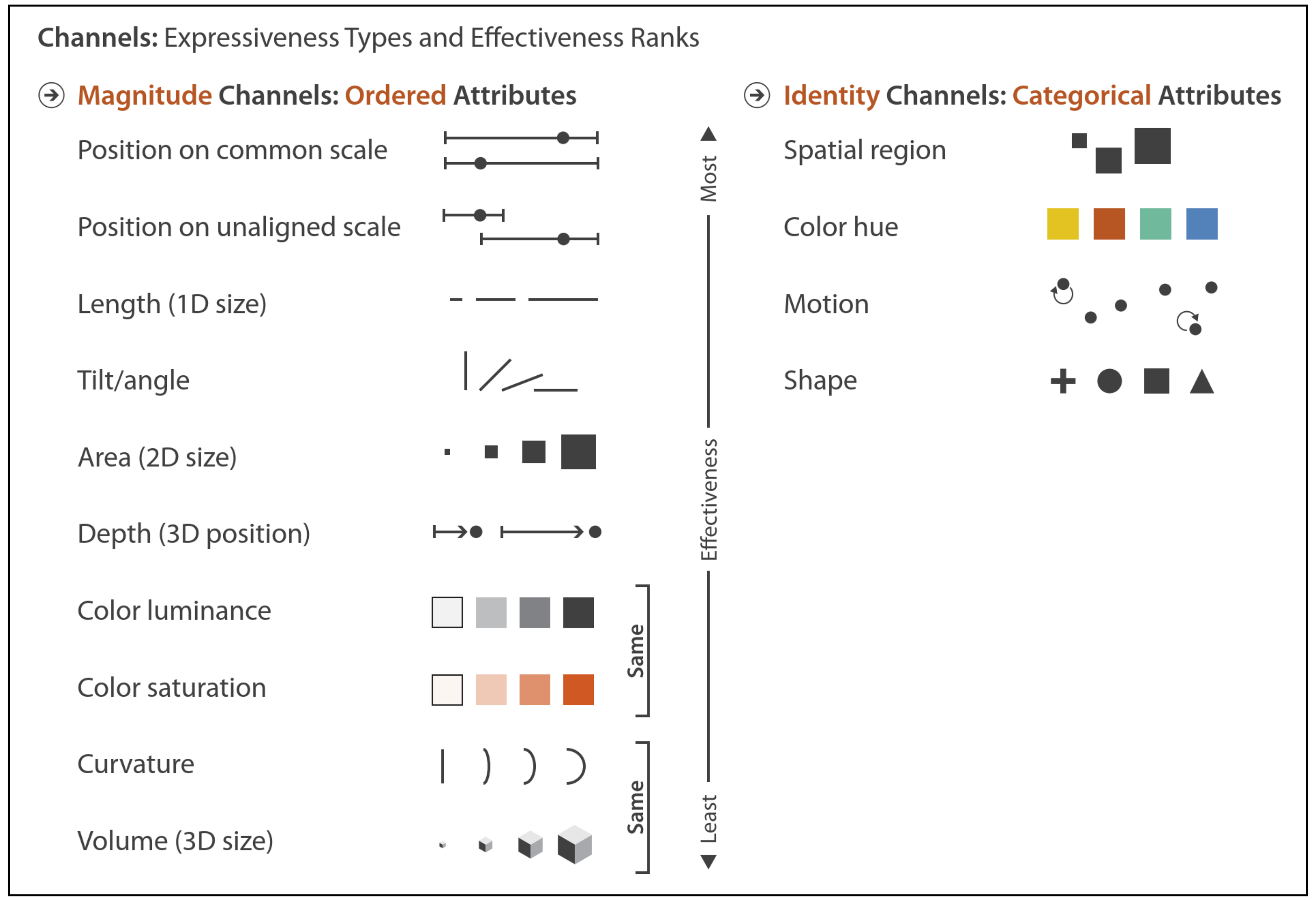
- Tilt

- Size
  - Length
  - Area
  - Volume



Note: these are all really important concepts when it comes time to coding your visualizations...!

How to pick? User study results!



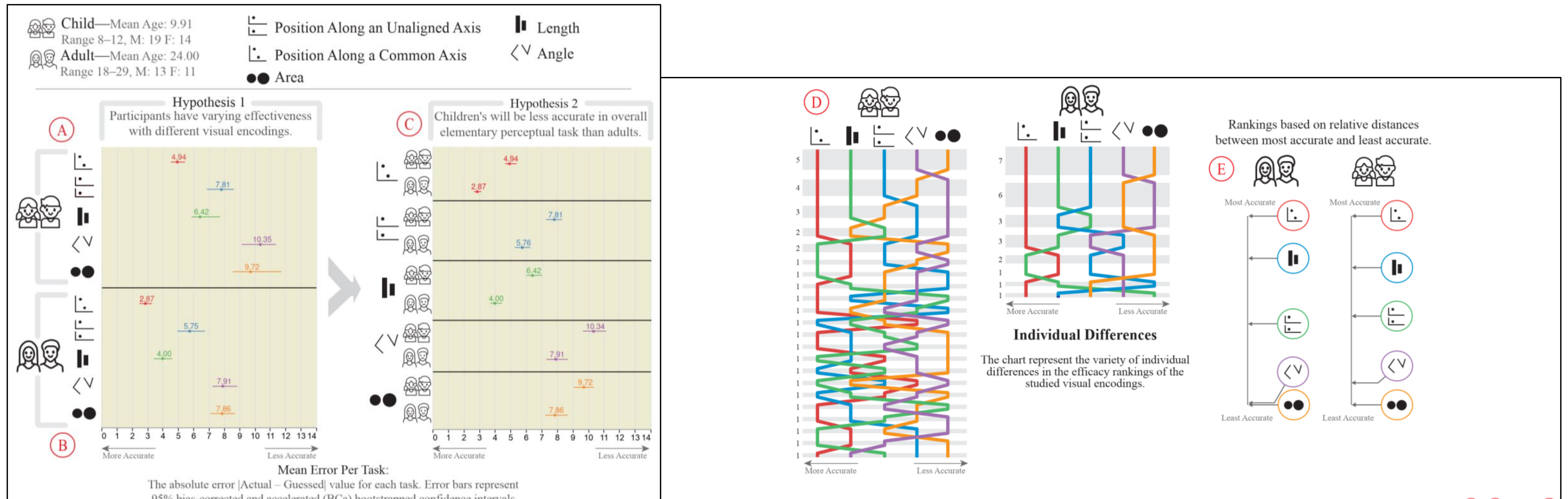


Fig. 5. Summative results for Hypothesis 1 and 2 and an exploratory analysis of individual differences in rankings. In Ⓐ, Ⓑ, and Ⓒ the error bars show 95% bias-corrected and accelerated (BCa) bootstrapped confidence intervals [23]. (A *rough* rule of thumb for reading 95% CIs is that if two intervals overlap by less than 1/4 of their average length, then the comparison will have p < .05 [22].) The mean absolute error for each encoding is shown in Ⓐ for children and Ⓑ for adults. In Ⓒ, the previous two charts are rearranged to compare children with adults. Children are clearly less accurate when using each of the encodings. The exploratory analysis included, Ⓓ, shows the variation in encoding rankings among individual children (left) and adults (right). Each line represents an encoding, ranked left-to-right in increasing mean absolute error for each task. The grey rows are sized to represent the count of individuals with a shared ranking. E.g,. the top row shows that 5 children ranked Position Along a Common Axis as most accurate, followed by Length, Position Along an Unaligned Axis, Angle, and lastly Area. The line-row intersections show the encoding ranking for that row. Children displayed a larger variety of individual differences in encoding rankings than adults. Finally, Ⓔ shows more simply the *overall* rankings we found for adults and children.

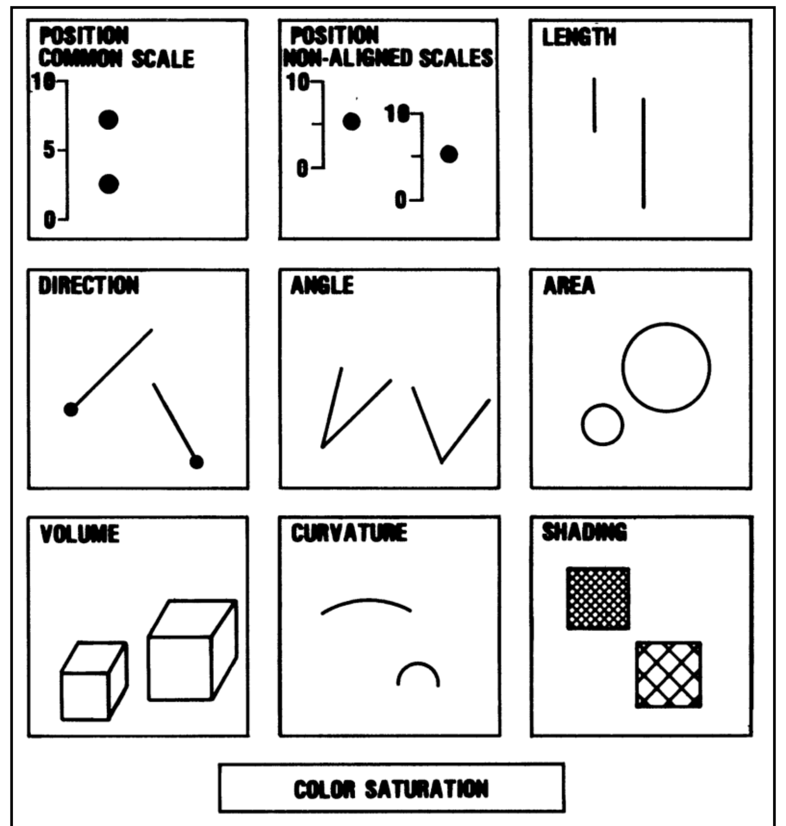


Figure 1. Elementary perceptual tasks.

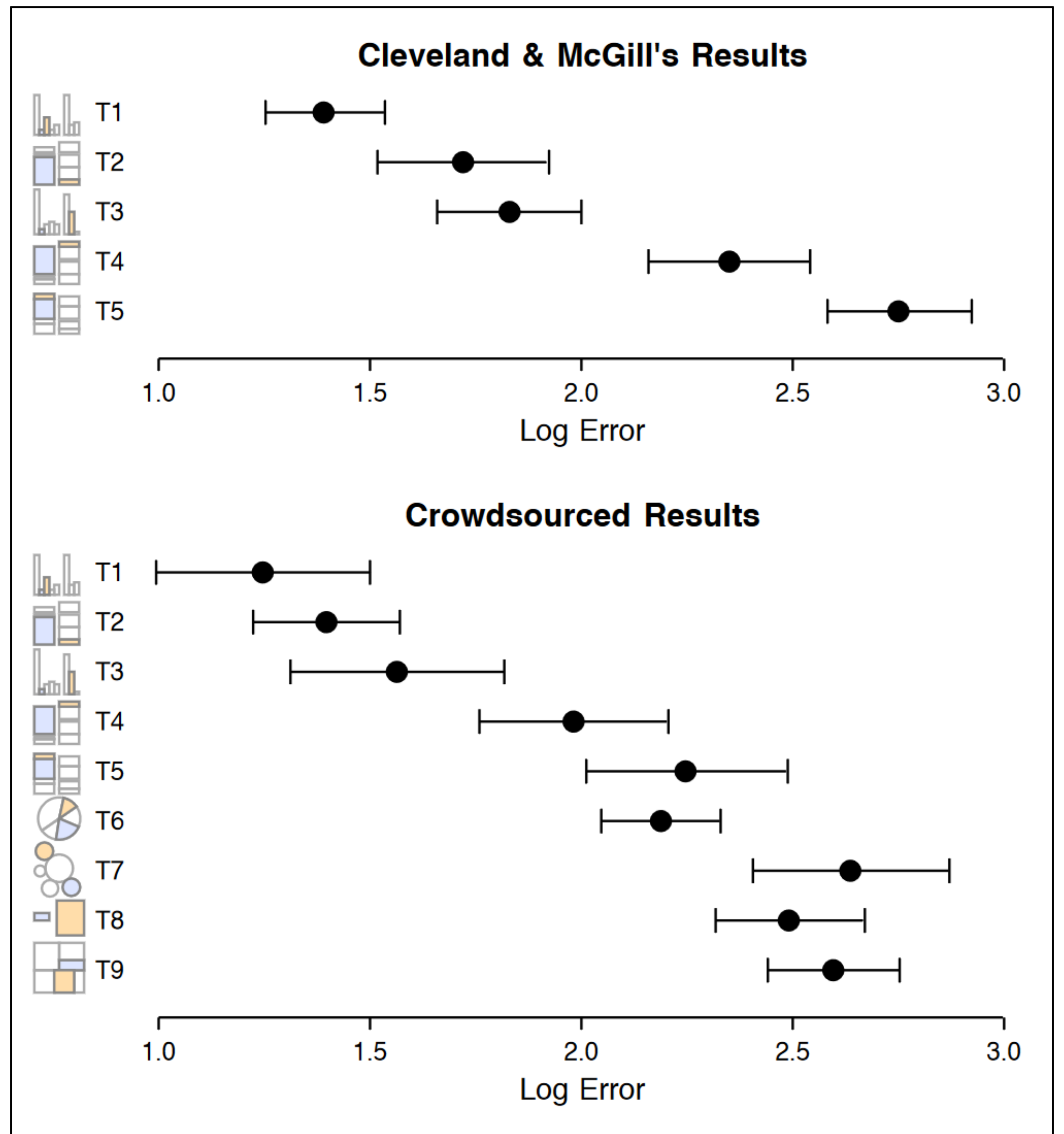


Figure 4: Proportional judgment results (Exp. 1A & B). Top: Cleveland & McGill's [7] lab study. Bottom: MTurk studies. Error bars indicate 95% confidence intervals.

Munzer, 2014
Cleveland & McGill, 1984
Heer & Bostock, 2010
Mackinlay, 1986
Panavas et al., 2021 (under submission)

Now, on CS 7295…

Layout Objectives

Sugiyama’s Graph Drawing Rules

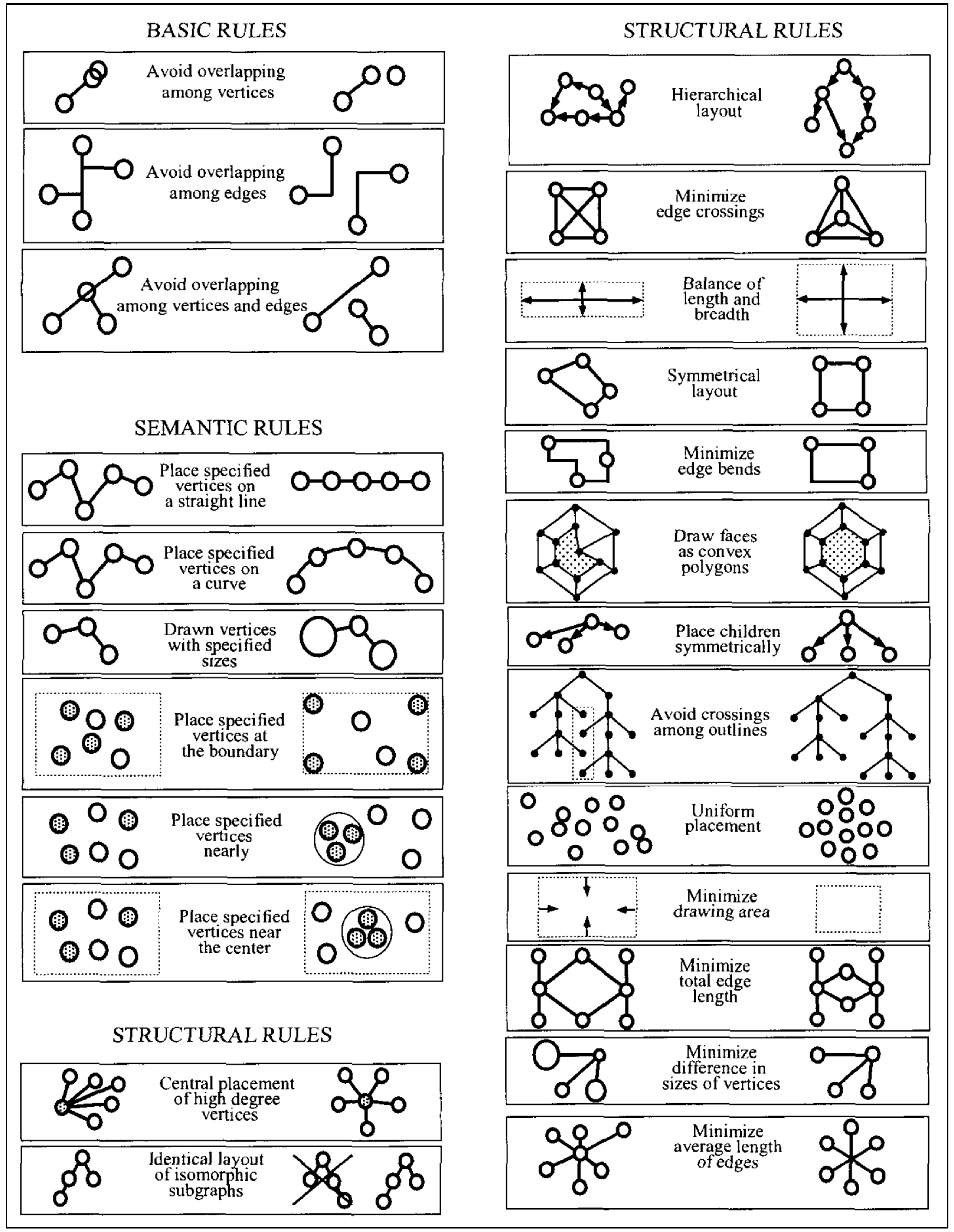


Figure 2.3.1. Simple examples of better (right) and worse (left) layouts.

TYPE	DRAWING RULES	CLASSIFI-CATION AXES
Semantic Rules	1. A specified sequence of vertices is placed on a straight line.	USLB
	2. A specified sequence of vertices is placed on a specified curve.	USLB
	3. Vertices are drawn with a specified size.	UMLB
	4. A specified set of vertices is placed at the boundary of the drawing.	NTLB
	5. A specified set of vertices are drawn near to each other.	NTLB
	6. A specified set of vertices is placed near the center.	NTLB
	7. An upper limit to the number of edge crossings is specified.	NTLB
	8. An upper limit to the number of edge bends is specified.	NSLF
	9. The lengths of specified edge have a specified upper limit.	NMLF
Structural Rules	1. Vertices of high degree are placed near the center.	UTLB
	2. Isomorphic subgraphs are always drawn identically.	USGB
	3. The vertices of isomorphic subgraphs are always placed identically.	USGB
	4. Hierarchical structure is clearly shown vertically or horizontally.	NTGH
	5. The number of edge crossings is minimized.	NTGB
	6. The ratio of length to breadth of the drawing area is balanced.	NSGB
	7. Symmetry is clearly shown.	NSGB
	8. The number of edge bends is minimized (using straight lines wherever possible).	NSGB
	9. The number of faces drawn as convex polygons is maximised.	NSLH
	10. Children of a vertex are symmetrically placed.	NMGH
	11. Crossings among outlines are eliminated. (see Figure 3.2.7)	NMGB
	12. The density of the placement and the routing is uniform.	NMGB
	13. The drawing area is minimized.	NMGB
	14. The total edge length is minimized.	NMGB
	15. The difference in sizes of vertices is minimized.	NMGF
	16. The average length of edges is minimized.	NMGF
	17. The difference between the length of contours of vertices and the length of edges is maximized.	NMGF
	18. The differences in edge lengths is minimized.	NMGF
	19. The length of the longest edge is minimized.	NMLF
	20. Vertices on the boundary are placed with uniform density.	NMLF

Table 2.3.1. Drawing rules.

Drawing rules can be classified using the following axes. A classification according to these 4 axes is noted in the right hand column of Table 2.3.1.

(1) Whether the solution to a rule can be obtained uniquely (U), or not (N).

(2) Whether the rule is topological (T) (specifying only the placement relationship between elements), shape-oriented (S) (specifying the direction also), or metric (M) (specifying distances as well).

(3) Whether the rule applies globally, to the whole drawing (G), or locally, only to a part of the drawing (L).

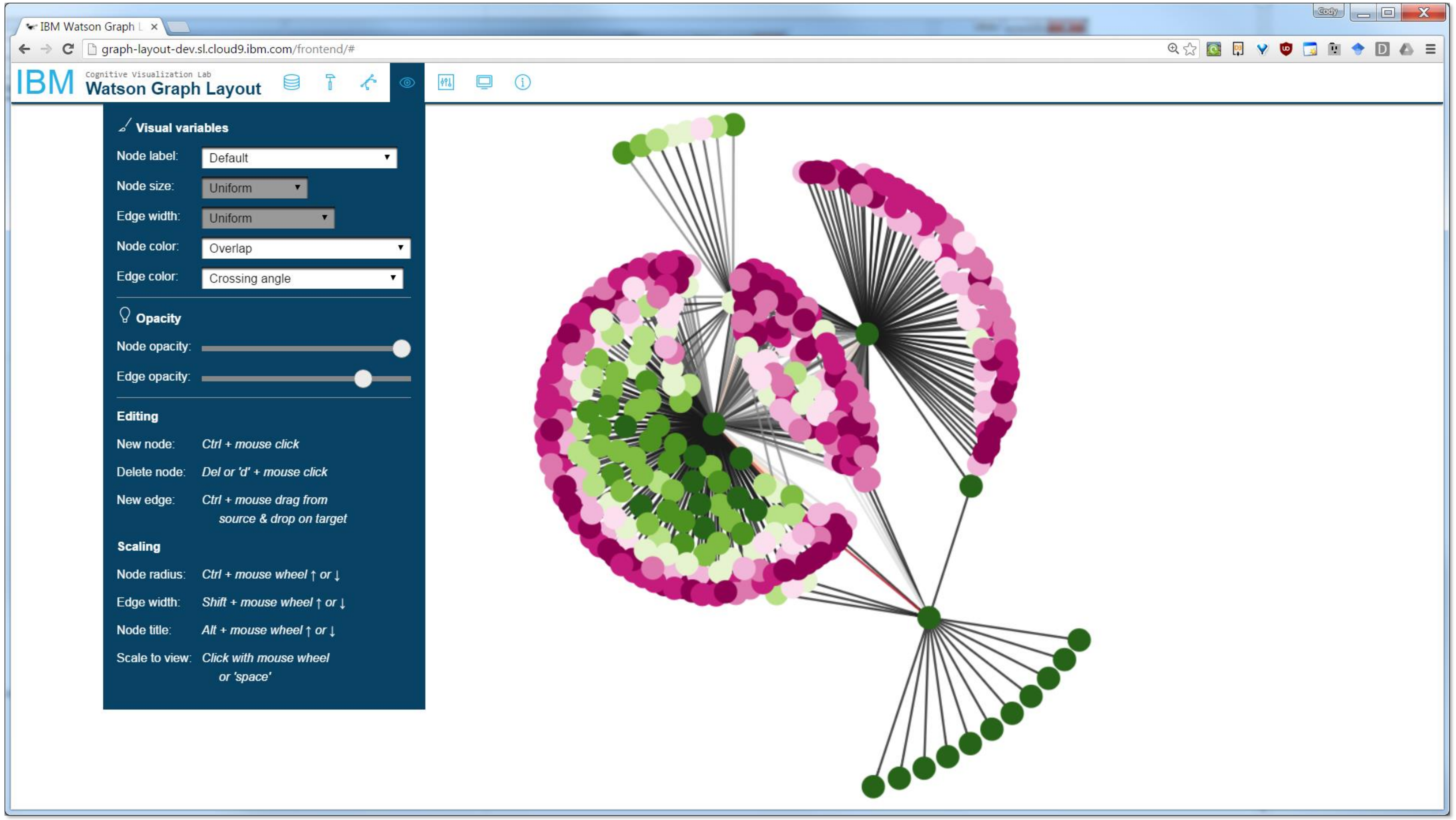
(4) Whether the rule is hierarchical (H), or flat (F), or both (B).

Sugiyama, 2002

Dunne et al.'s Readability Metrics

- Distance coherence
- Edge crossing angle
- Edge crossing
- Angular resolution (correction of deviation formula in Gove 2018)
- Node overlap
- Edge tunnel
- Group overlap
- Drawing space used

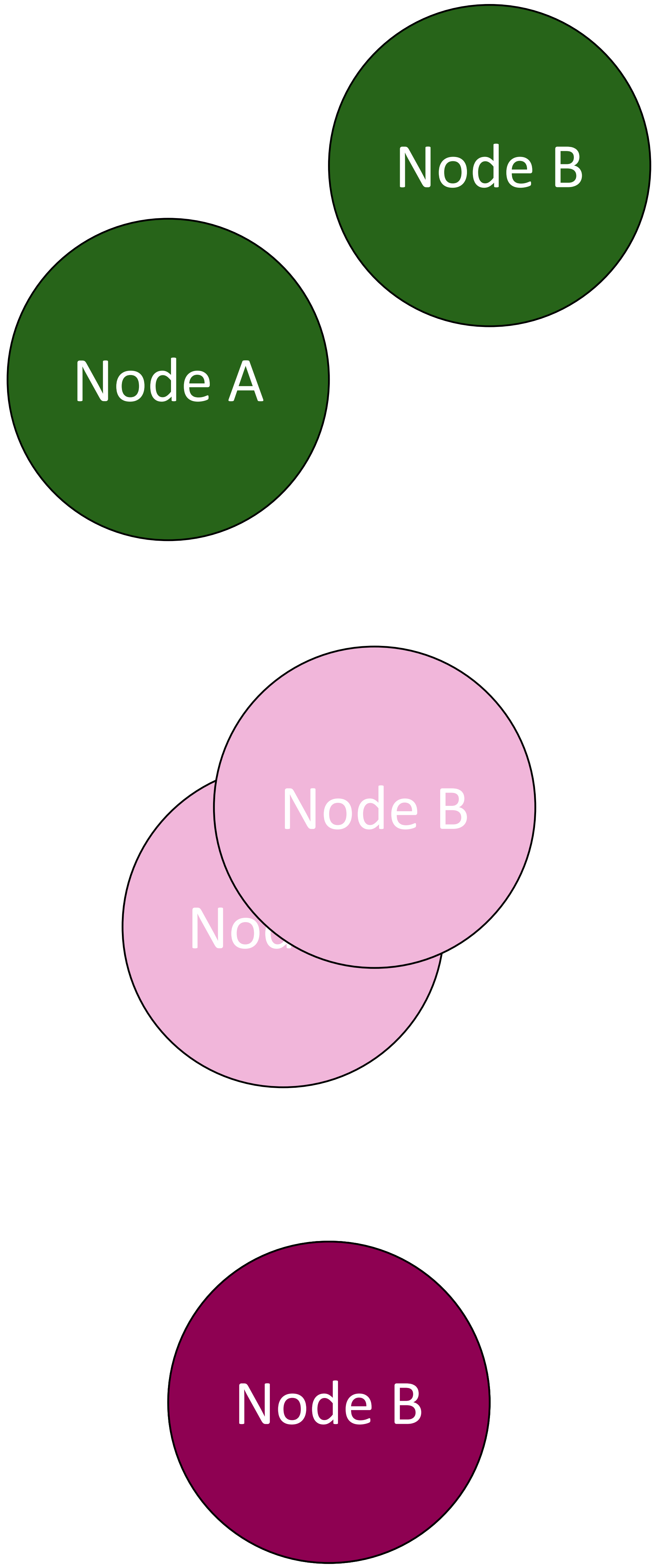
Global & Local!

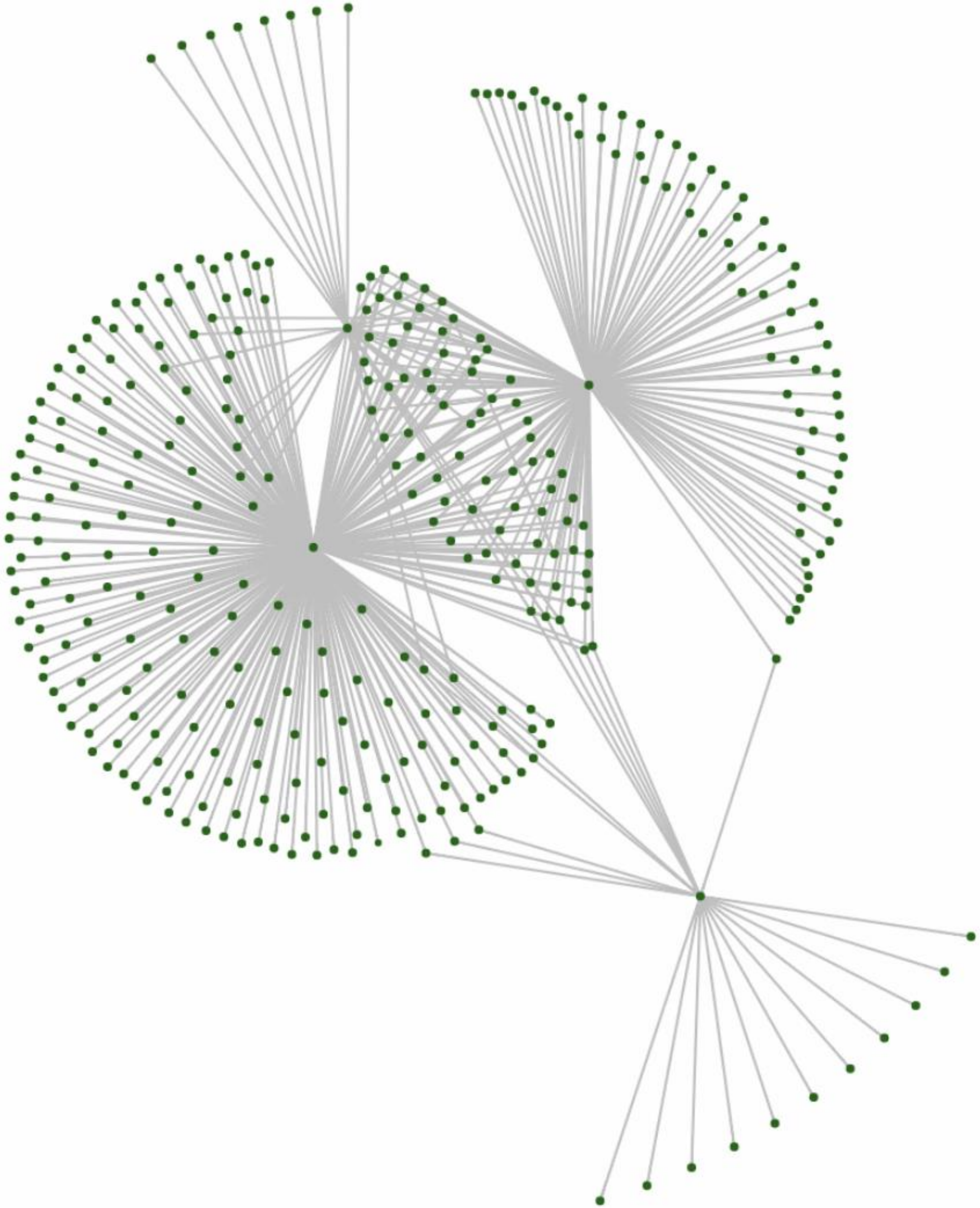


Dunne et al., 2015

Node Overlap

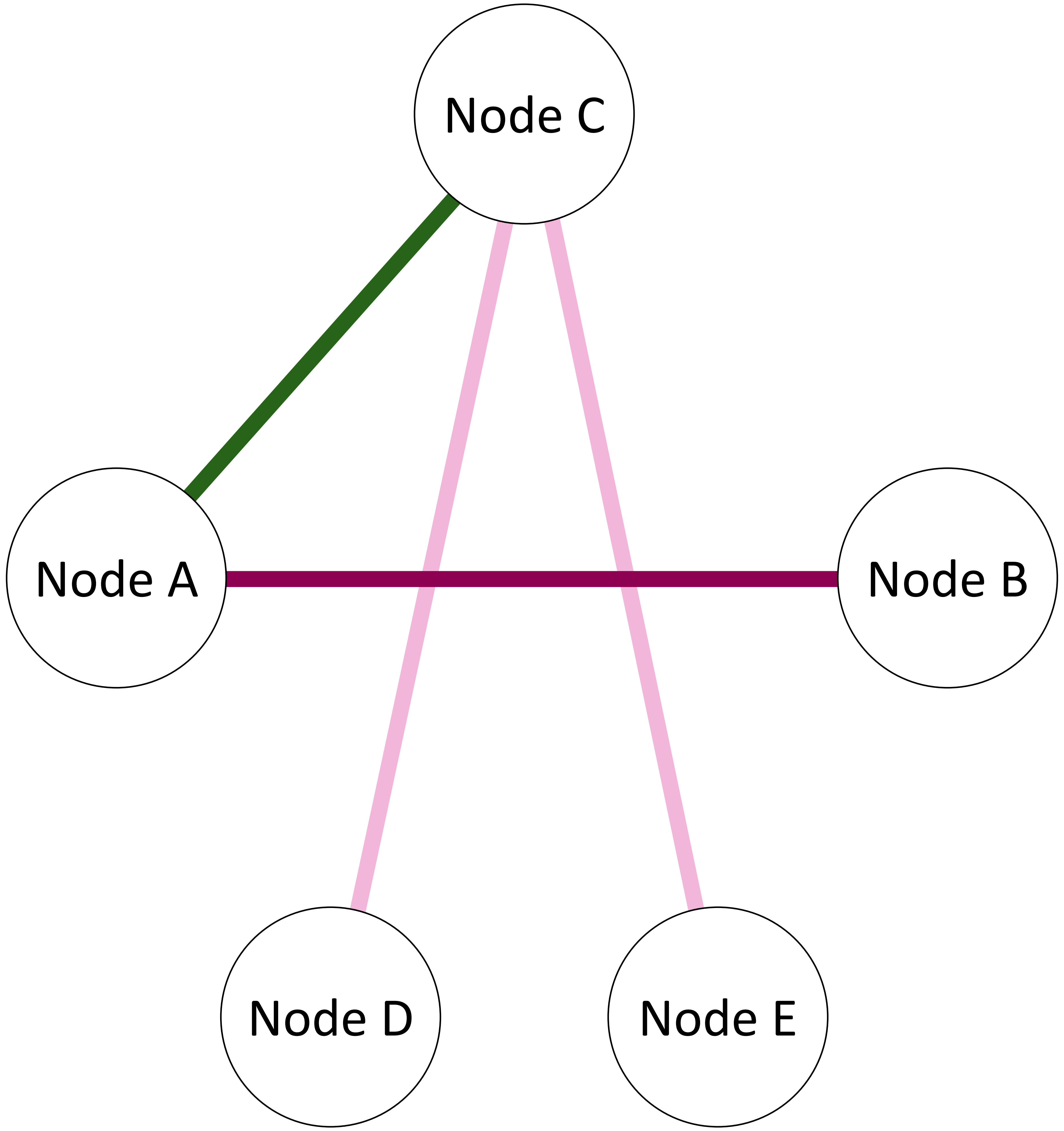
Node-Local Metric

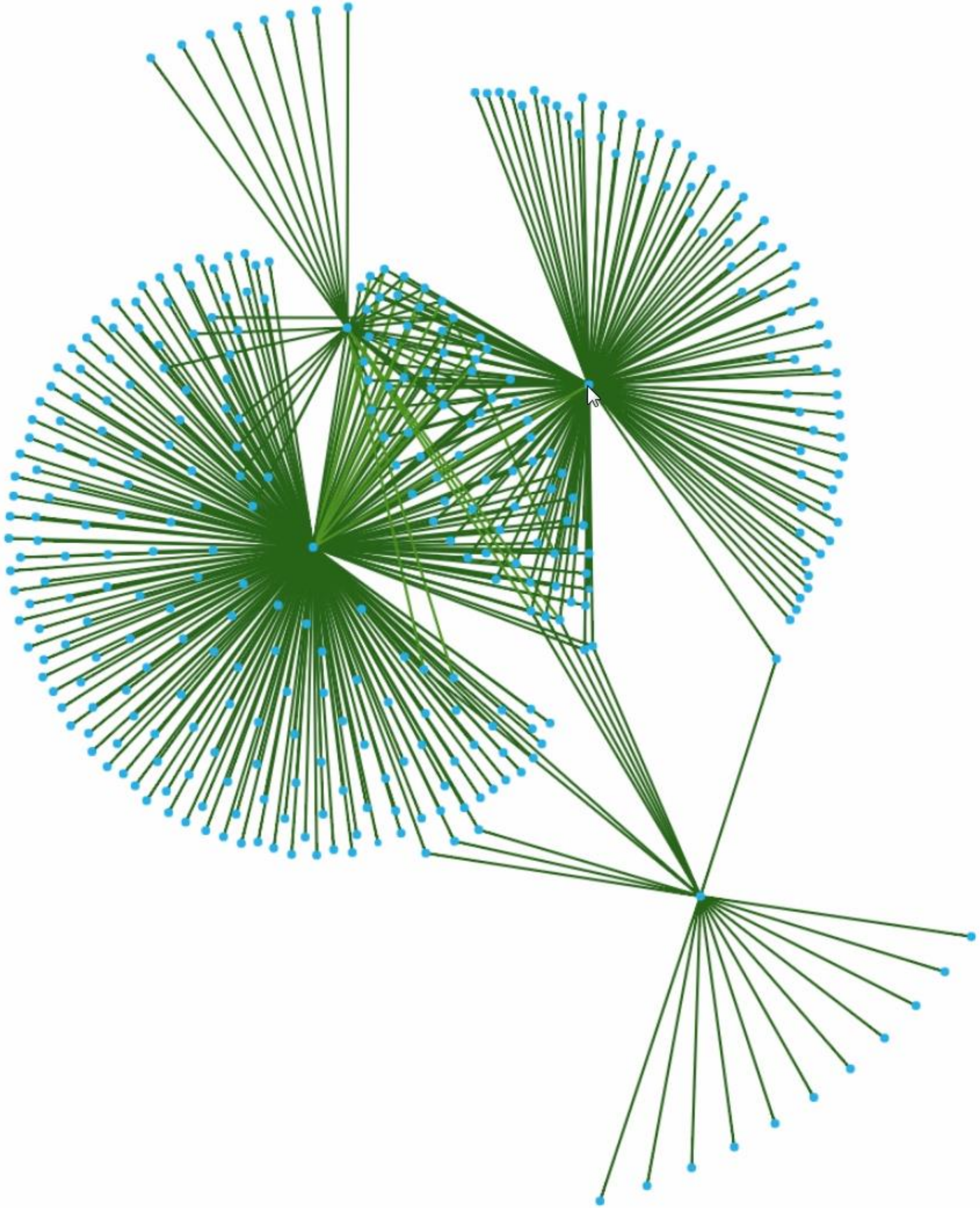




Edge Crossing

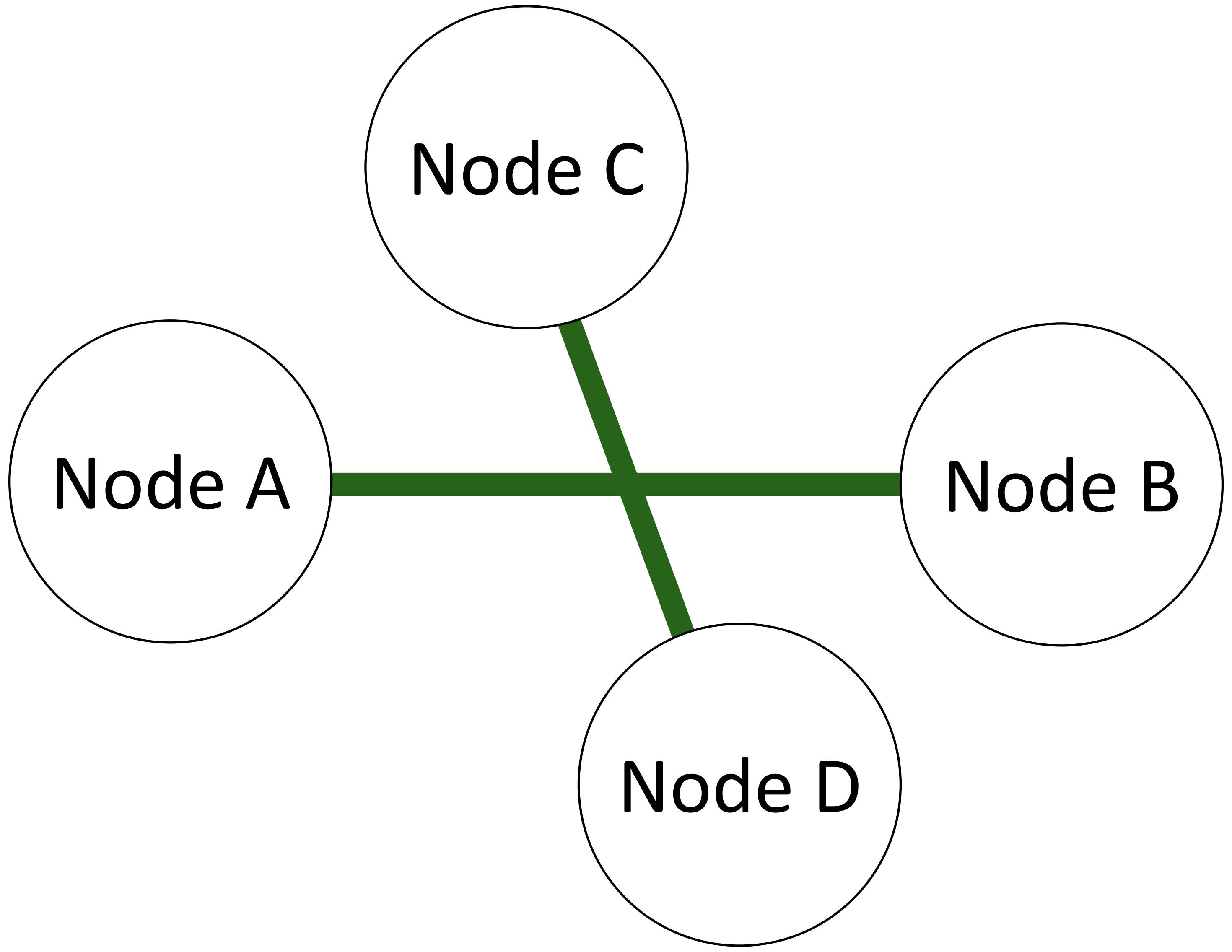
Edge-Local Metric

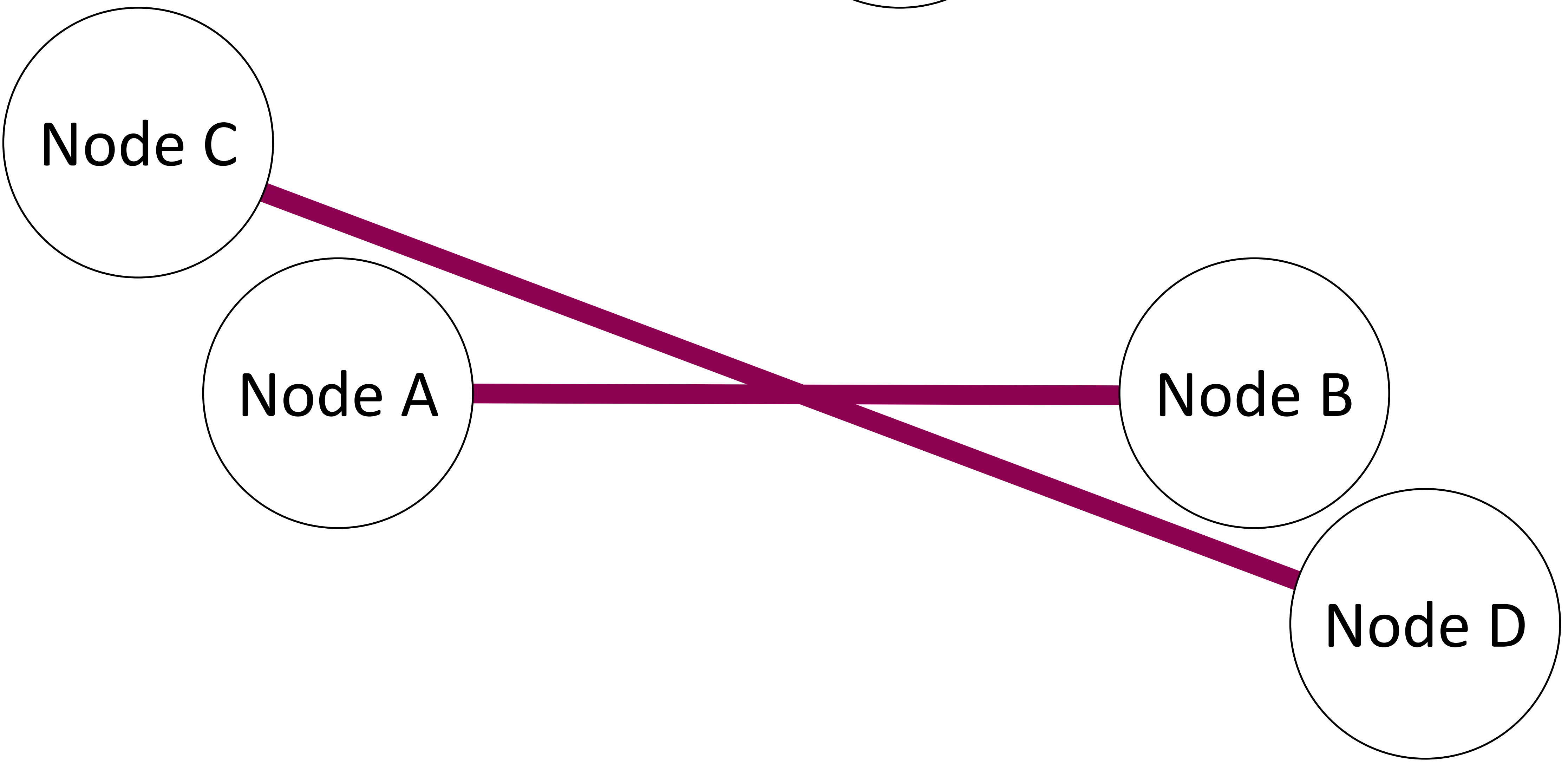


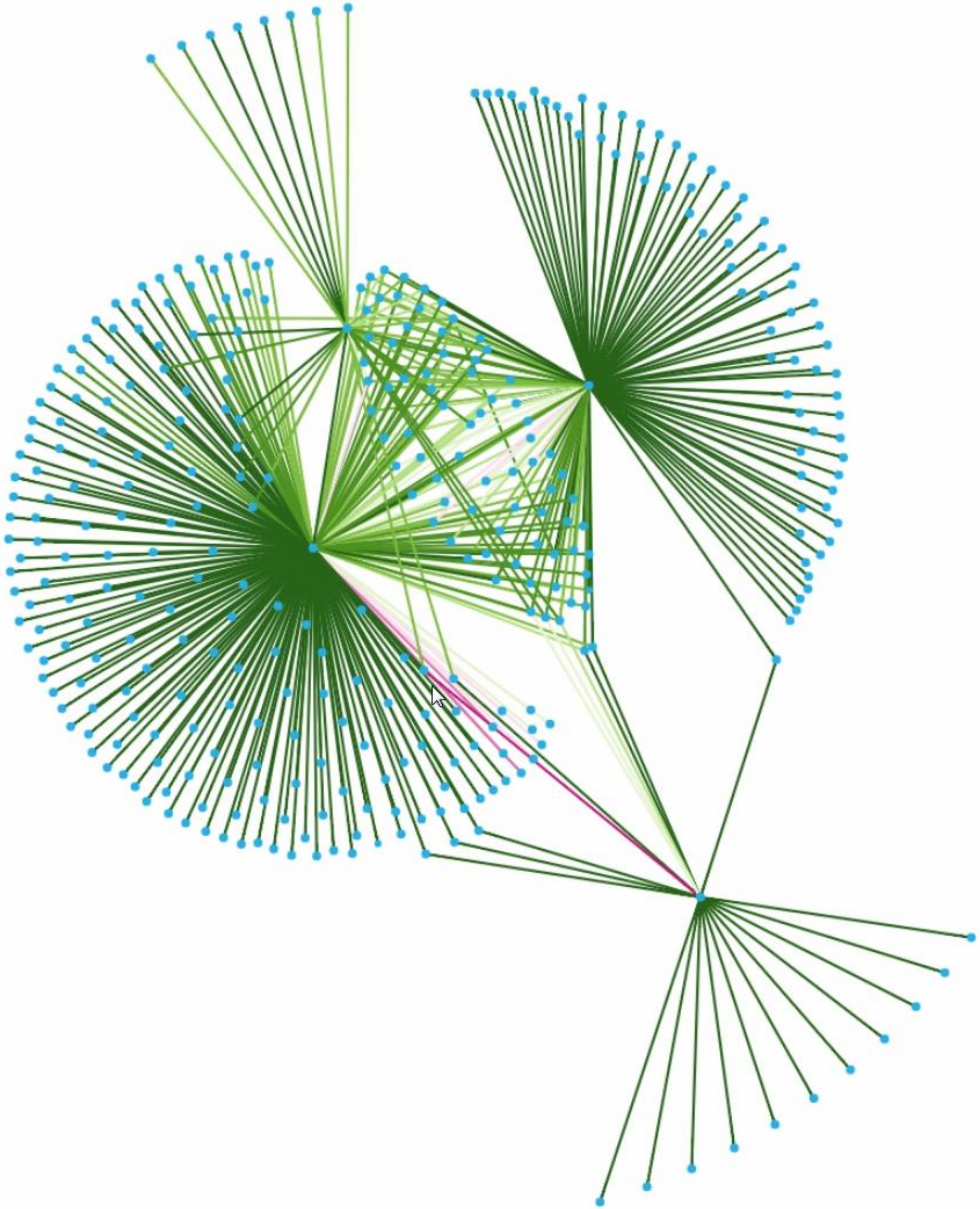


Edge Crossing Angle

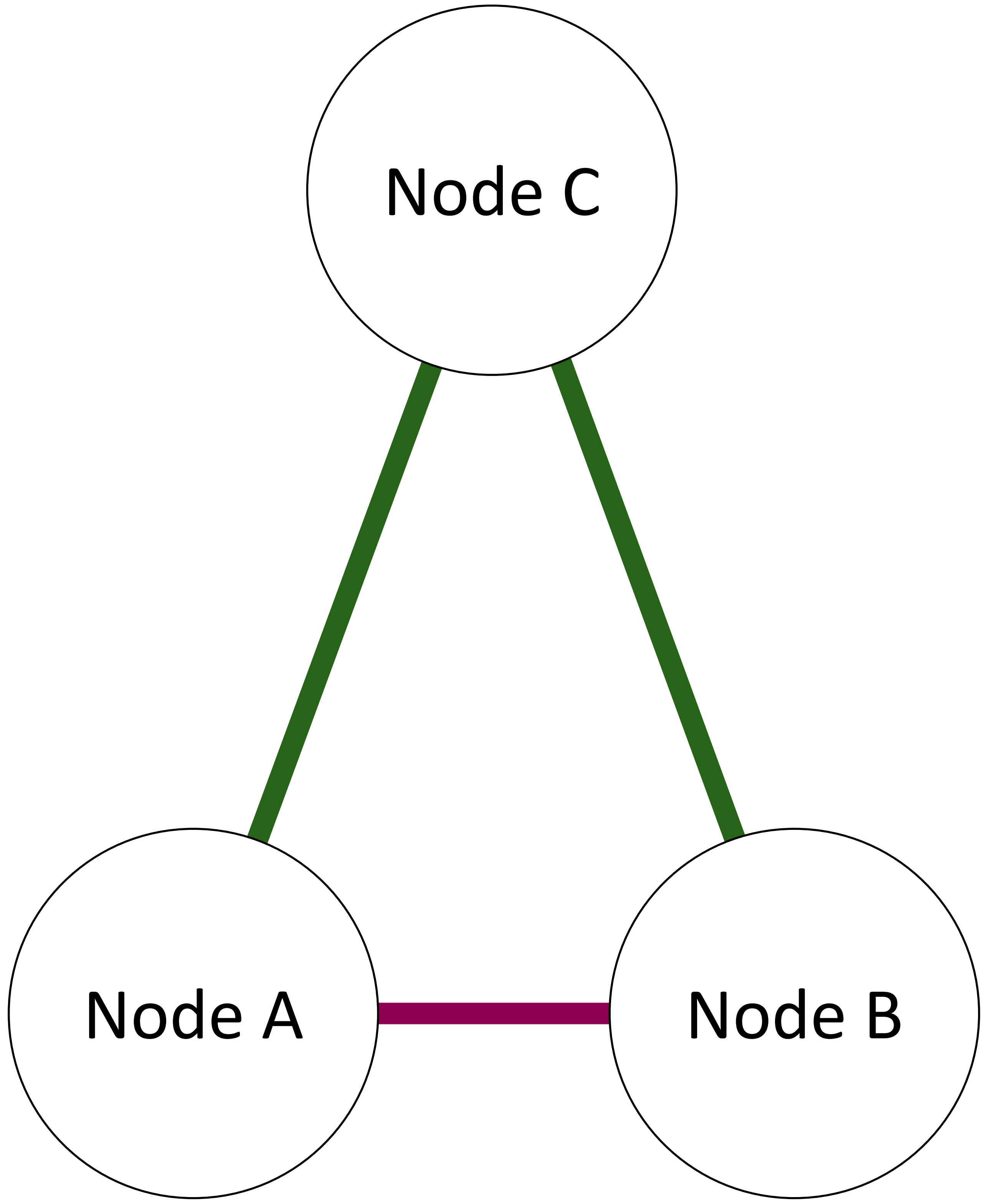
Edge-Local Metric

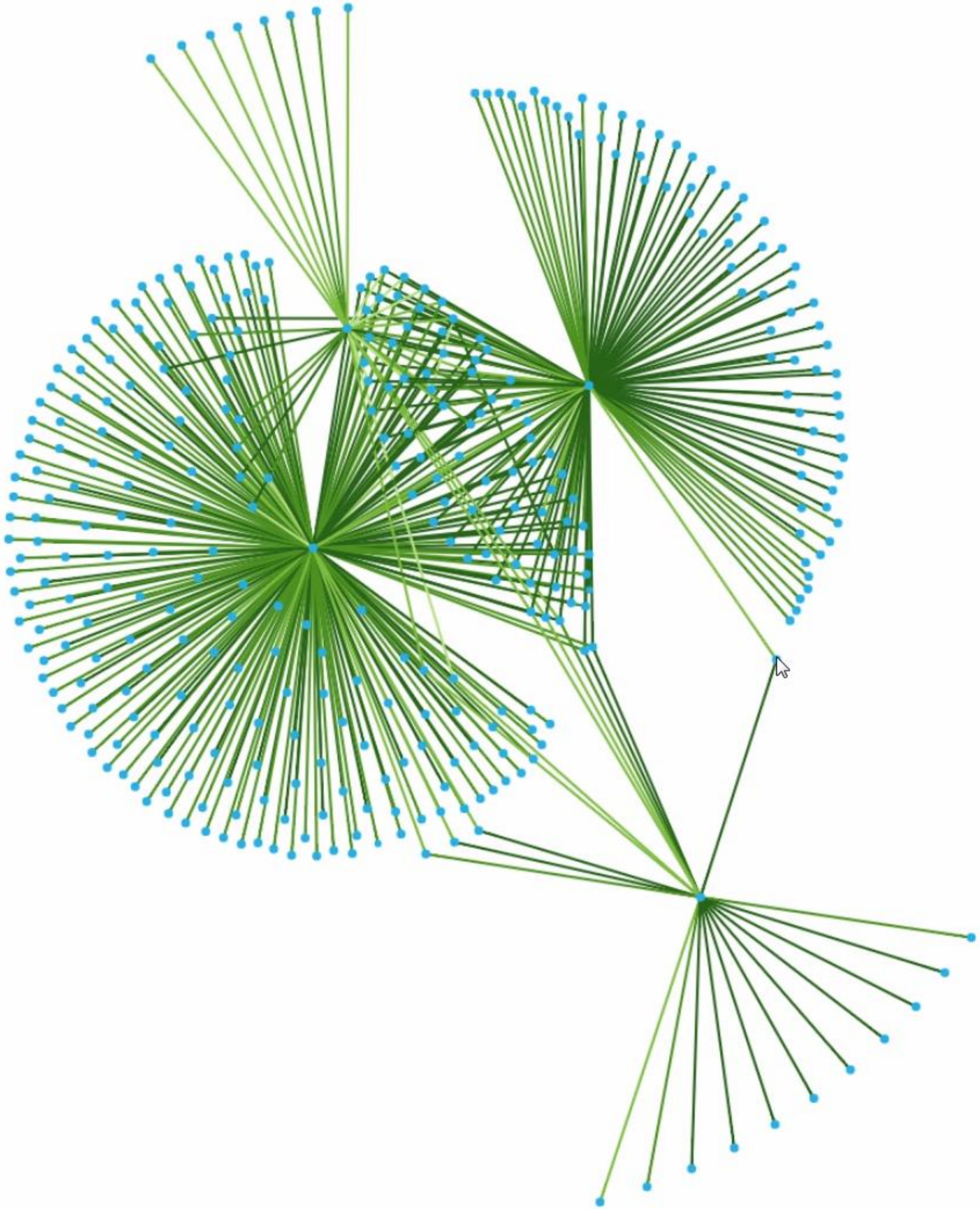






Distance Coherence
Edge-Local Metric



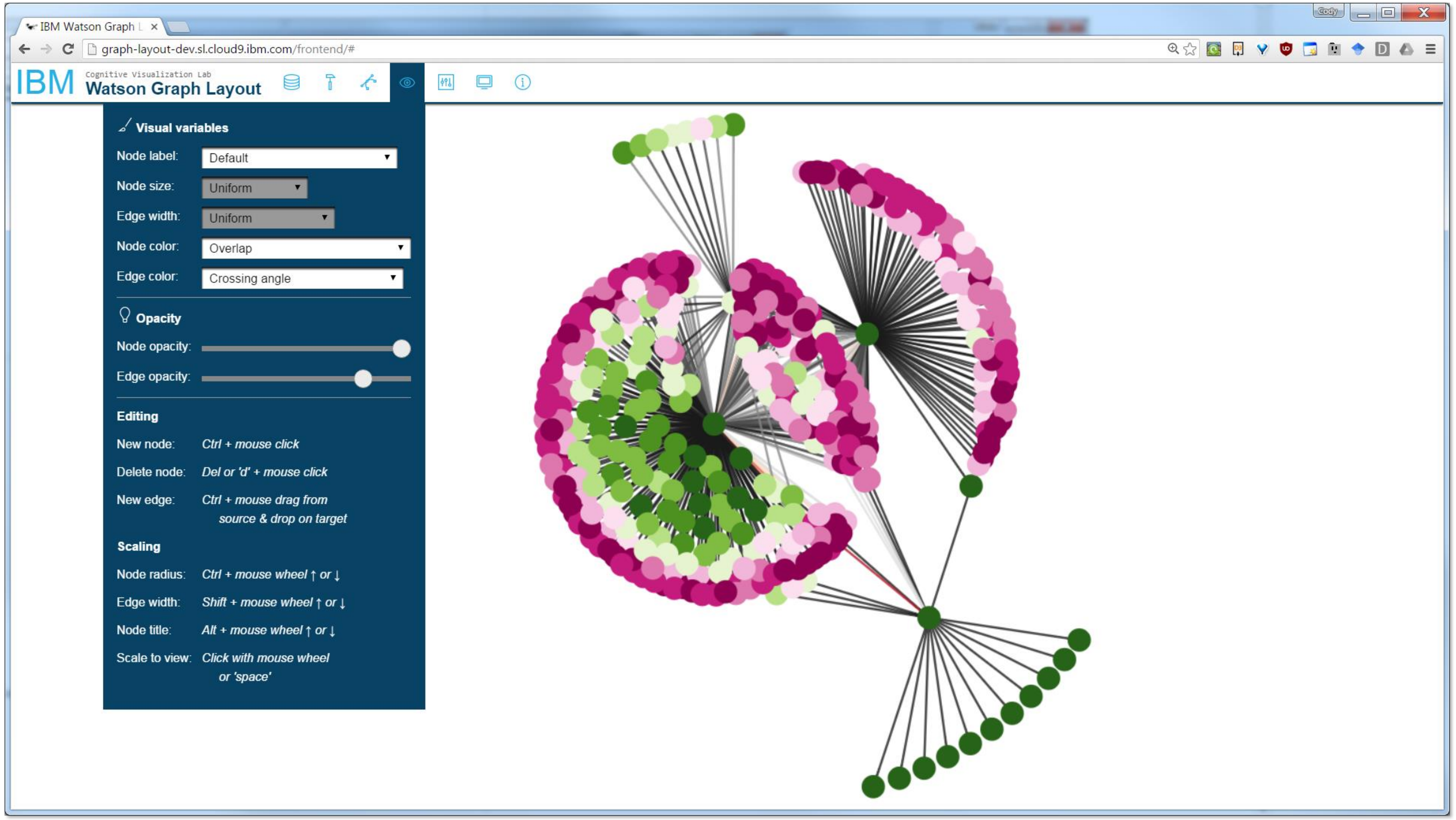


File Name	Nodes	Edges	EC	NO	ECA	AR_M	AR_D
ar_base.graphml	9	10	1.00	1.00	1.00	0.72	0.73
ar_test2.graphml	9	10	1.00	1.00	1.00	0.53	0.57
ar_test3.graphml	9	10	0.96	1.00	0.88	0.65	0.65
GraphML-10201_v2_scale_und~1	311	564	0.98	0.92	0.73	0.57	0.58
GraphML-10201_v2_scale_und~2	311	564	0.98	0.76	0.71	0.60	0.61
small-good_ec-good_eca.graphml	4	4	1.00	1.00	1.00	0.47	0.42
small-med_no.graphml	4	4	1.00	1.00	1.00	0.37	0.42
small-poor_ec-good_eca.graphml	4	4	0.00	1.00	0.83	0.45	0.42
small-poor_ec-ok_eca.graphml	4	4	0.00	1.00	0.84	0.43	0.42
small-poor_ec-poor_eca.graphml	4	4	0.00	1.00	0.03	0.33	0.41
gg-18806.graphml	10433	11944	1.00	0.88	0.68	0.93	0.93
gg-18807.graphml	10433	11944	0.99	1.00	0.71	0.92	0.92
gg-19242.graphml	2658	4039	0.98	0.38	0.68	0.64	0.66
gg-19243.graphml	4099	3350	1.00	0.31	0.62	0.94	0.95

bad — good

Dunne et al.’s Readability Metrics

- Raise awareness of readability issues
- Compare layouts of a graph
- Localized identification of where improvement is needed
- Interactive optimization
- Feed into algorithms



Dunne et al., 2015

22m

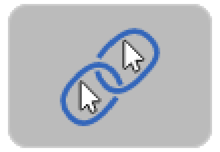
In-Class Algorithms: Network Planarity Party

INSTRUCTIONS:

Aim of the assignment:
In this exercise you will learn about network layout readability criteria, especially edge crossing minimization. You will work in teams to eliminate edge crossings from several node-link network visualizations. You will do this using Planarity Party, a puzzle game we created that will let you connect with your group members and work to solve the puzzle together. Your goal is to solve as many puzzles as possible within 15 minutes.

Background information:
A planar graph is a graph that can be drawn with no edge crossings. However, actually drawing the graph quickly but with no edge crossings can be a challenging algorithmic task.

Instructions:
(3 min) Setup

- Break into groups of 3–4
- Pick a leader for your group.
- The leader should load Planarity Party, preferably in Firefox or Chrome: https://michaschwab.github.io/VisConnect/examples/planarity/
- Click the link icon at the bottom-right corner to copy invite link for your group to the clipboard. It looks like this: 
- Share the link to your group members and wait for them to join. You will be able to see how many people are connected by the number in the bottom. You will also be able to see the mouse cursor of all members as a small colored circle.

(15 min) Start solving puzzles!

- Each can be solved by dragging around the nodes until there are no edge crossings. The number of crossings is shown at the top, along with the number of moves you all have made.
- When all edge crossings are removed the nodes will turn yellow and you will be able to move to the next graph. A force-directed layout of the network will also appear at the bottom of the screen for comparison.
- Every new network will be harder than the last one. See how far you can make it in 15 minutes!

Wrap up:

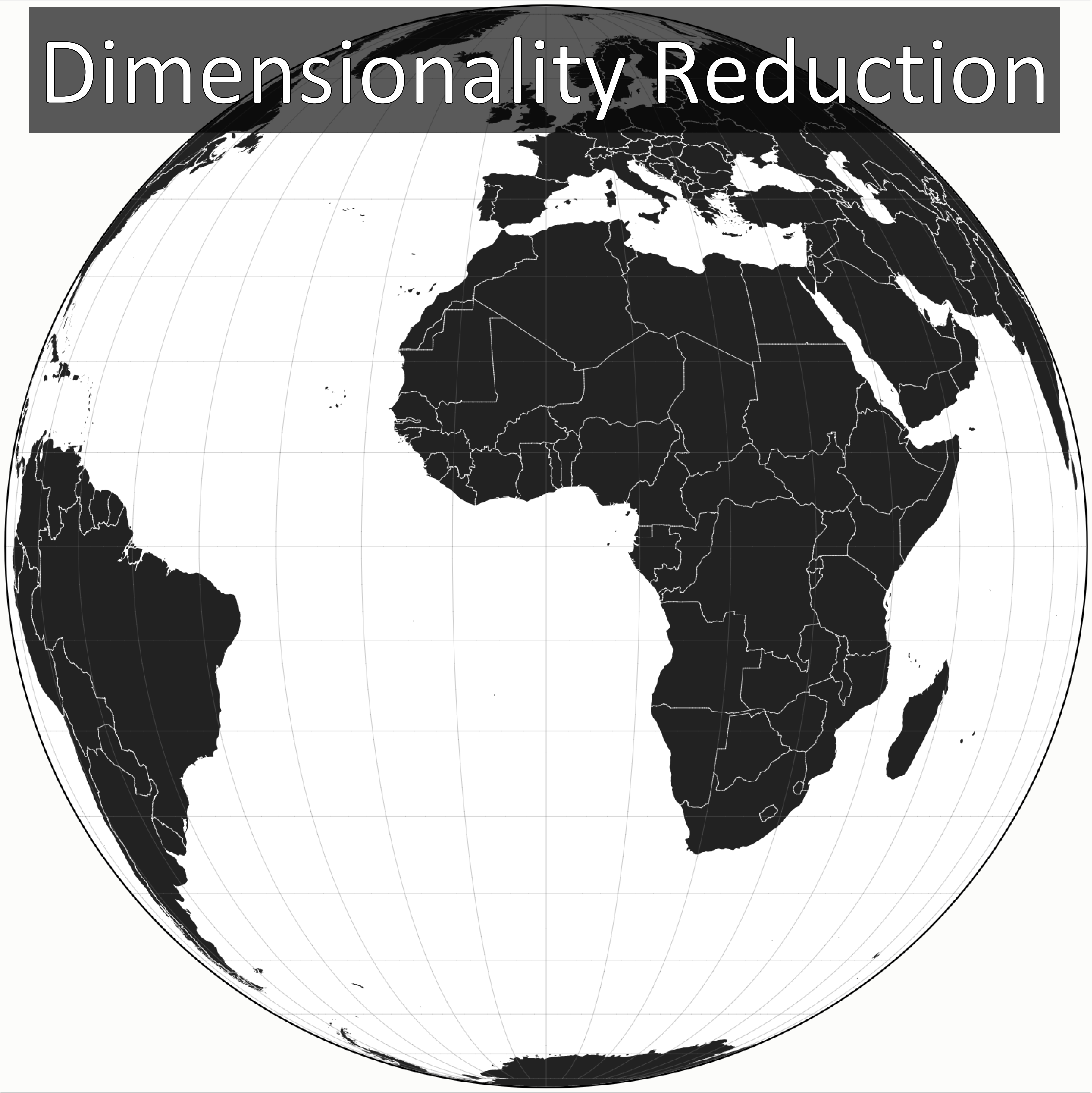
(4 min) We will discuss the exercise as a class.

Troubleshooting:
Unfortunately, Planarity Party is a research demo and can be a bit finicky. If you have any problems:

- Please reach out to the teaching staff.
- Try starting from scratch with a new instance of Planarity Party.
- Try a different browser / private browsing window.
- Have a different student create the instance.

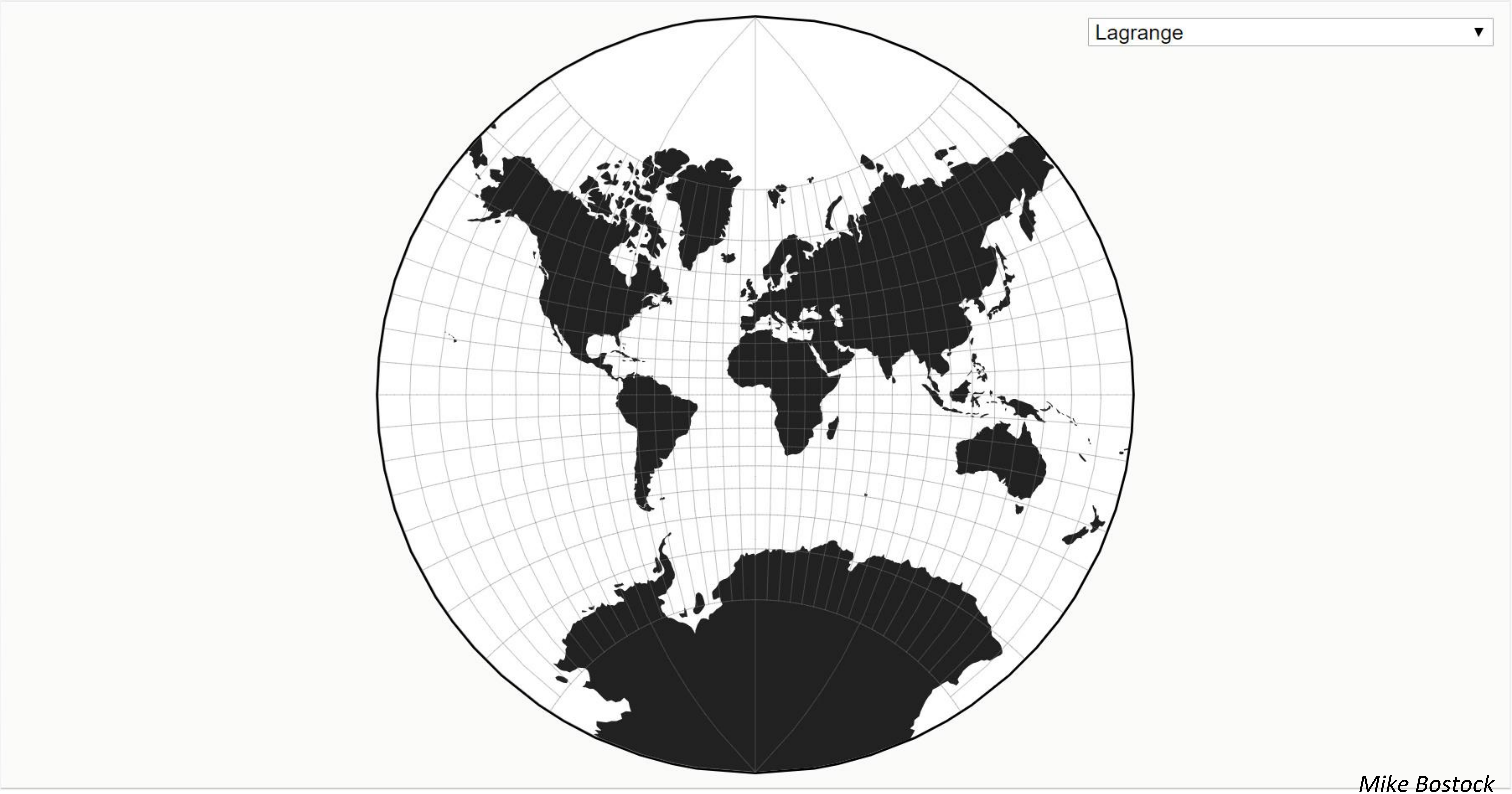
HEURISTIC LAYOUT ALGORITHMS

Dimensionality Reduction



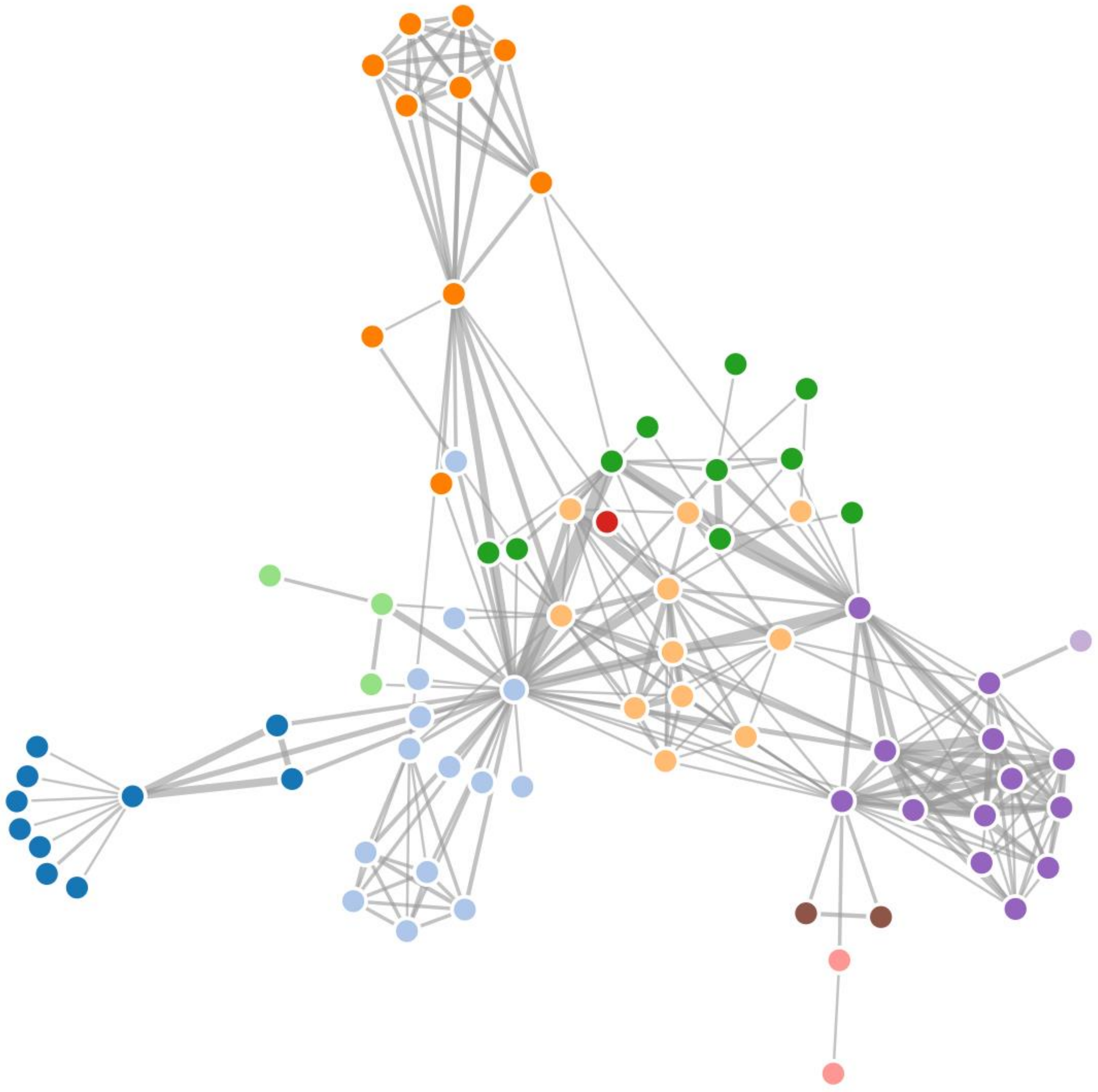
Mike Bostock

Projection Transitions



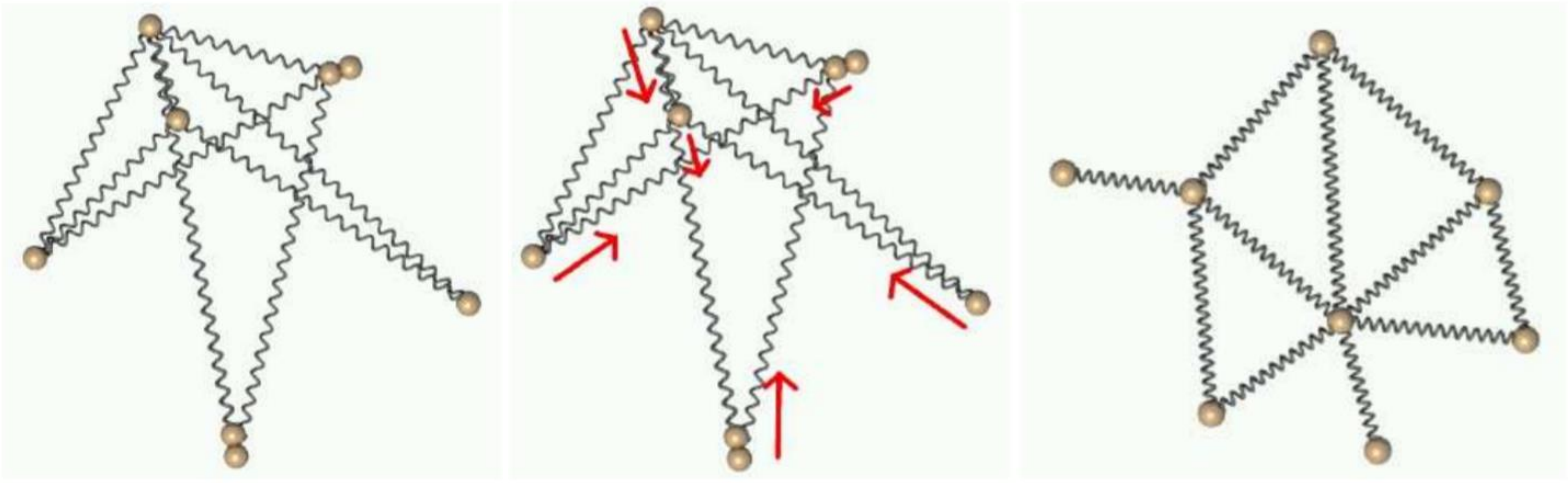
Mike Bostock

D3 Force-Directed Layout



Mike Bostock

Force-Directed Algorithms



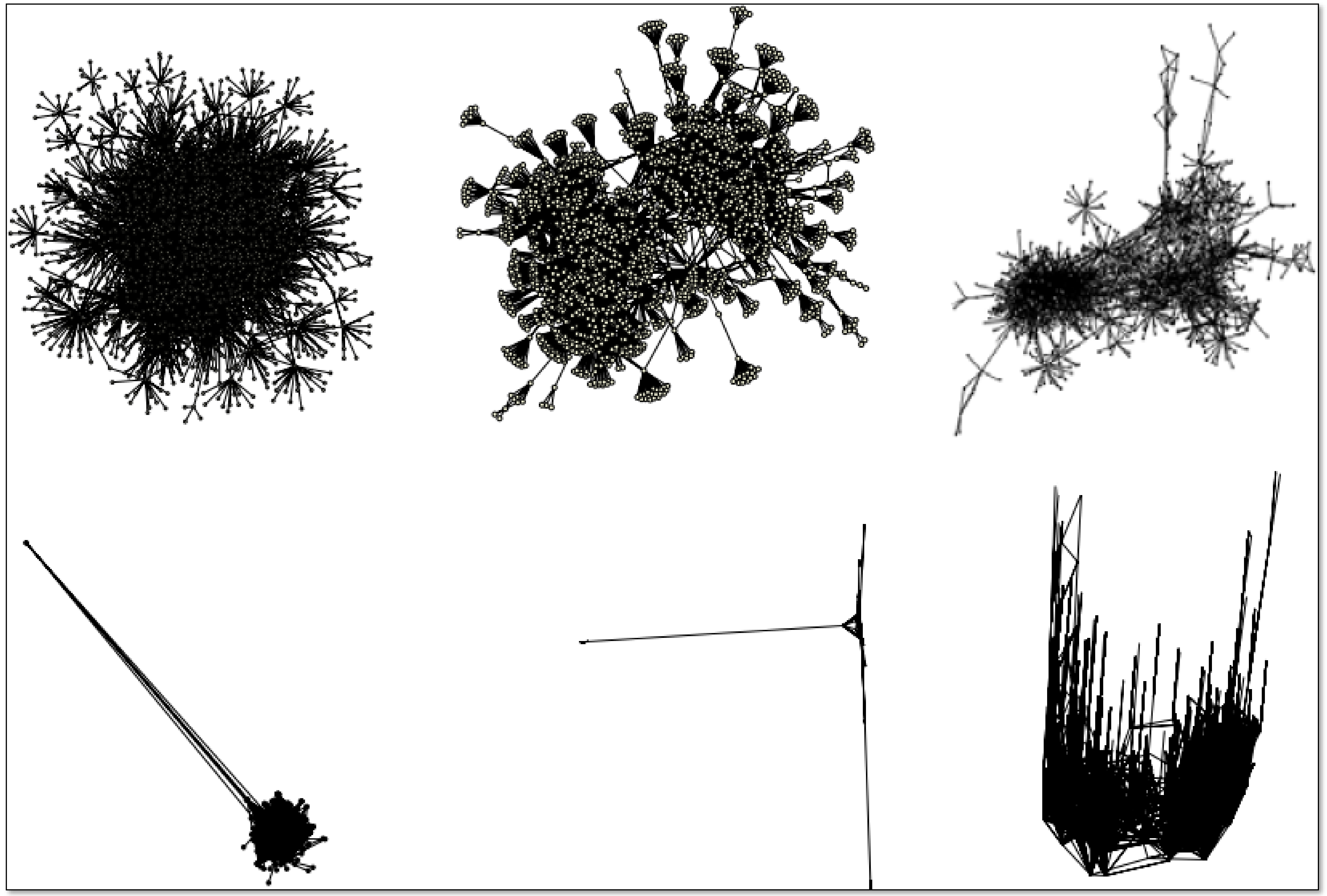
Kobourov, 2012


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

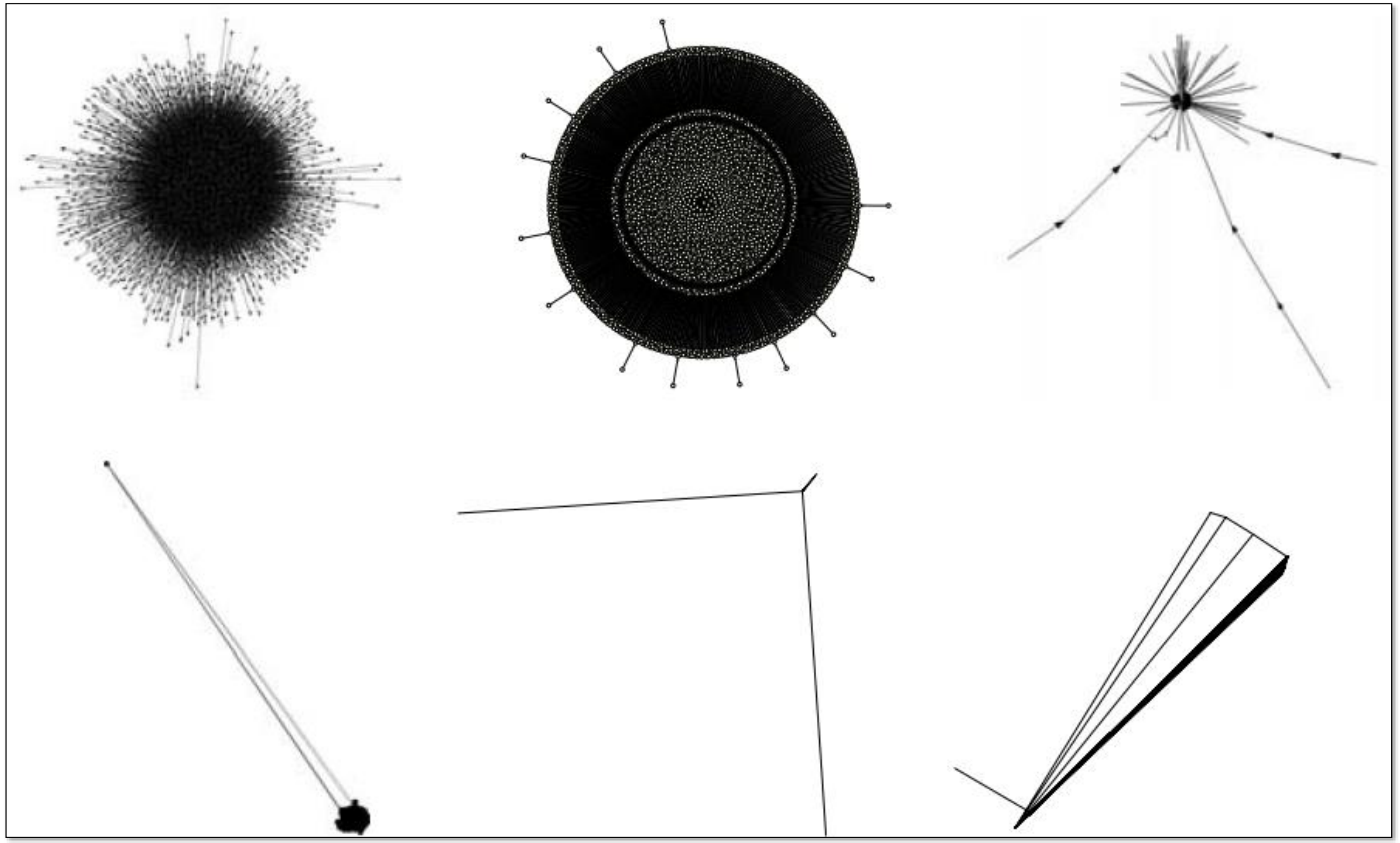
localhost:8080/euler.html
localhost:8080/euler.html
Layout
IBM Watson Graph Layout
graph-layout-dev.sl.cloud9.ibm.com/frontend/#
IBM
Cognitive Visualization Lab
Watson Graph Layout
Layout
Algorithm:
SFDP
Parameters
Layout

Algorithm Comparisons

Graph A



Graph B



Hachul & Jünger, 2006

How to compare?

User performance,
controlled experiments

Huang et al., 2007, etc.

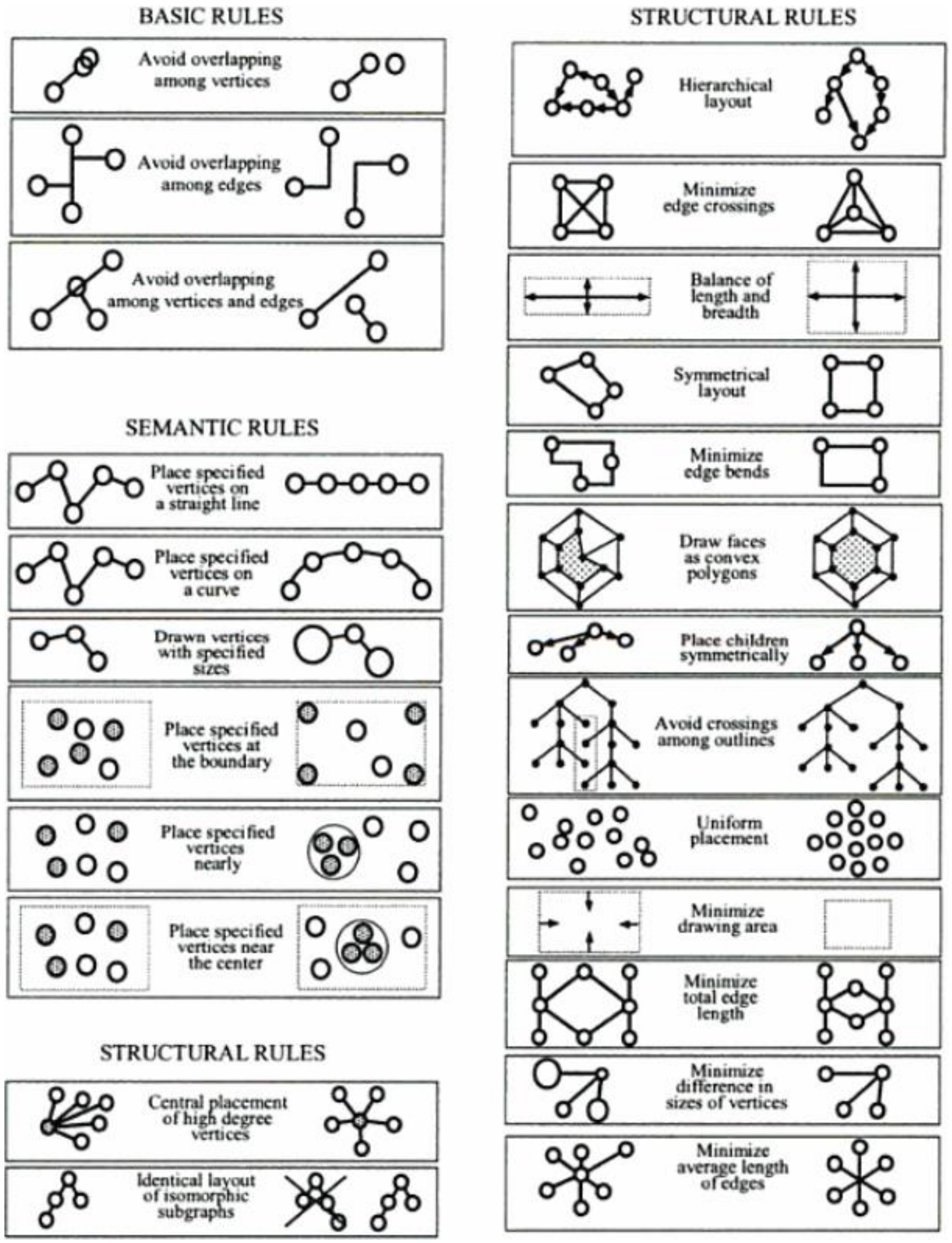
Simple rules or heuristics

Davidson & Harel, 1996

Global and local readability metrics

Purchase et al., 2002

Dunne et al., 2015



Sugiyama, 2002, p. 14

For Next Time & Communication

Homepage: https://c.dunne.dev/cs7295f21/
(project details + assignments to be added)

For next time:
- Discussion lead 1 — Topic Areas
- Assignment 1 — Read the Syllabus

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

Use Canvas Discussions for general questions, email the instructor for questions specific to you.