

Mid-term feedback:

t.ly/OXXXI

Course outline:

Week 6: Networks + Geographic data

Week 7: Temporal visualizations

Week 8: Storytelling

Week 9: Guest lecture

Week 10: Evaluation

Week 11: Pitches!

> Assignment 2

Assignment 2

- Due on April 3 (Friday), **4pm**
- Groups of 3
- Create
 - Interactive, physicalization, comic, or infographic
- Describe
 - Challenge (tutorial 2)
 - Visualization exploration (tutorial 3, 3 designs, 2 iterations each)
 - Design

Graph $G = (N, V)$

Point

Actor

Vertex

Nodes



Link

Arc

Relation(ship)

Connection

Node-link Diagram



Directed Link



Multiple Links



Link Types



Node type

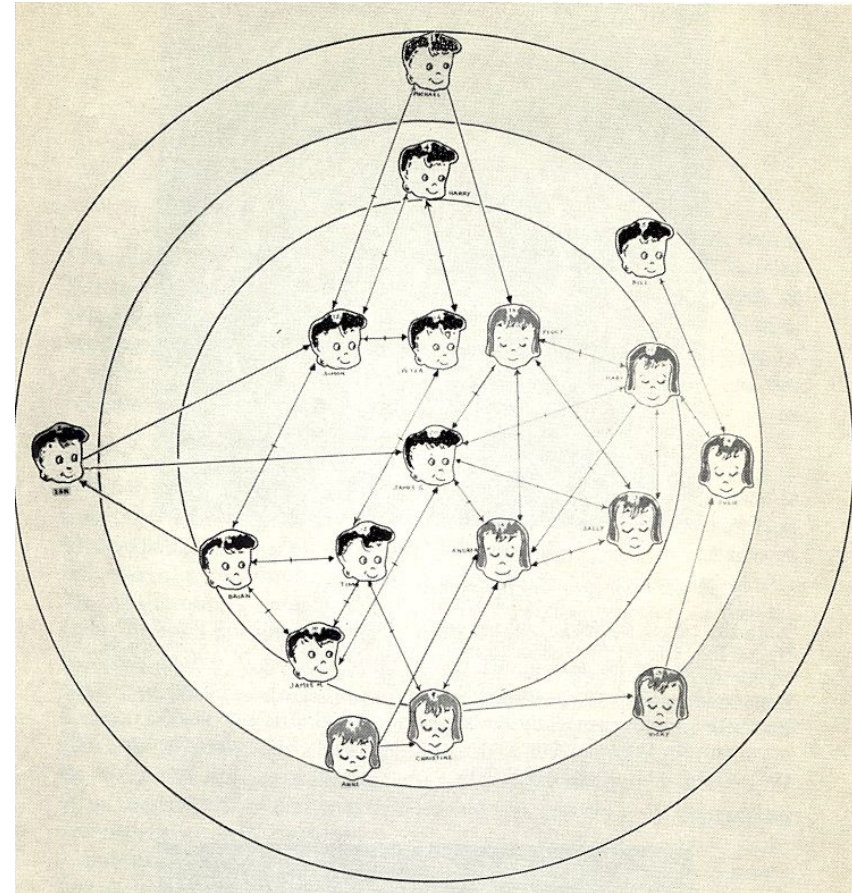


Weighted link



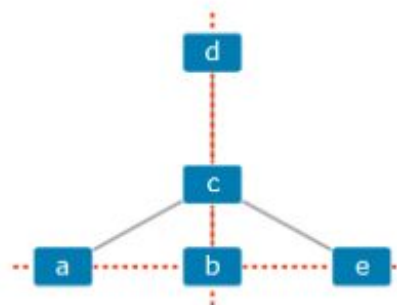
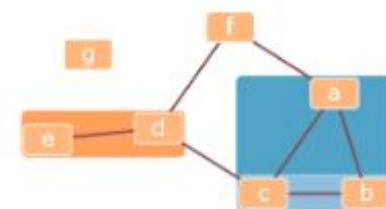
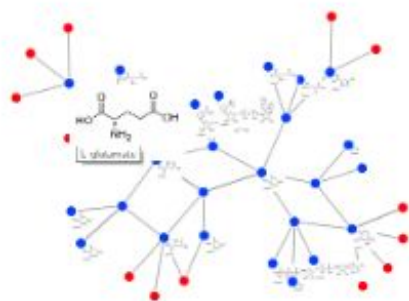
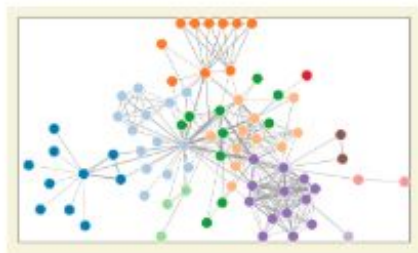
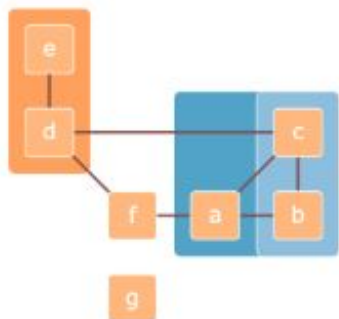
Visualizing Networks

- Finding an **embedding**
- > *Force-directed* layouts
- > springs with weights
- > finding optimal layout
- Visualize attributes
- Support network tasks



Sociograms:
Jacob Levy Moreno
(1889 – 1974)

More layouts with web-cola:



Why do we visualize networks?

- Topology

- Find nodes
- Find neighbors
- Find shortest path
- Find clusters
- Find bridge nodes

- Attributes

- Node attributes
- Link attributes

- Browse

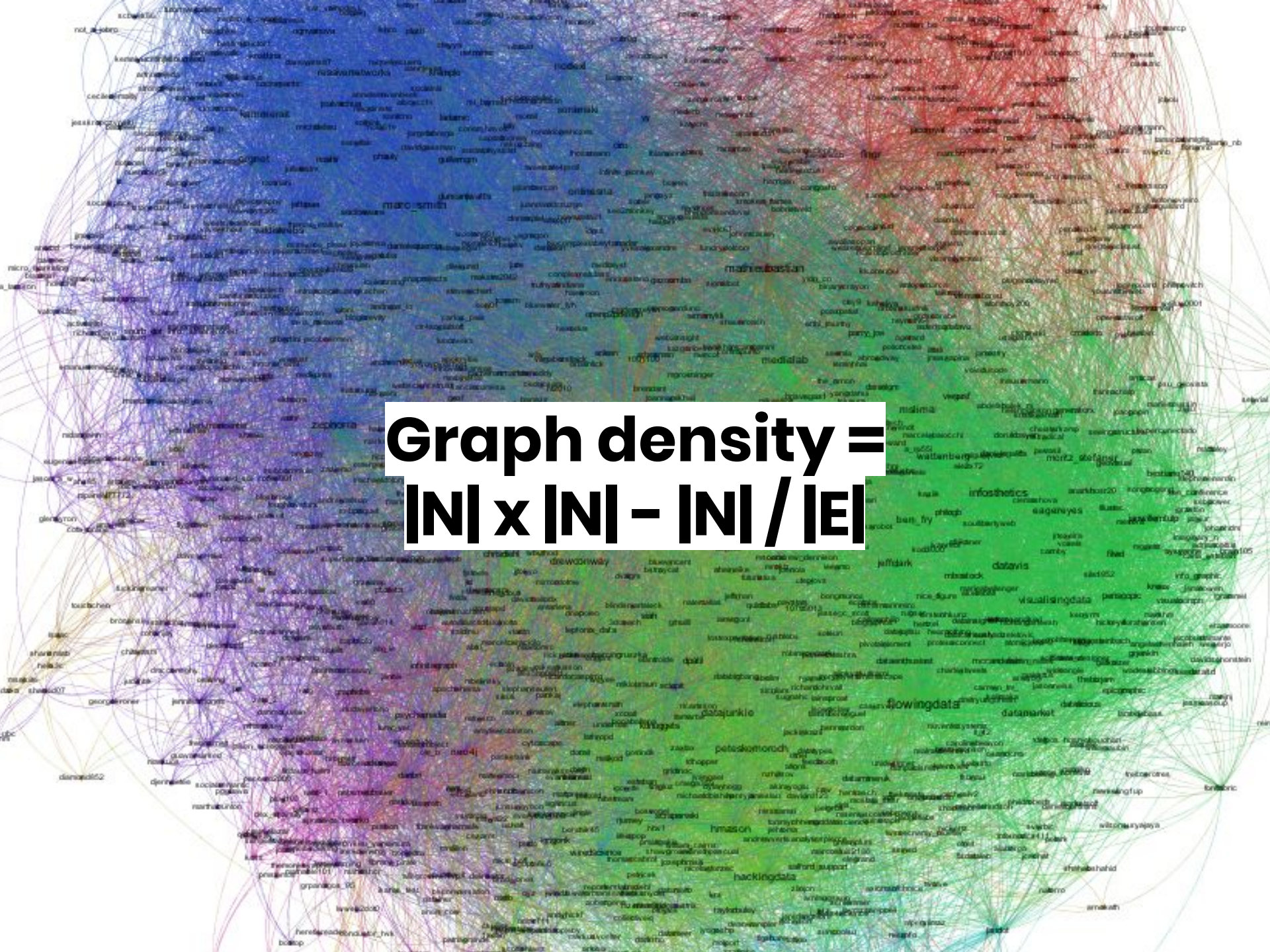
- Follow links
- Discover
- Overview

- High level

- High-level

- Graph comparison
- Temporal networks
- Geographic networks
- ...

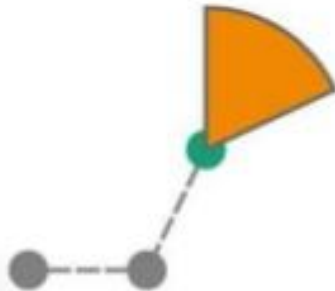
Lee, Bongshin, et al. "Task taxonomy for graph visualization." *Proceedings of the 2006 AVI workshop on BEyond time and errors: novel evaluation methods for information visualization*. 2006.



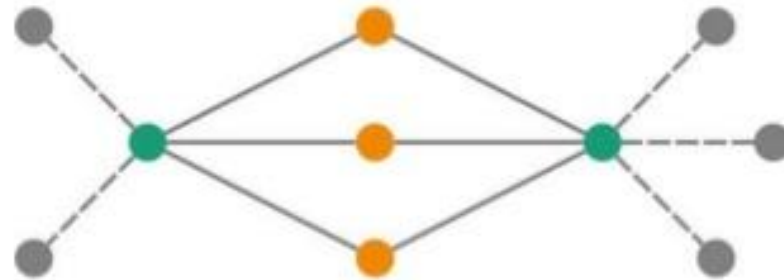
Graph density =
 $|E| / (|V| \times |V| - |V|)$

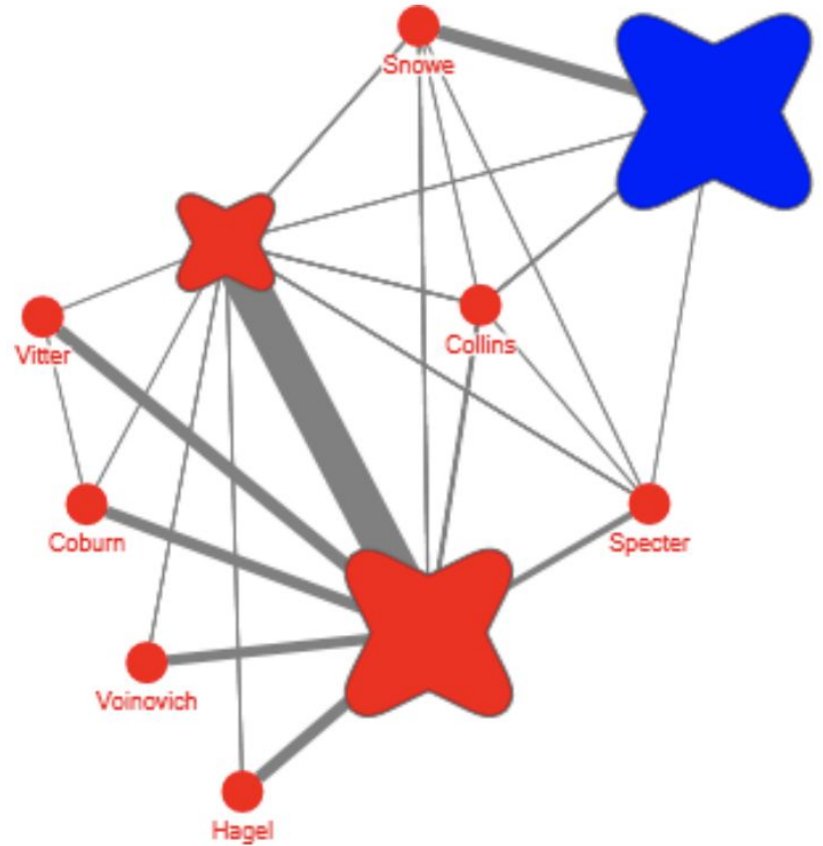
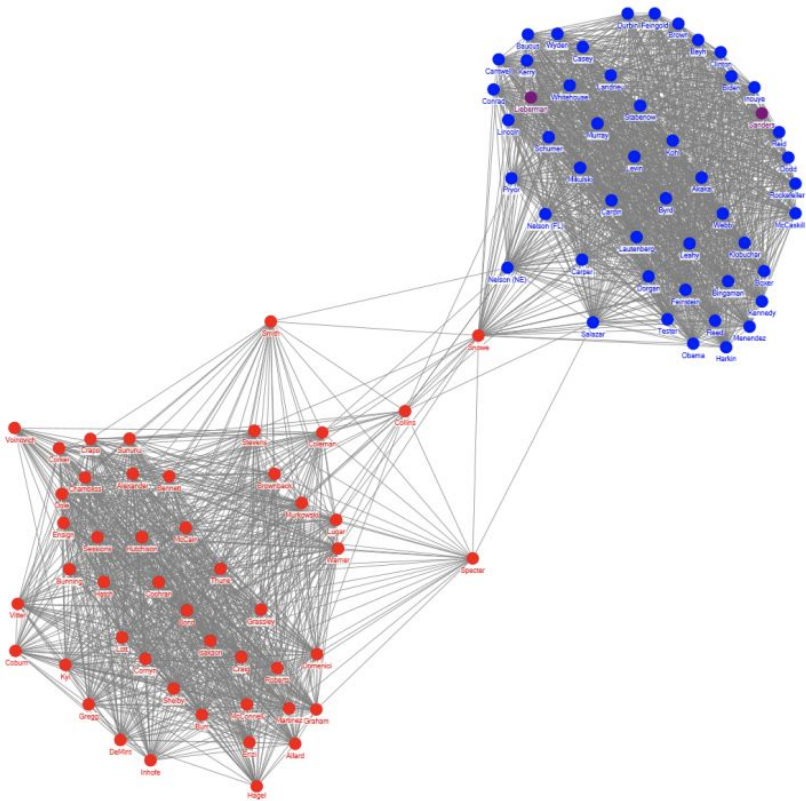
Motif Simplification

Fan Motif

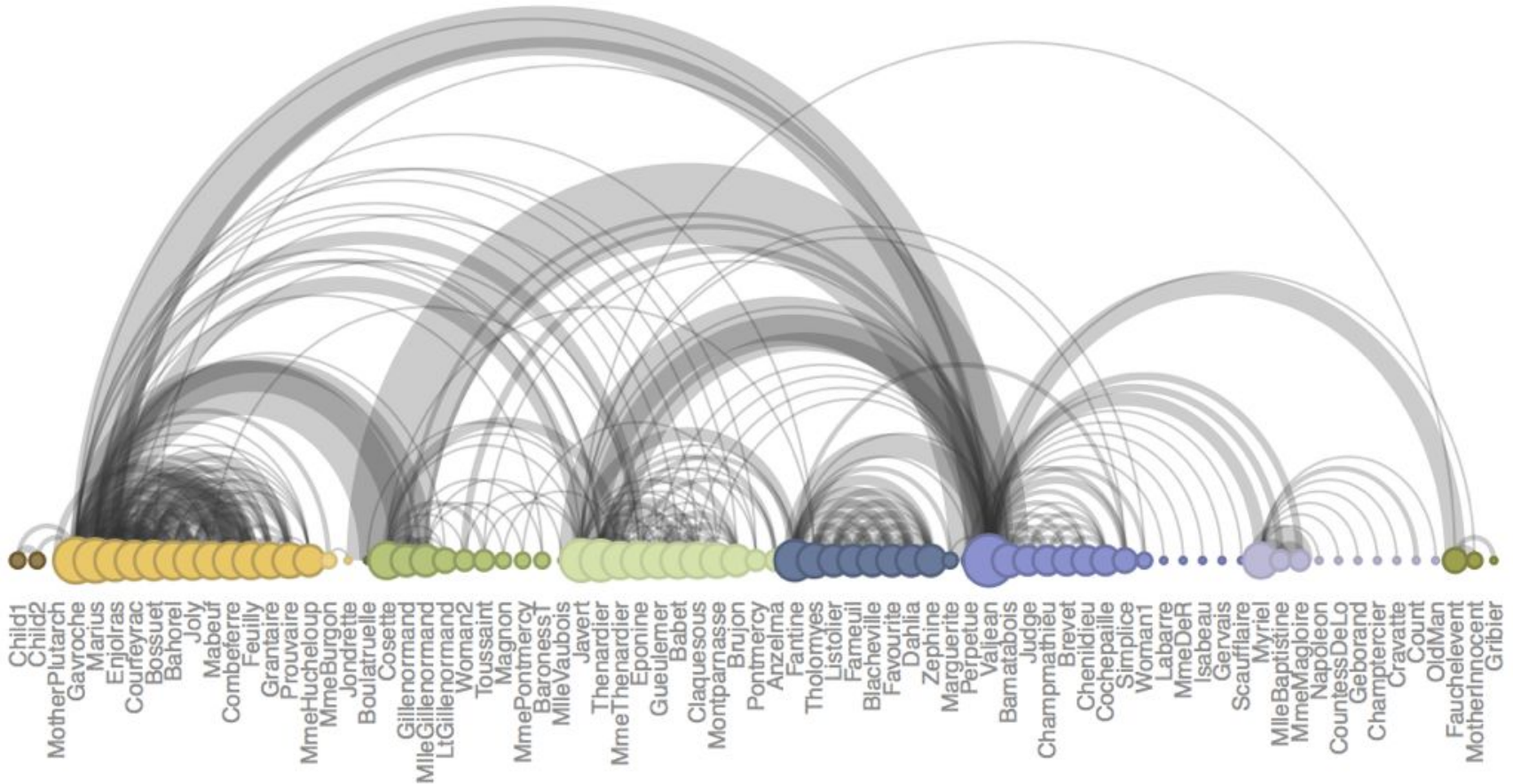


2-Connector Motif





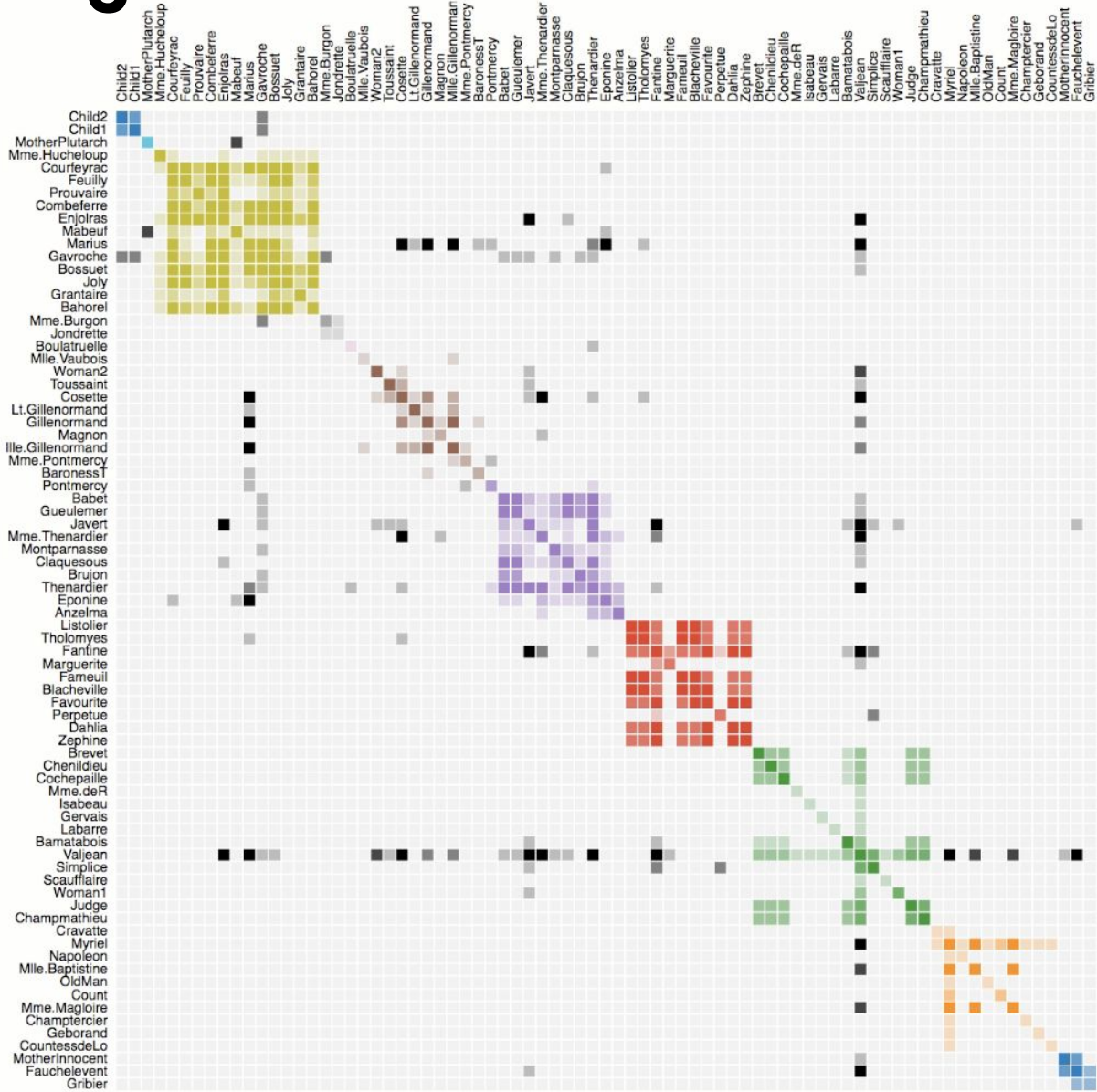
Arc Diagram

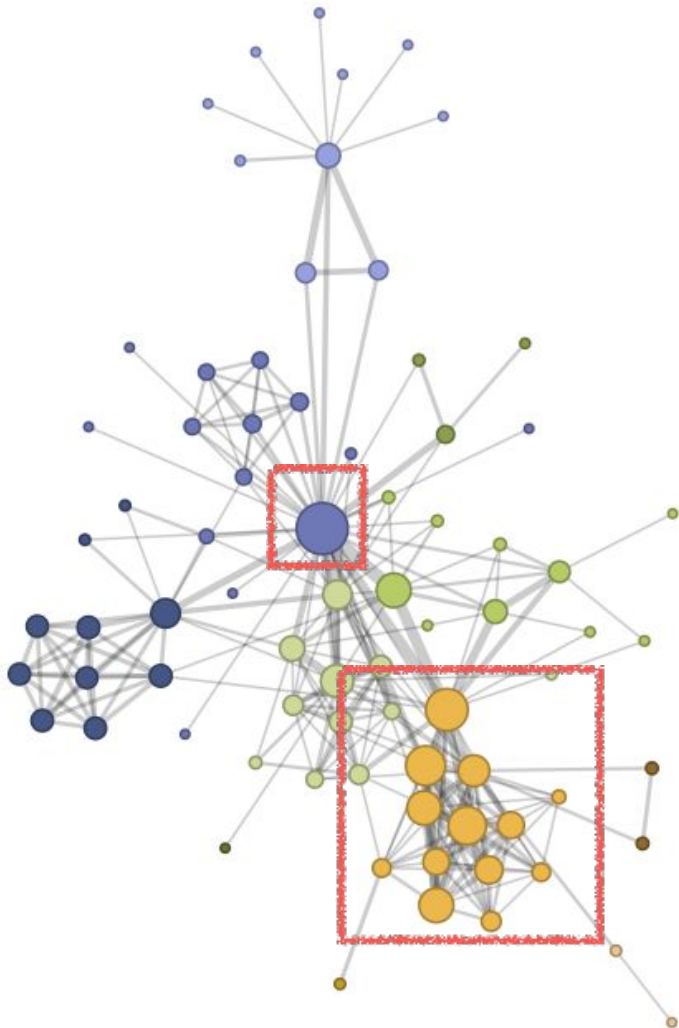


- + Node ordering
- + Node groups

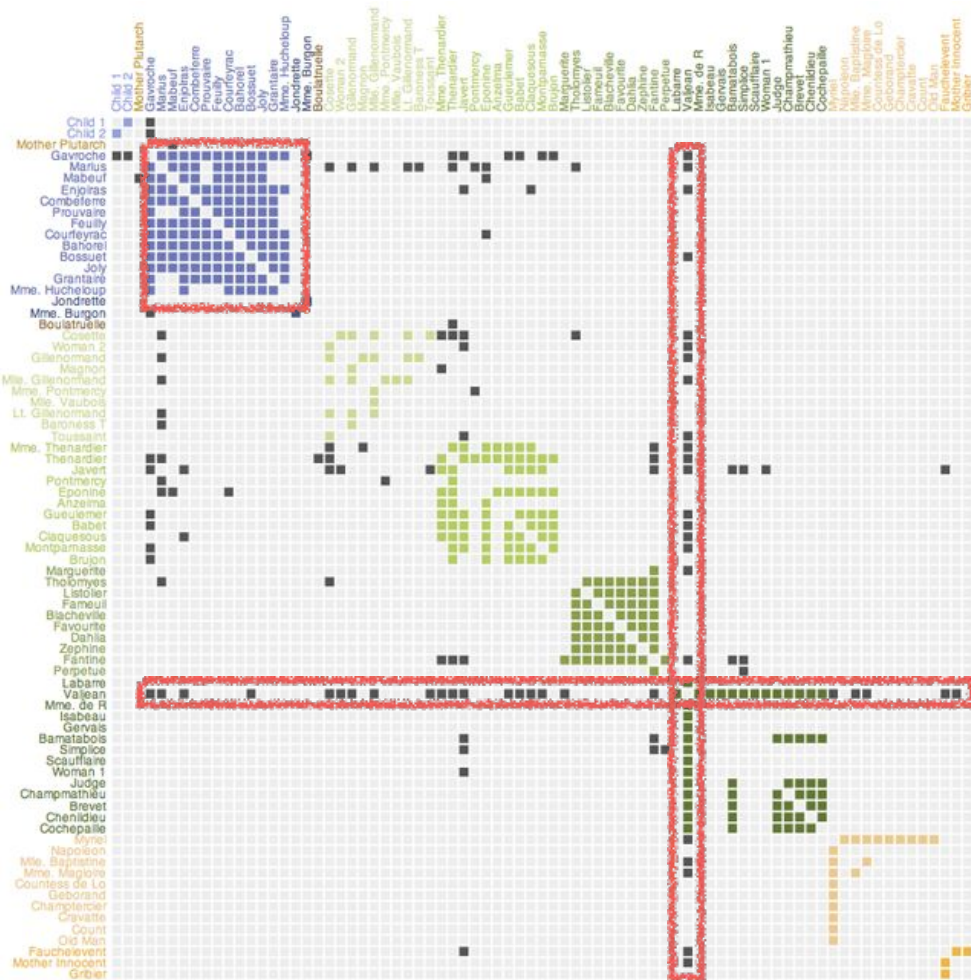
- Requires meaningful ordering
- Does not scale with density

Ordering





Node
Link



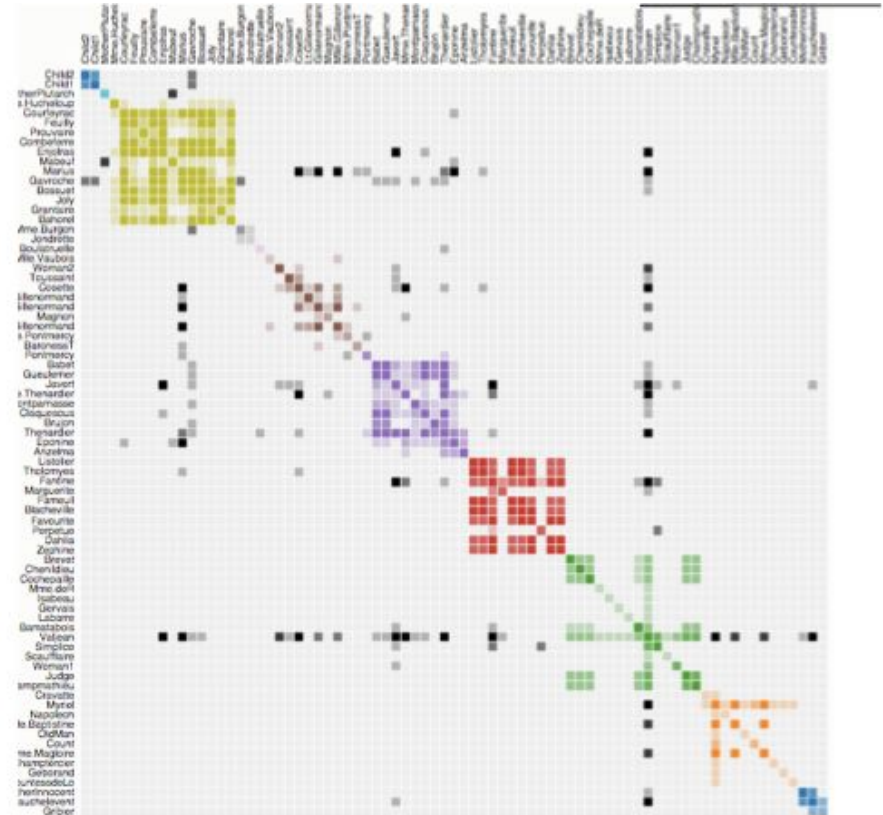
Matrice
s

Adjacency Matrix



- + Path finding / following
- + Outliers
- + Disconnected components (if sparse)

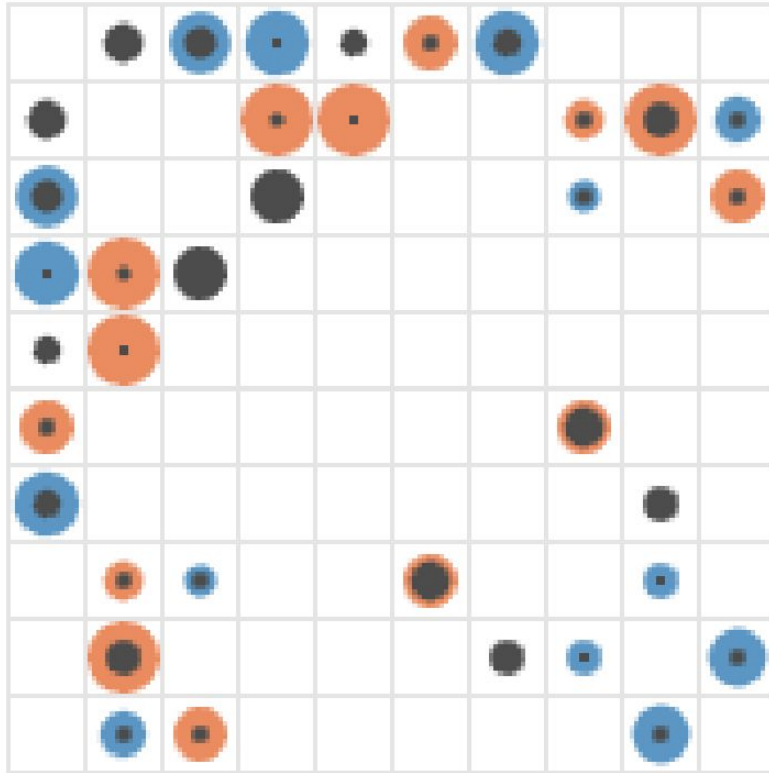
=> Sparse networks



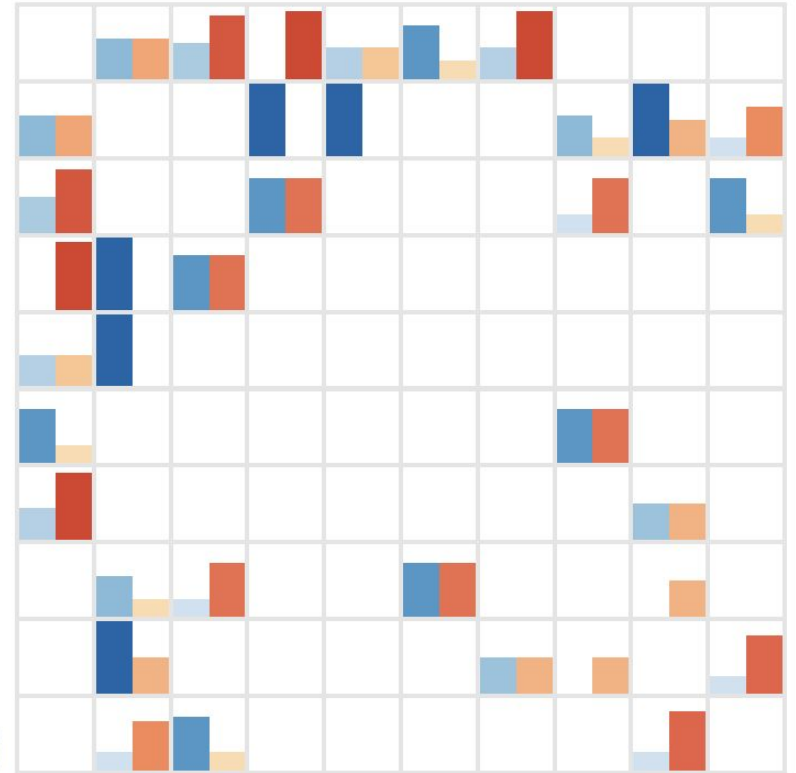
- + Clusters
- + Missing links in clusters
- + Highly connected nodes

=> Dense networks

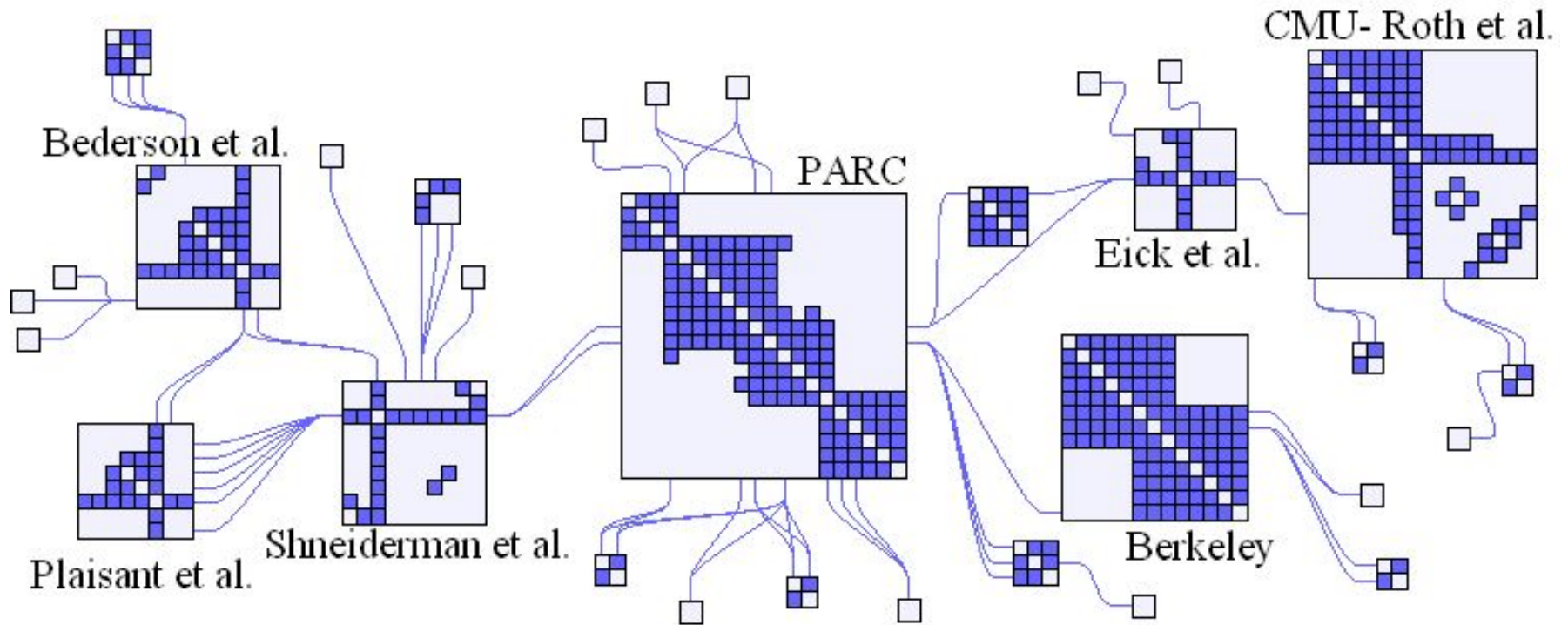
Matrix Cells



(d)

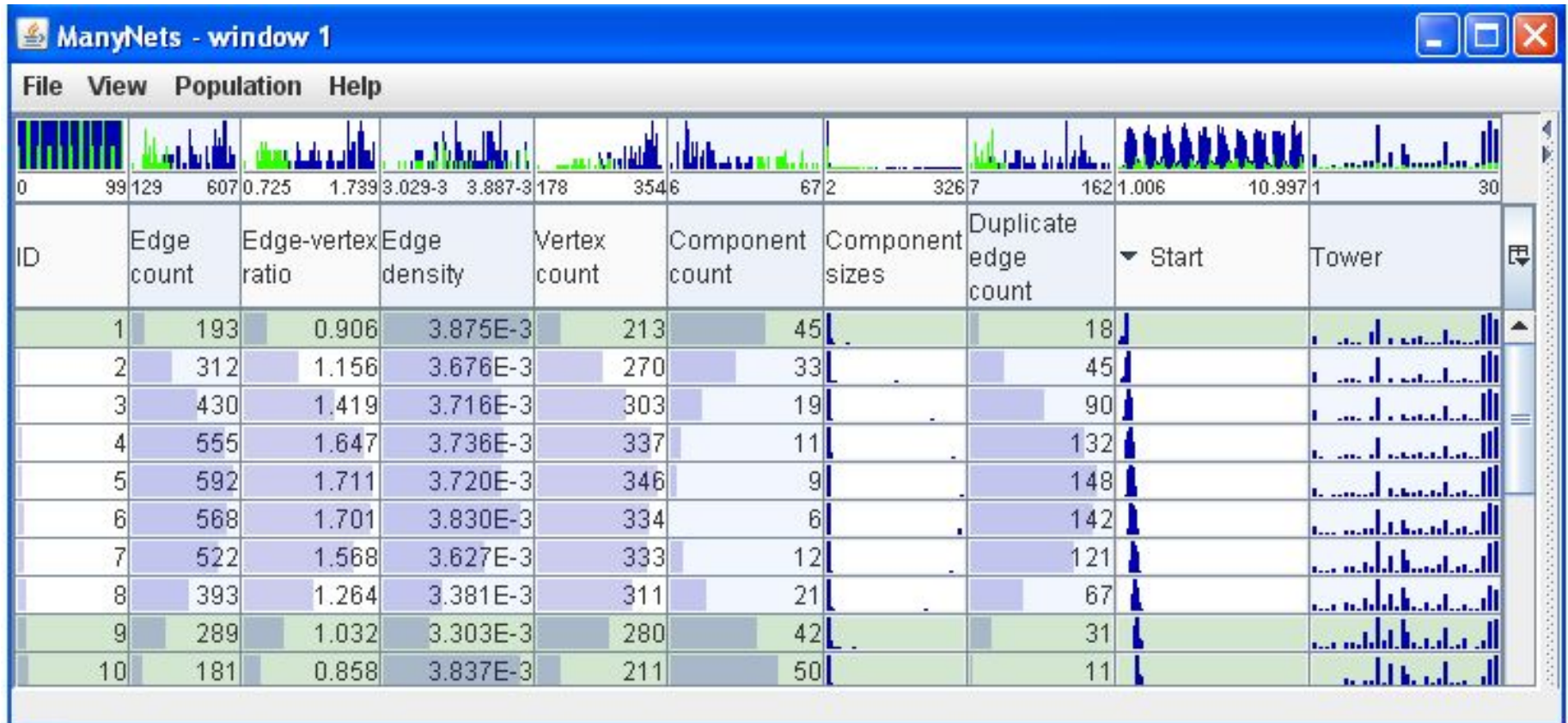


Clusters

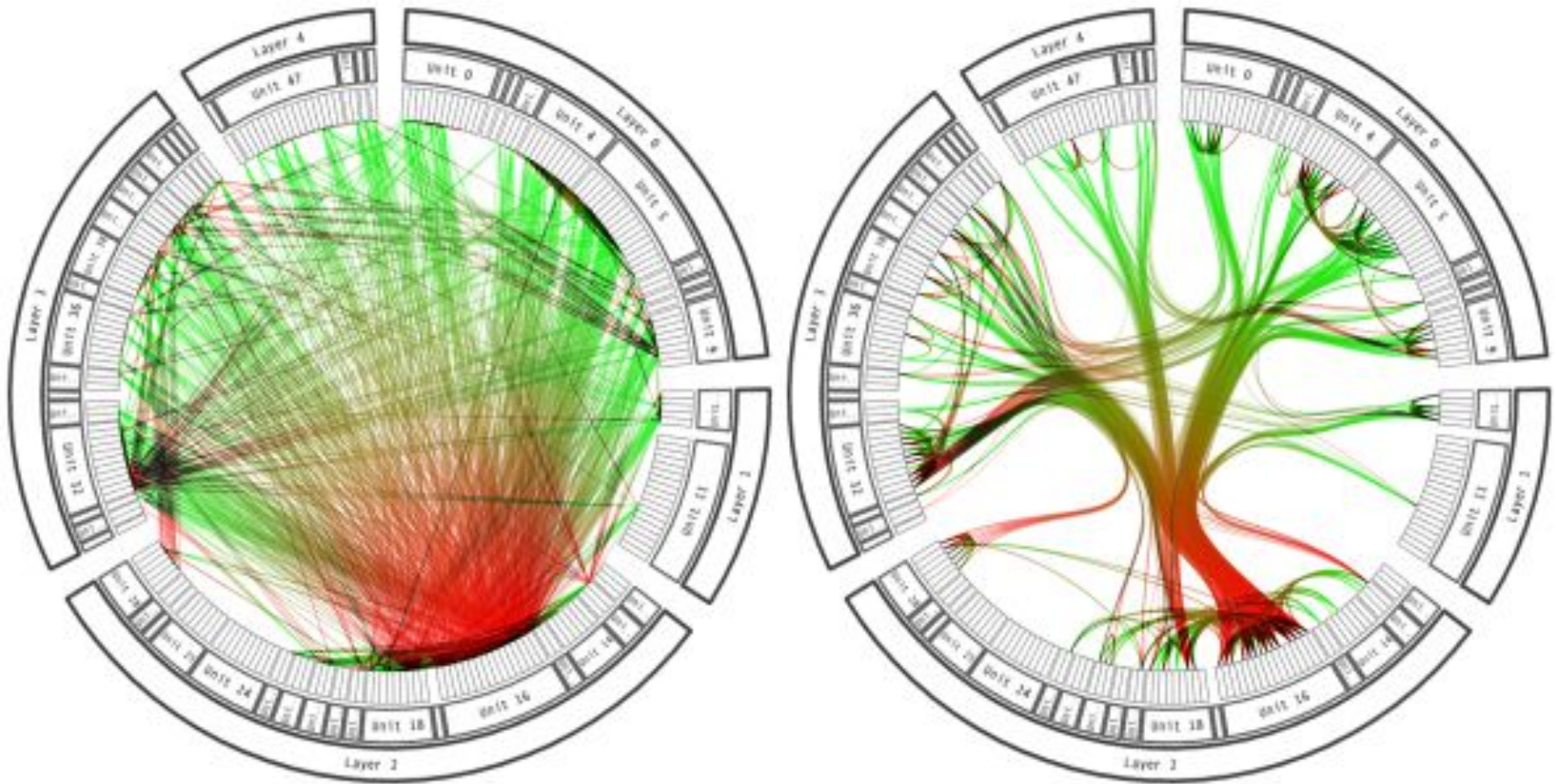


Henry, N., Fekete, J. D., & McGuffin, M. J. (2007). NodeTriX: a hybrid visualization of social networks. *IEEE transactions on visualization and computer graphics*, 13(6), 1302-1309.

Comparing networks

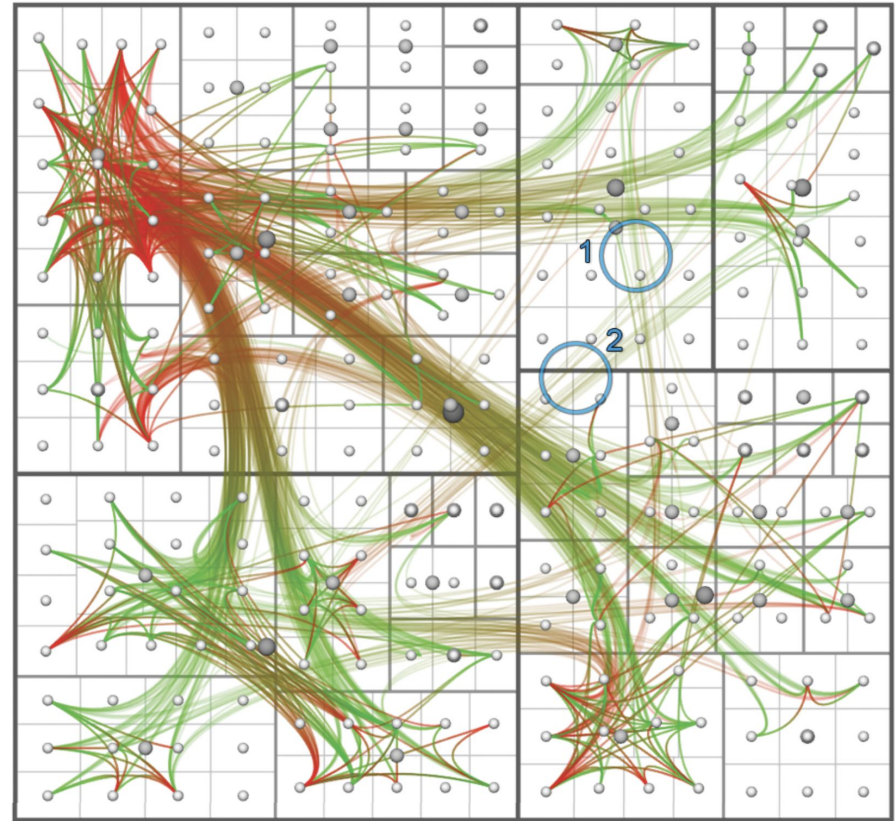
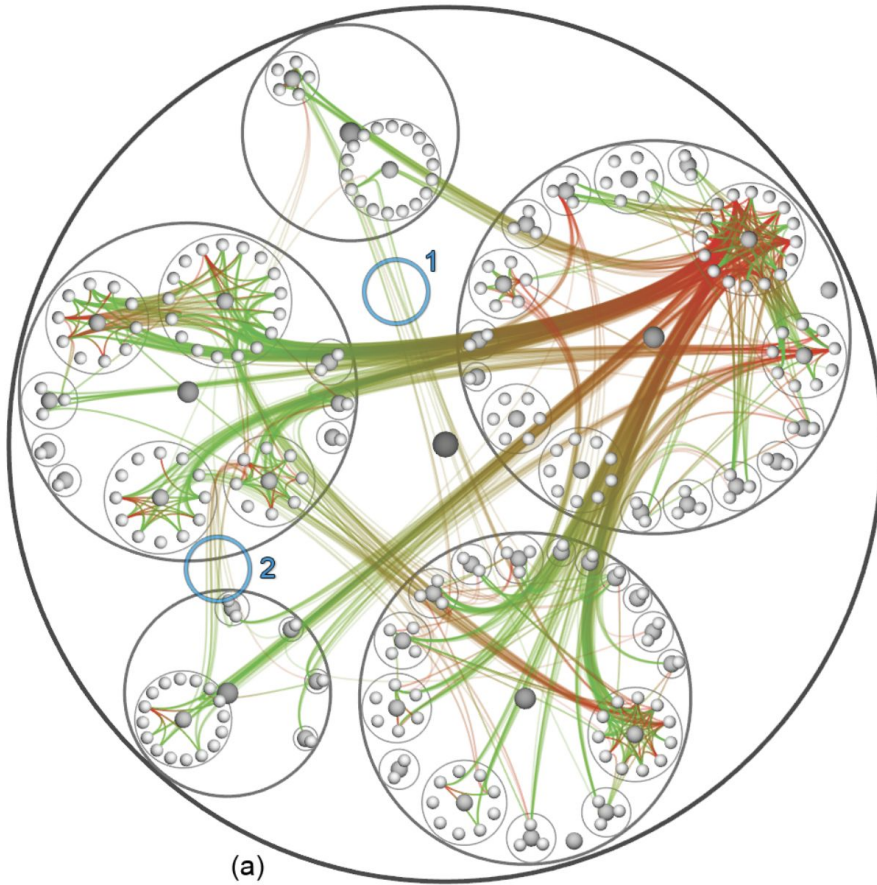


Edge Bundling

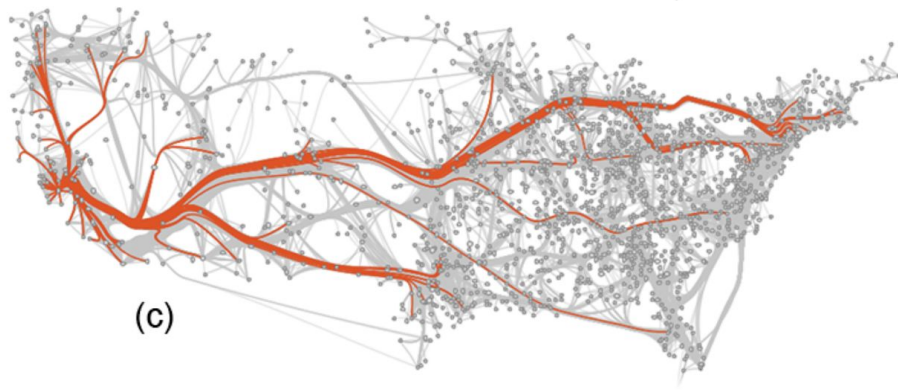


Holten, Danny. "Hierarchical edge bundles: Visualization of adjacency relations in hierarchical data." *IEEE Transactions on visualization and computer graphics* 12.5 (2006): 741-748.

Hierarchical Edge Bundling



Edge Bundling

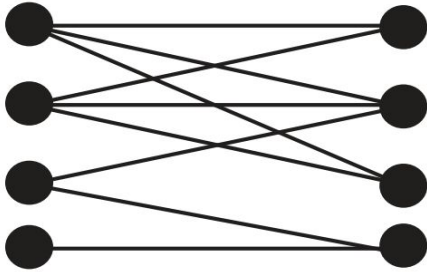


Holten, Danny, and Jarke J. Van Wijk. "Force-directed edge bundling for graph visualization." *Computer graphics forum*. Vol. 28. No. 3. Oxford, UK: Blackwell Publishing Ltd, 2009.

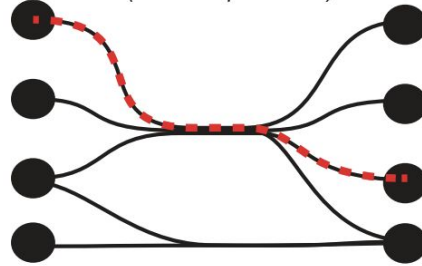
Sun, Guo-Dao, et al. "A survey of visual analytics techniques and applications: State-of-the-art research and future challenges." *Journal of Computer Science and Technology* 28.5 (2013): 852-867.

Ambiguity

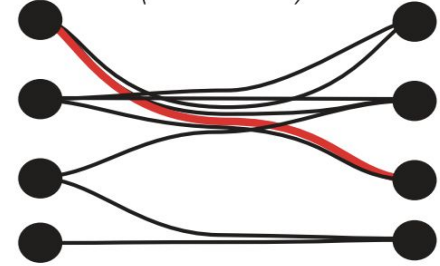
(a) No bundling



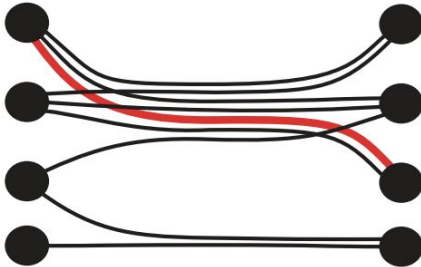
(b) Edge Bundling
(complete)



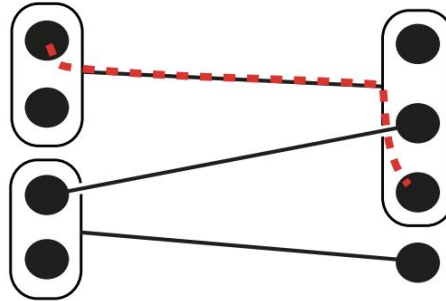
(c) Edge Bundling
(relaxed)



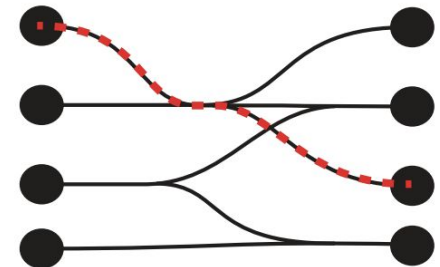
(d) Metro-Style Bundling



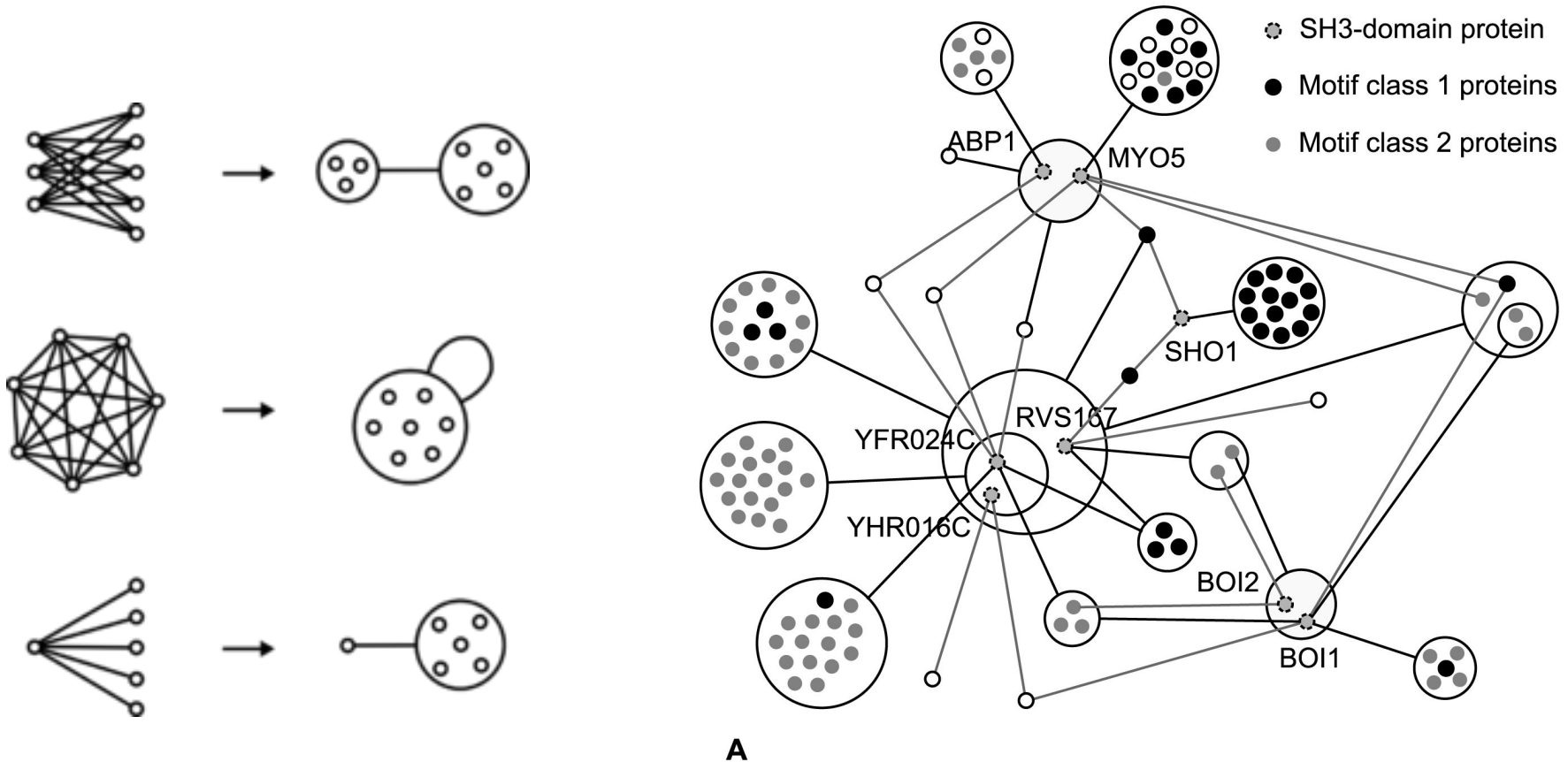
(e) Power Graphs



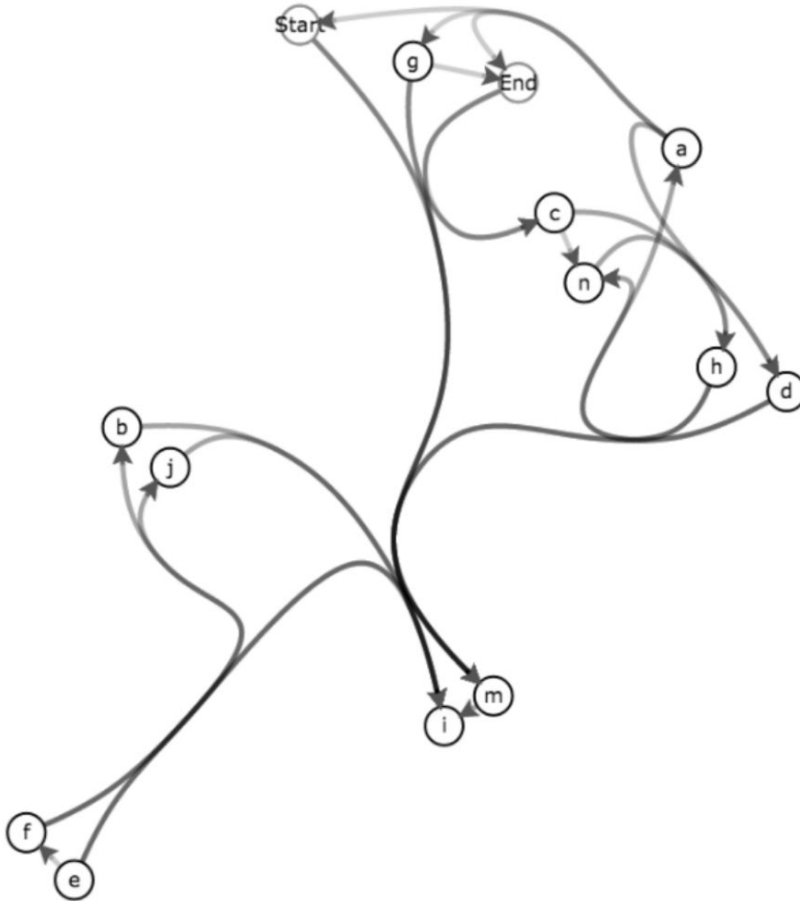
(f) Confluent Drawing



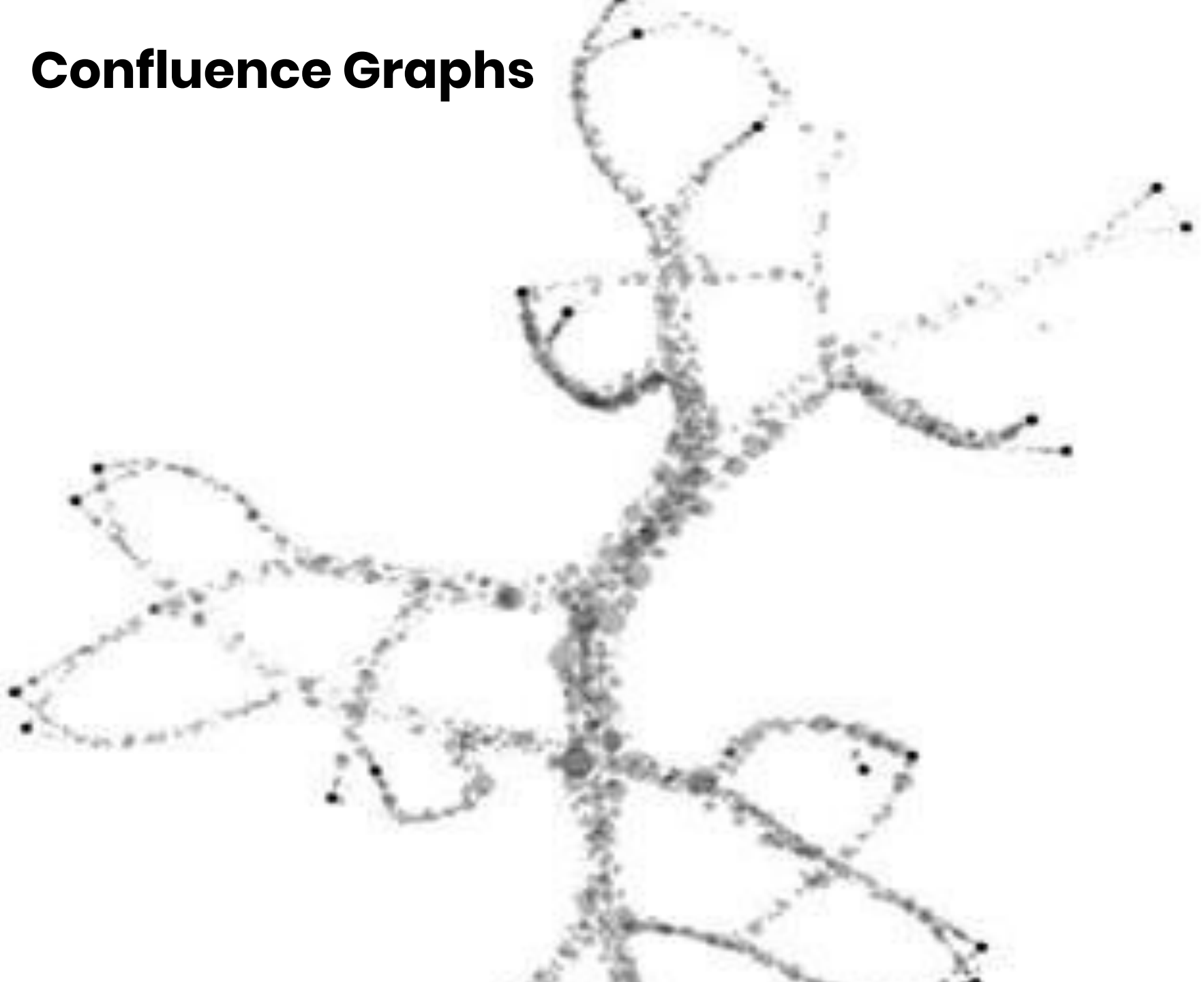
Powergraphs



Confluence Graphs



Confluence Graphs



**Multivariate
(*Multilayer*)
Networks**

Node-link Diagram



Directed Link



Multiple Links



Link Types



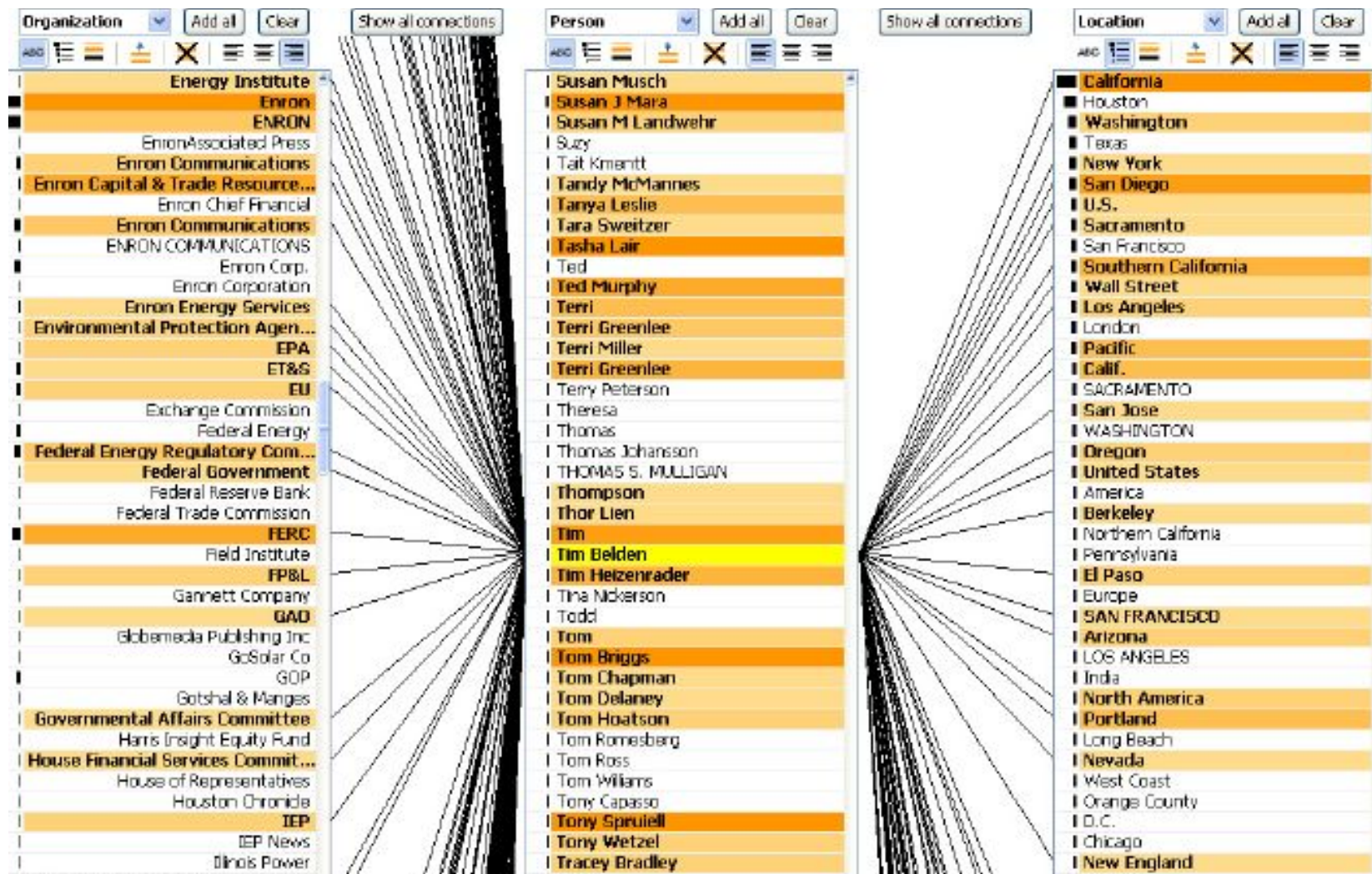
Node type



Weighted link

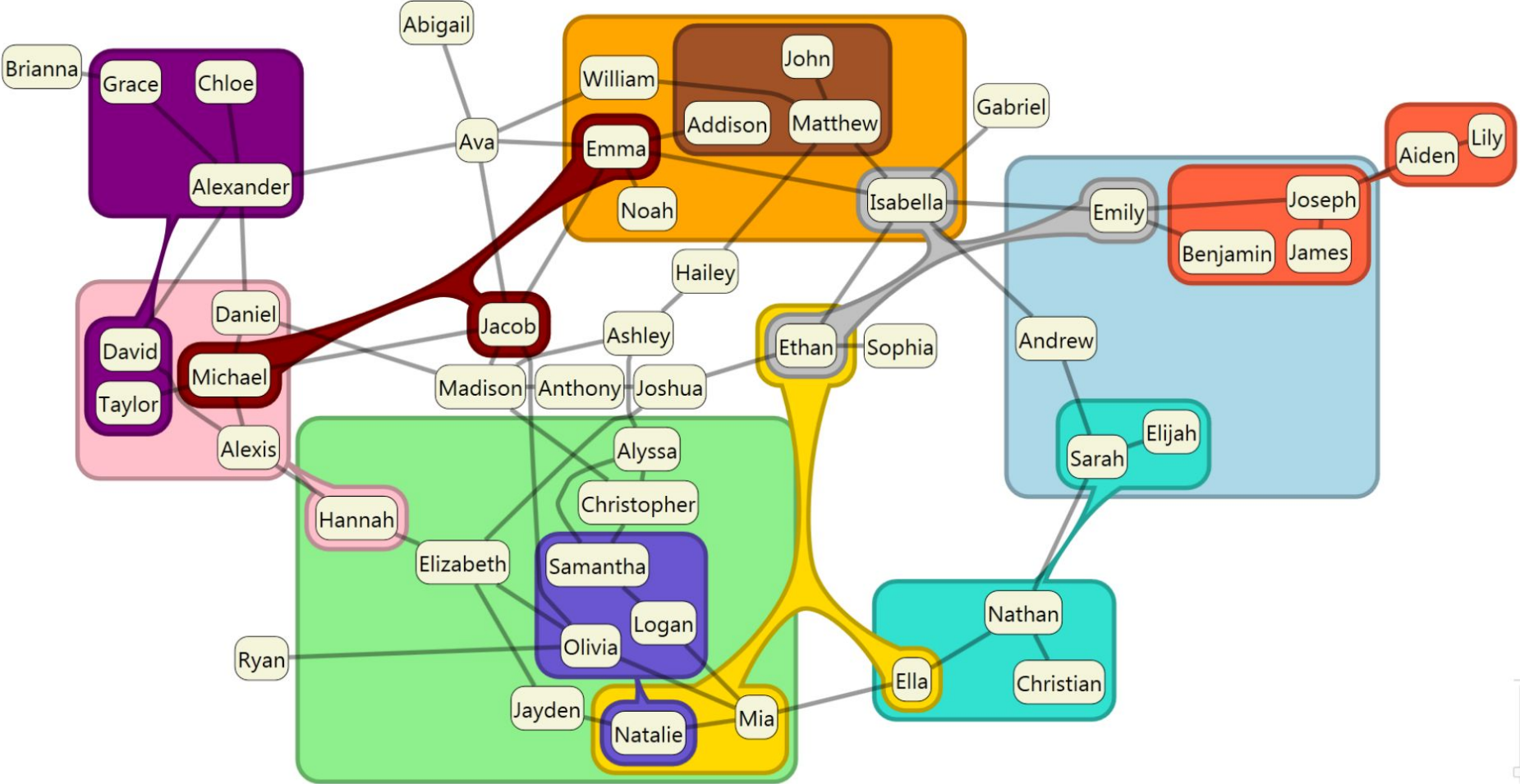


Jigsaw

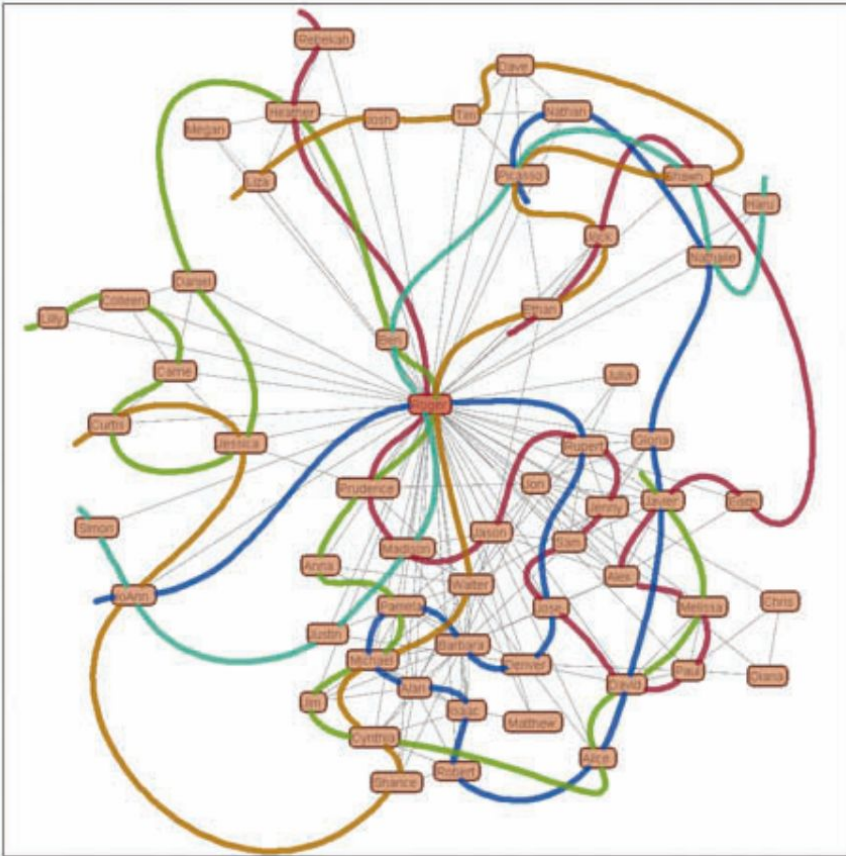


Stasko, J., Görg, C., & Liu, Z. (2008). Jigsaw: supporting investigative analysis through interactive visualization. *Information visualization*, 7(2), 118-132.

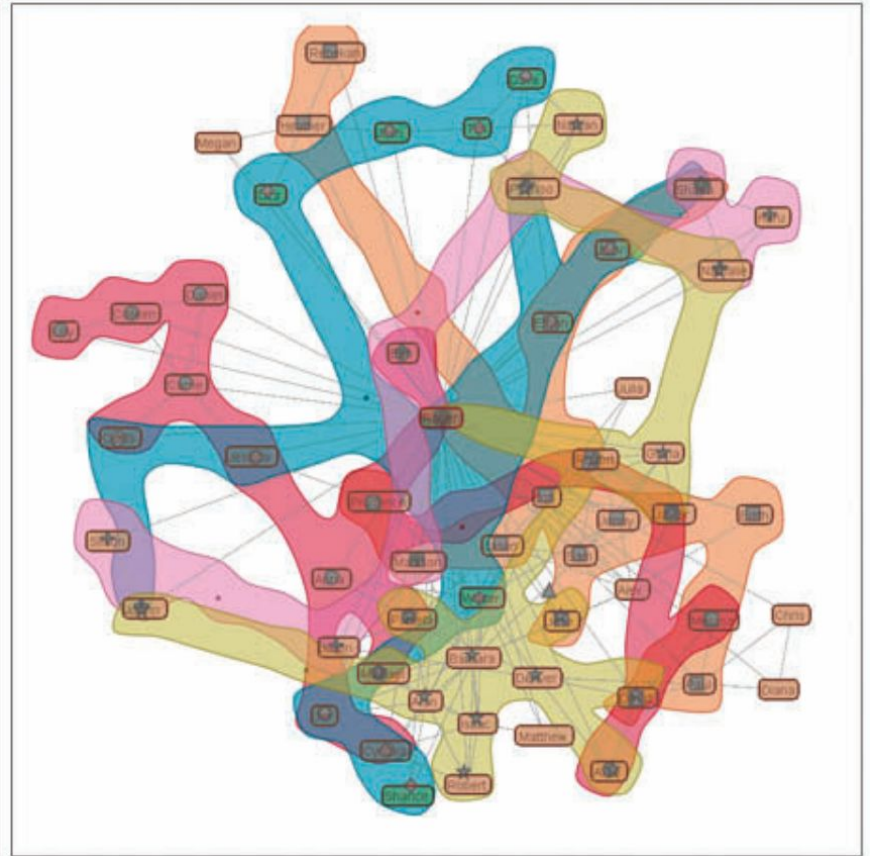
Networks and Sets



Riche, N. H., & Dwyer, T. (2010). Untangling euler diagrams. *IEEE Transactions on Visualization and Computer Graphics*, 16(6), 1090-1099.

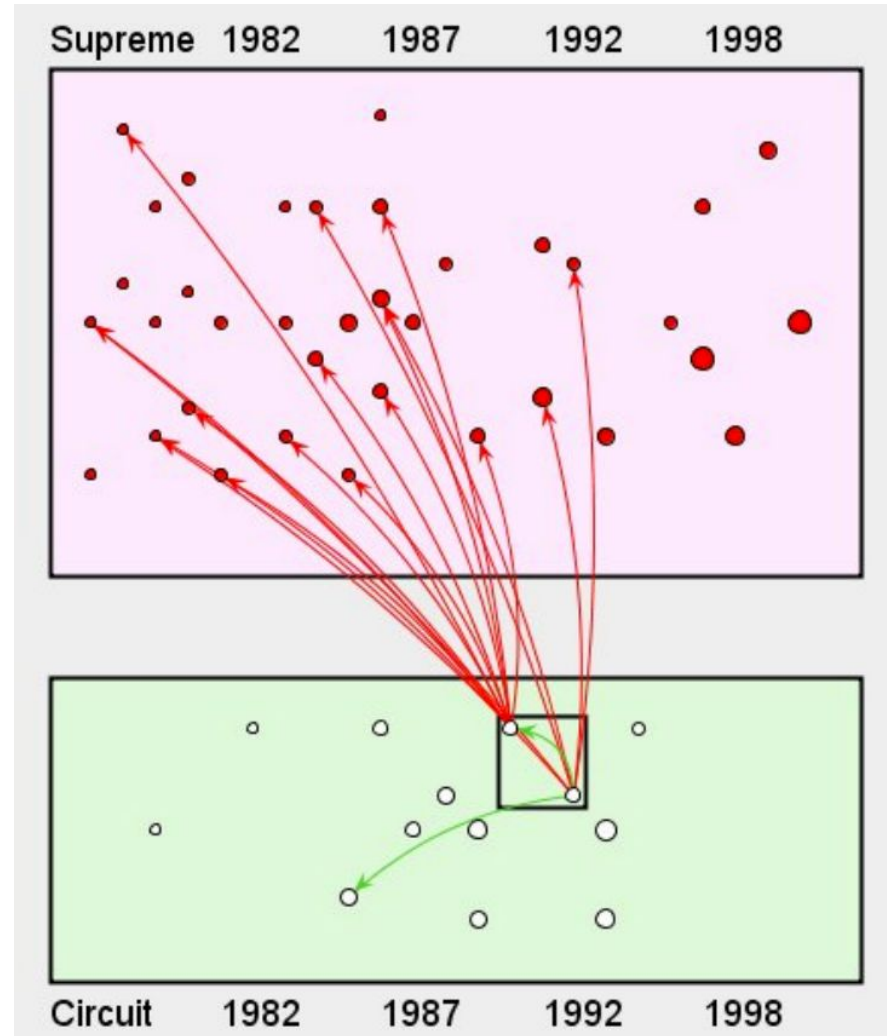
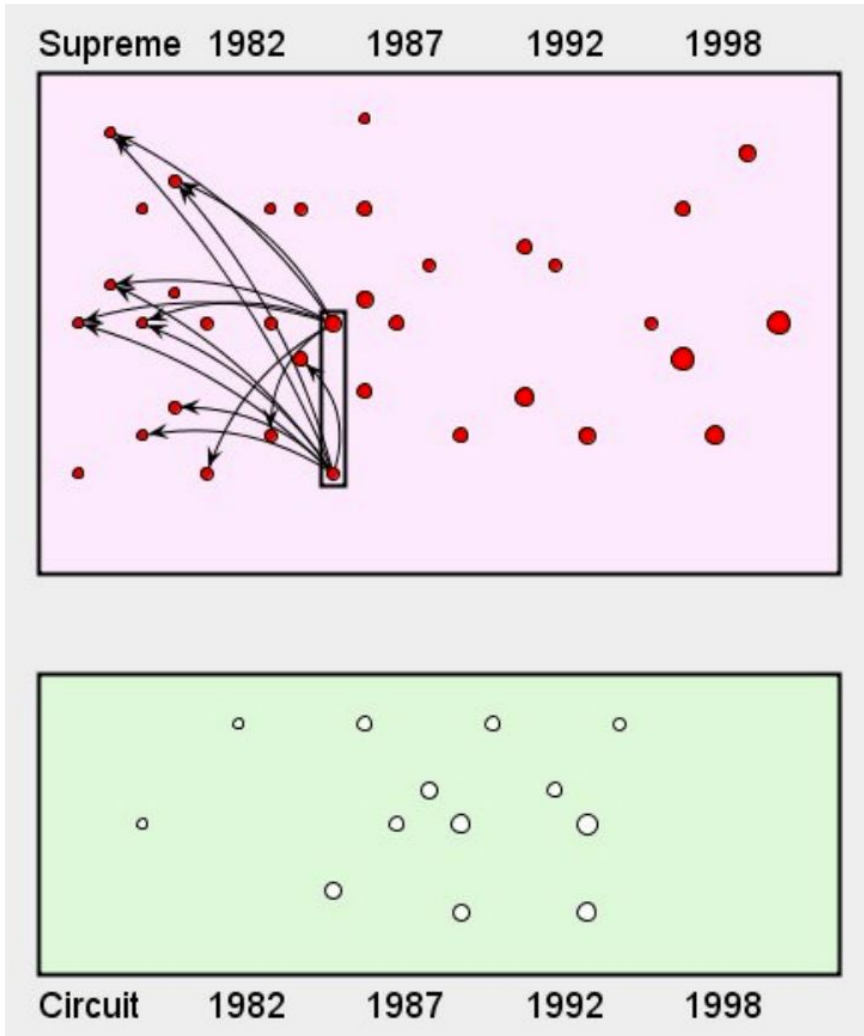


Line
Sets

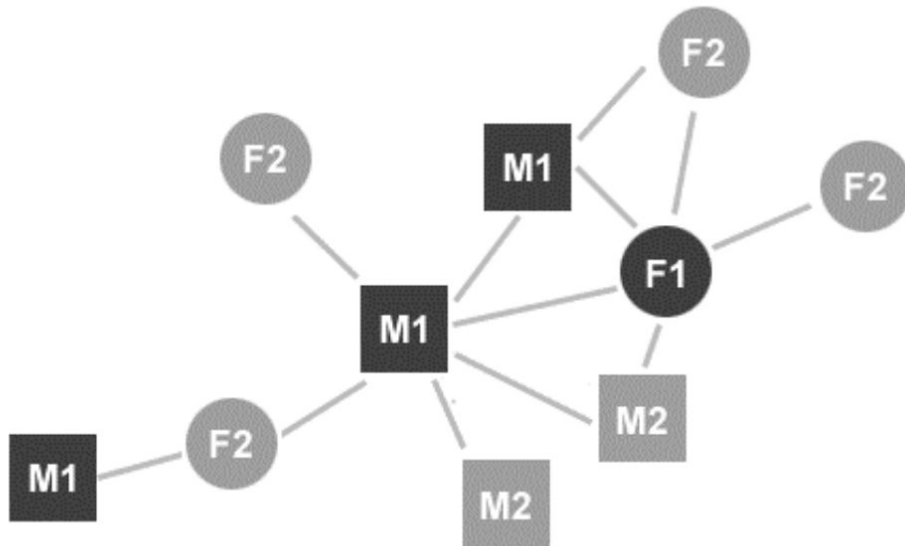


Bubble
Sets

Semantic Substrates

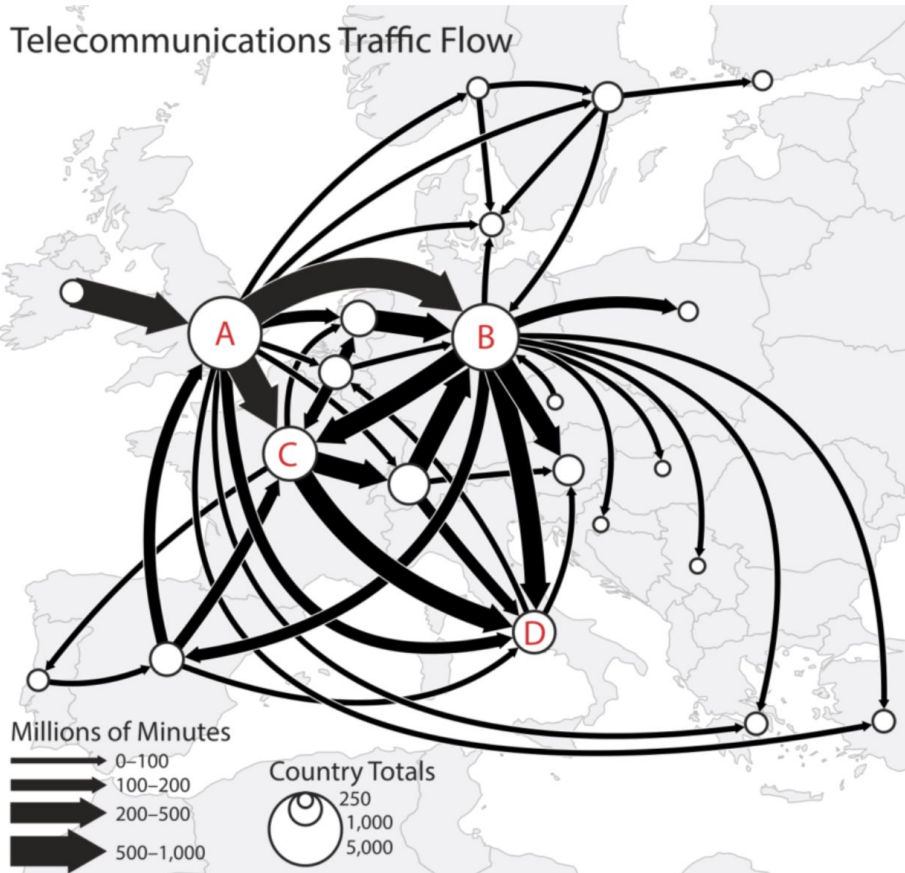


Pivot Graphs

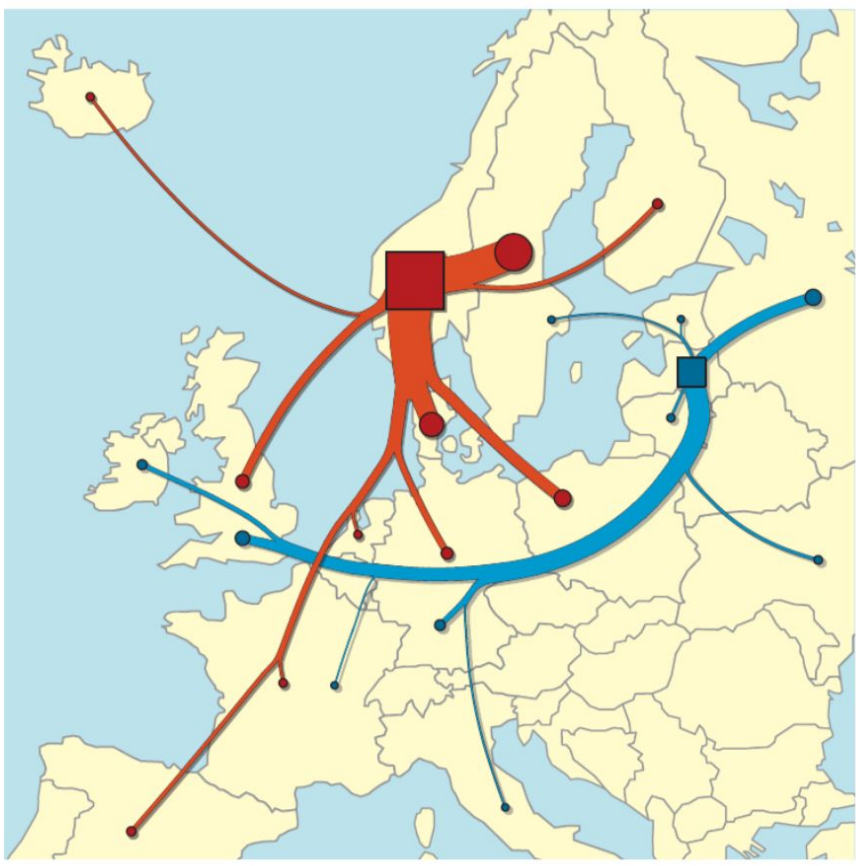


Node and Link Diagram

Geographic Networks

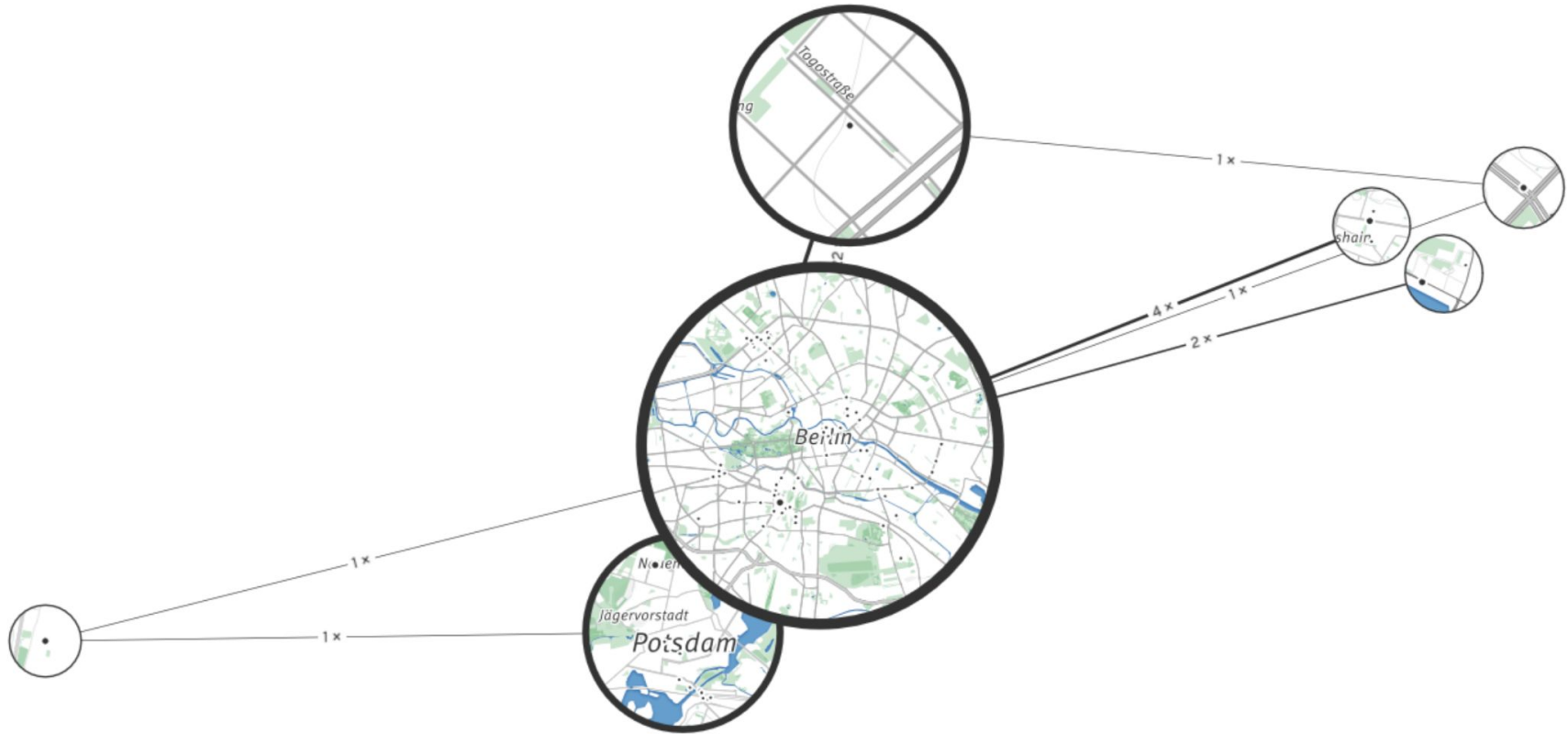


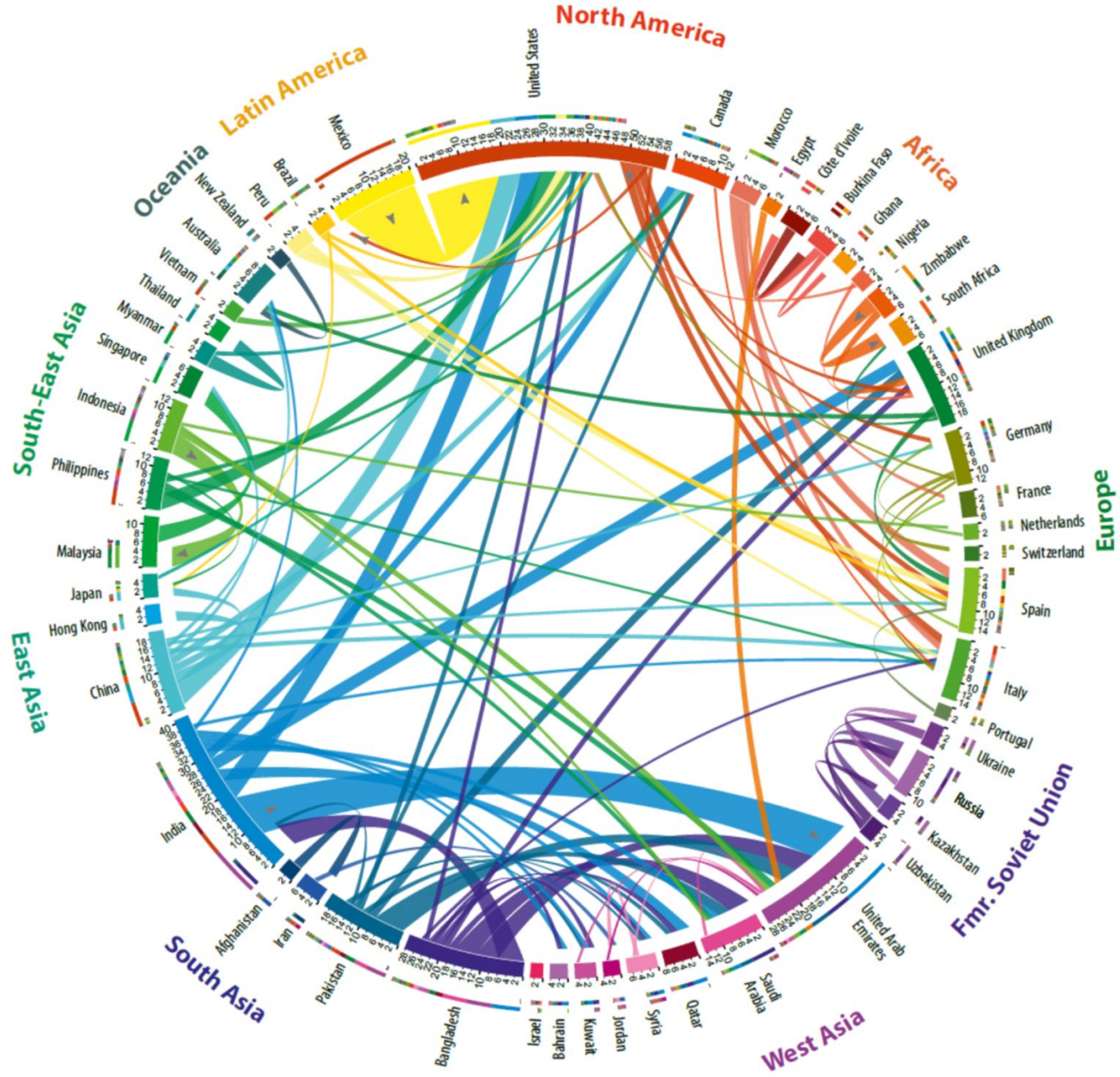
JENNY, BERNHARD, STEPHEN, DANIEL M., MUEHLENHAUS, IAN, et al. "Design principles for origin-destination flow maps". *Cartography and Geographic Information Science* 45.1 (Jan. 2, 2018)



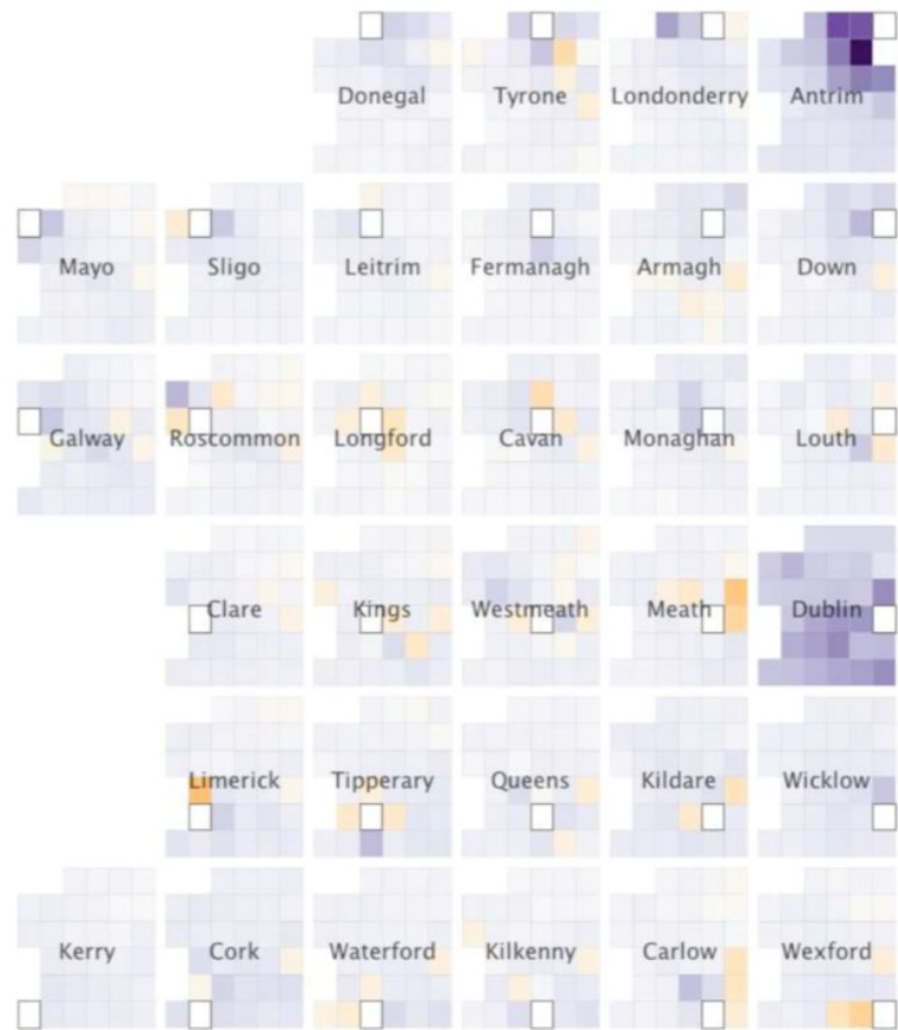
BUCHIN, K., SPECKMANN, B., and VERBEEK, K. "Flow Map Layout via Spiral Trees". *IEEE Transactions on Visualization and Computer Graphics* 17.12 (Dec. 2011)

Shifted Maps





ABEL, GUY J. and SANDER, NIKOLA. "Quantifying Global International Migration Flows". *Science* 343:6178 (Mar. 28, 2014)



GEOGRAPHIC NETWORK VISUALISATION

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61 techniques ([show all](#))

Geography Representation

Map	Distorted Map	Abstract
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Network Representation

Abstract Nodes & Explicit Edges	Abstract Nodes & Abstract Edges
Explicit Nodes & Explicit Edges	Explicit Nodes & Abstract Edges

Integration

Geography as Basis	Balanced	Network as Basis
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Interaction

No Interaction	Optional Interaction
Required Interaction	Interaction Technique



Origin-Destination Flow Maps in Immersive Environments

Yang, Y.; Dwyer, T.; Jenny, B.; Marriott, K.; Cordeil, M.; Chen, H. (2019) [[DOI Link](#)]

[map](#) [explicit-explicit](#) [base-geo](#)
[required-interaction](#)



Visual Abstraction of Large Scale Geospatial Origin-Destination Movement Data

Zhou, Z.; Meng, L.; Tang, C.; Zhao, Y.; Guo, Z.; Hu, M.; Chen, W. (2019) [[DOI Link](#)]

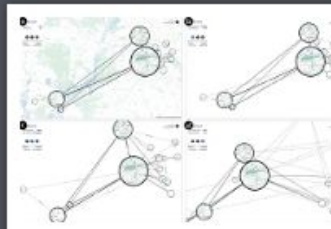
[map](#) [abstract-abstract](#) [balanced](#)
[required-interaction](#)



Animated Edge Textures in Node-Link Diagrams: A Design Space and Initial Evaluation

Romat, Hugo; Appert, Caroline; Bach, Benjamin; Henry-Riche, Nathalie; Pietriga, Emmanuel (2018) [[DOI Link](#)]

[map](#) [explicit-explicit](#) [base-geo](#)
[no-interaction](#)



Shifted Maps: Revealing spatio-temporal topologies in movement data

Otten, Heike; Hildebrand, Lennart; Nagel, Till; Dörk, Marian; Müller, Boris (2018) [[DOI Link](#)]

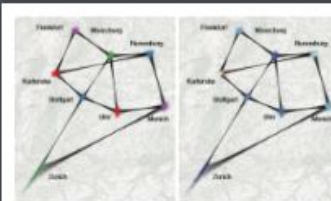
[map](#) [abstract-explicit](#) [balanced](#)
[required-interaction](#)



Revealing Patterns and Trends of Mass Mobility Through Spatial and Temporal Abstraction of Origin-Destination Movement Data

Andrienko, G.; Andrienko, N.; Fuchs, G.; Wood, J. (2017) [[DOI Link](#)]

[map](#) [abstract-abstract](#) [base-geo](#)
[optional-interaction](#)



Probabilistic Graph Layout for Uncertain Network Visualization

Schulz, C.; Nocaj, A.; Goertler, J.; Deussen, O.; Brandes, U.; Weiskopf, D. (2017) [[DOI Link](#)]

[map](#) [explicit-explicit](#) [base-geo](#)
[no-interaction](#)



Module-based visualization of large-scale graph network data

Li, Chenhui; Baci, George; Wang, Yunzhe (2017) [[DOI Link](#)]

[map](#) [abstract-explicit](#) [balanced](#)
[required-interaction](#)

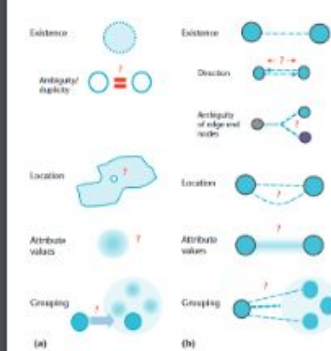
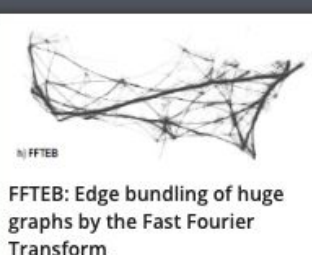
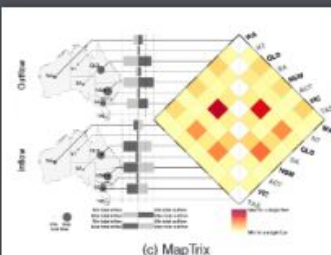
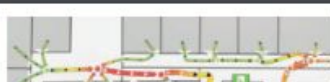


Figure 2. Overview and comparison of (a) node and (b) edge uncertainty. Node uncertainty encompasses the uncertainties that might affect individual nodes, whereas edge uncertainty is directly connected to and compounded by the various types of node uncertainty.

Typology of Uncertainty in Static Geolocated Graphs for Visualization

Landesberger, T. von; Bremm, S.; Wunderlich, M. (2017) [[DOI Link](#)]

[map](#) [explicit-explicit](#) [base-geo](#)
[no-interaction](#)



FFTEB: Edge bundling of huge graphs by the Fast Fourier Transform

Readings

- Beck, Fabian, et al. "A taxonomy and survey of dynamic graph visualization." *Computer Graphics Forum*. Vol. 36. No. 1. 2017: <http://dynamicgraphs.fbeck.com/>
- Herman, Ivan, Guy Melançon, and M. Scott Marshall. "Graph visualization and navigation in information visualization: A survey." *IEEE Transactions on visualization and computer graphics* 6.1 (2000): 24-43.
- Von Landesberger, Tatiana, et al. "Visual analysis of large graphs: state-of-the-art and future research challenges." *Computer graphics forum*. Vol. 30. No. 6. Oxford, UK: Blackwell Publishing Ltd, 2011.
- Goyal, Palash, and Emilio Ferrara. "Graph embedding techniques, applications, and performance: A survey." *Knowledge-Based Systems* 151 (2018): 78-94.
- Hadlak, Steffen, Heidrun Schumann, and Hans-Jörg Schulz. "A Survey of Multi-faceted Graph Visualization." *EuroVis (STARs)*. 2015.
- Schöttler, Sarah, Tobias Kauer, and Benjamin Bach. "Geographic Network Visualization Techniques: A Work-In-Progress Taxonomy." *Computer Graphics* 20 (2014): 2043-2052.: <https://geographic-networks.github.io/>