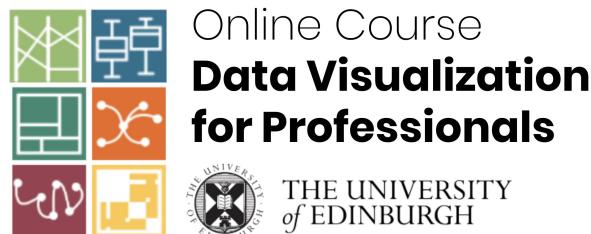


Techniques Graphs & Networks



Benjamin Bach
June 2020
<http://benjbach.me>
<https://datavis-online.github.io>

Outline

How to visualize relational data, *i.e.* graphs and networks?

- Basic concepts
- Density
- Multivariate networks
- Geographic networks

Outline

How to visualize relational data, *i.e.* graphs and networks?

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Outline

How to visualize relational data, *i.e.* graphs and networks?

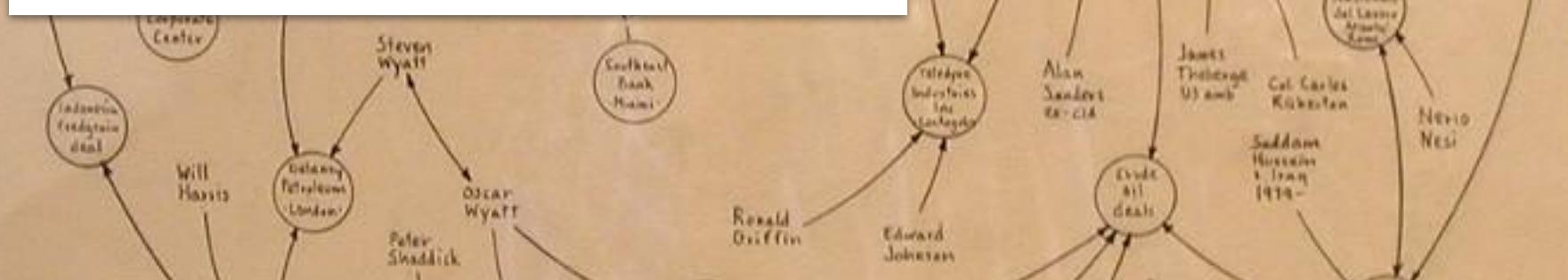
- Basic concepts
- Density
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Outline

How to visualize relational data, *i.e.* graphs and networks?

- Basic concepts
- Density
- Multivariate networks
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Techniques Network Basics



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June 2020

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Graph $G = (N, V)$

Point

Actor

Vertex

Nodes



Link

Arc

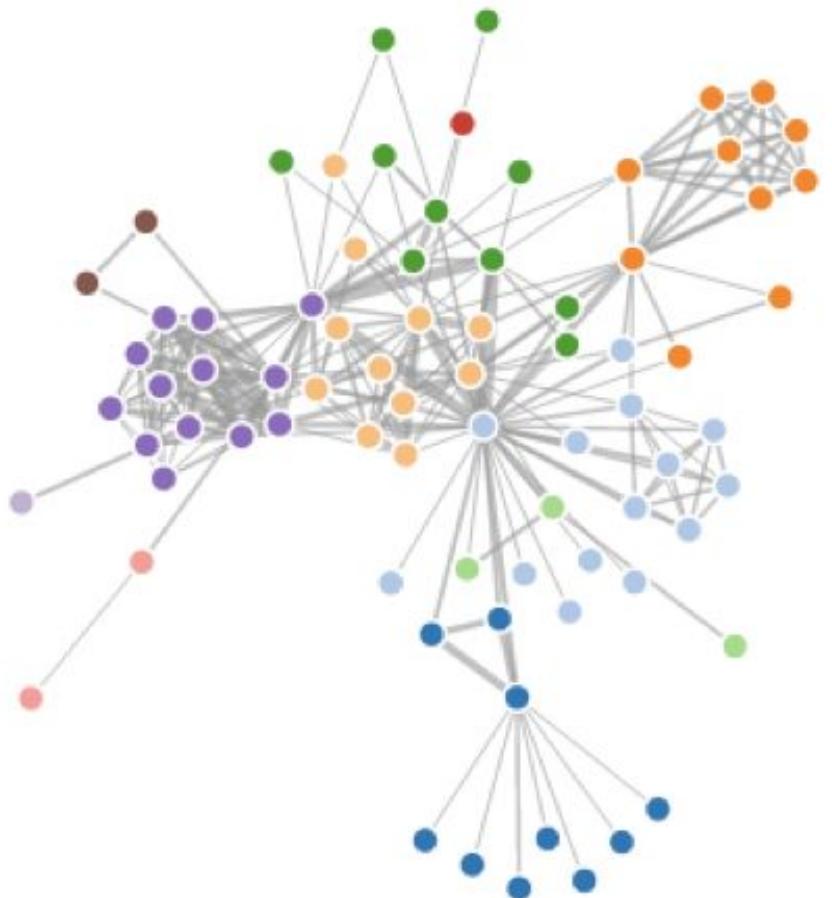
Relation(ship)

Connection

Node-link Diagram



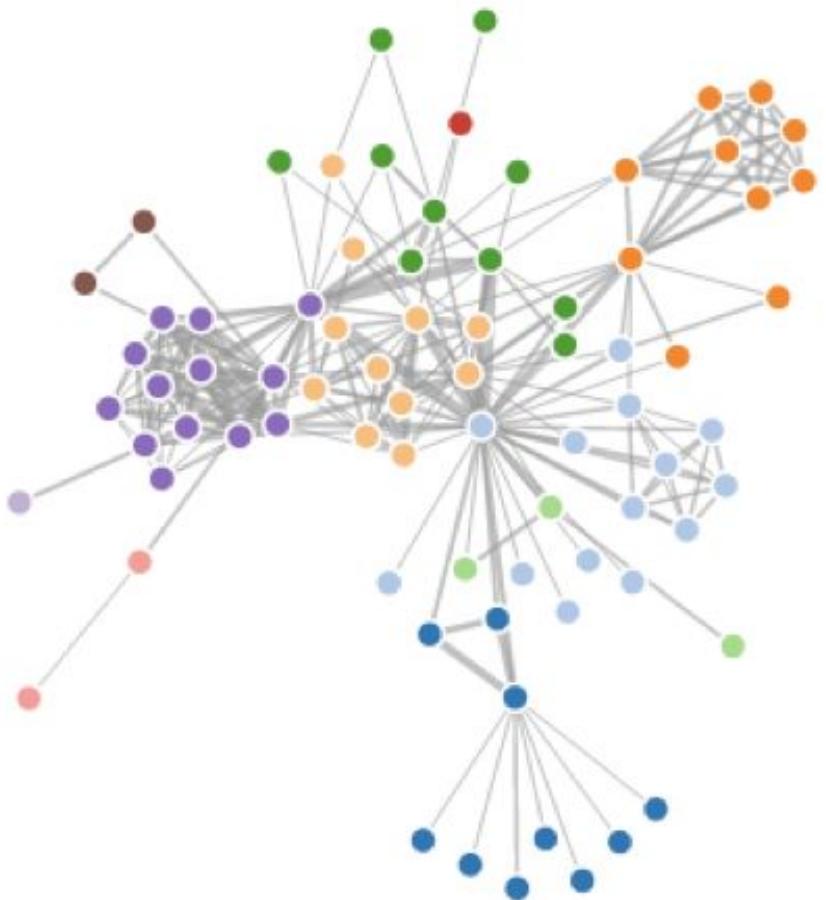
Node-link Diagram



Directed
Link



Node-link Diagram



Directed
Link



Multiple
Links



Node-link Diagram



Directed
Link



Multiple
Links



Link
Types



Node-link Diagram



Directed
Link



Multiple
Links



Link
Types



Node
type



Node-link Diagram



Directed
Link



Multiple
Links



Link
Types



Node
type

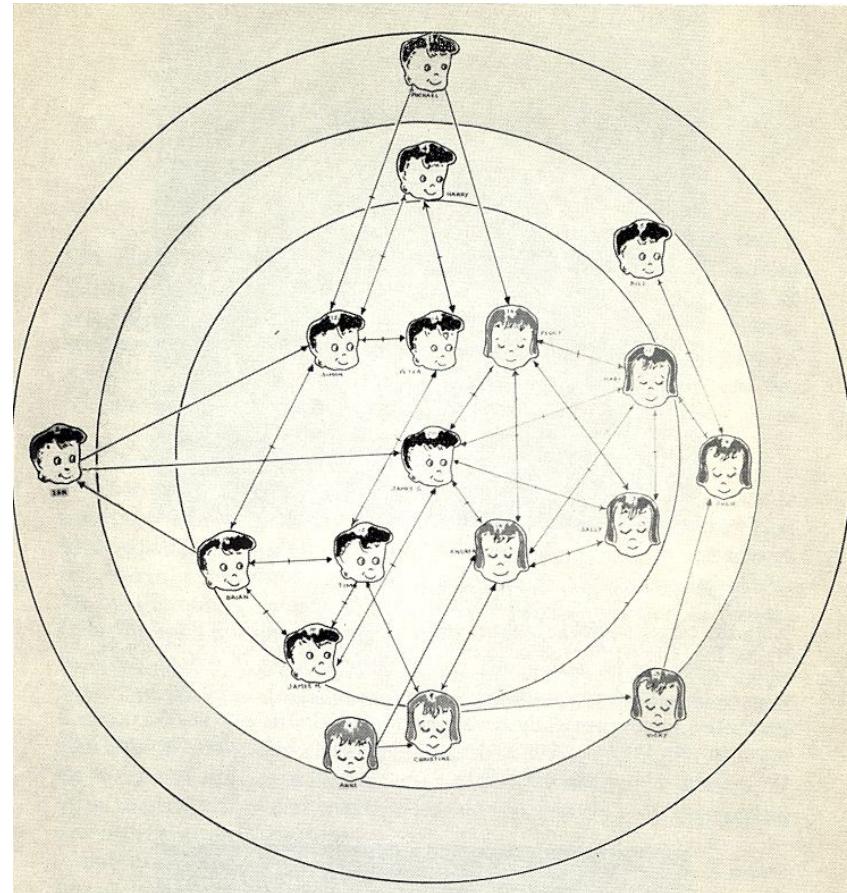


Weighted
link



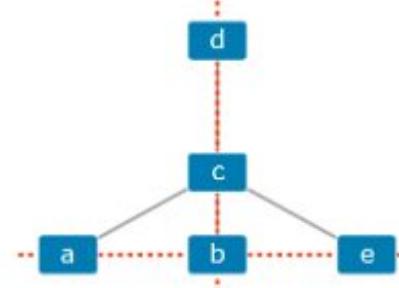
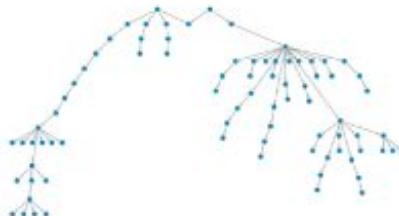
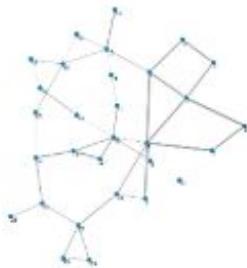
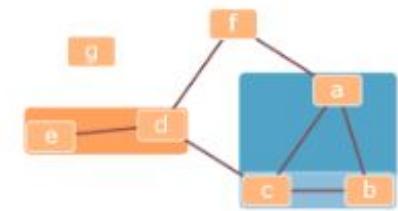
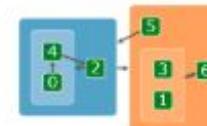
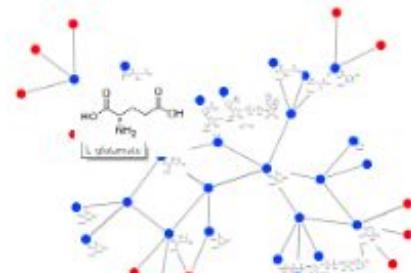
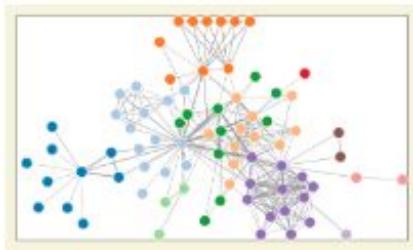
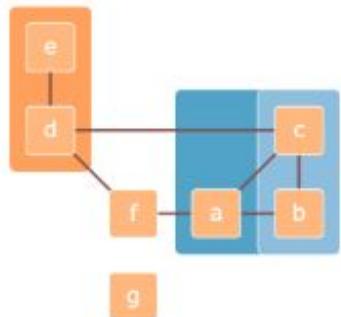
Visualizing Networks

- 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

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.

Why do we visualize networks?

- **Topology**
 - Find nodes
 - Find neighbors
 - Find shortest path
 - Find clusters
 - Find bridge nodes
- **Attributes**
 - Node attributes
 - Link attributes

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.

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

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.

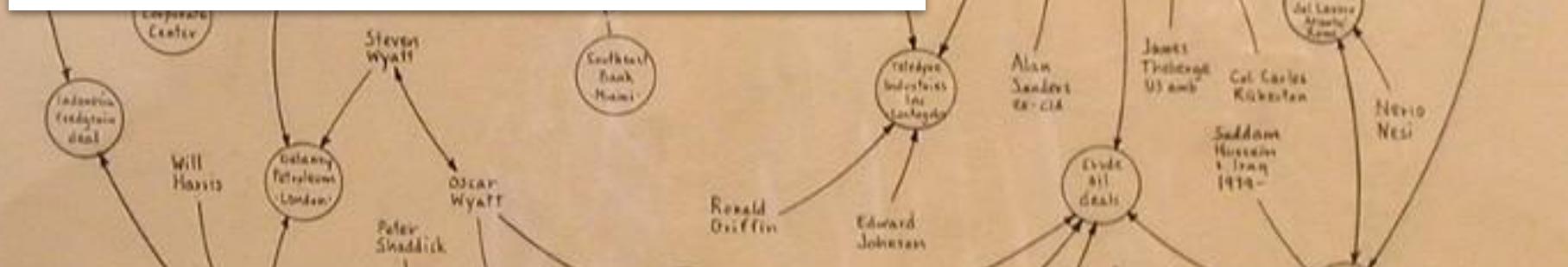
Why do we visualize networks?

- **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**
 - 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.

Techniques

Dense Networks



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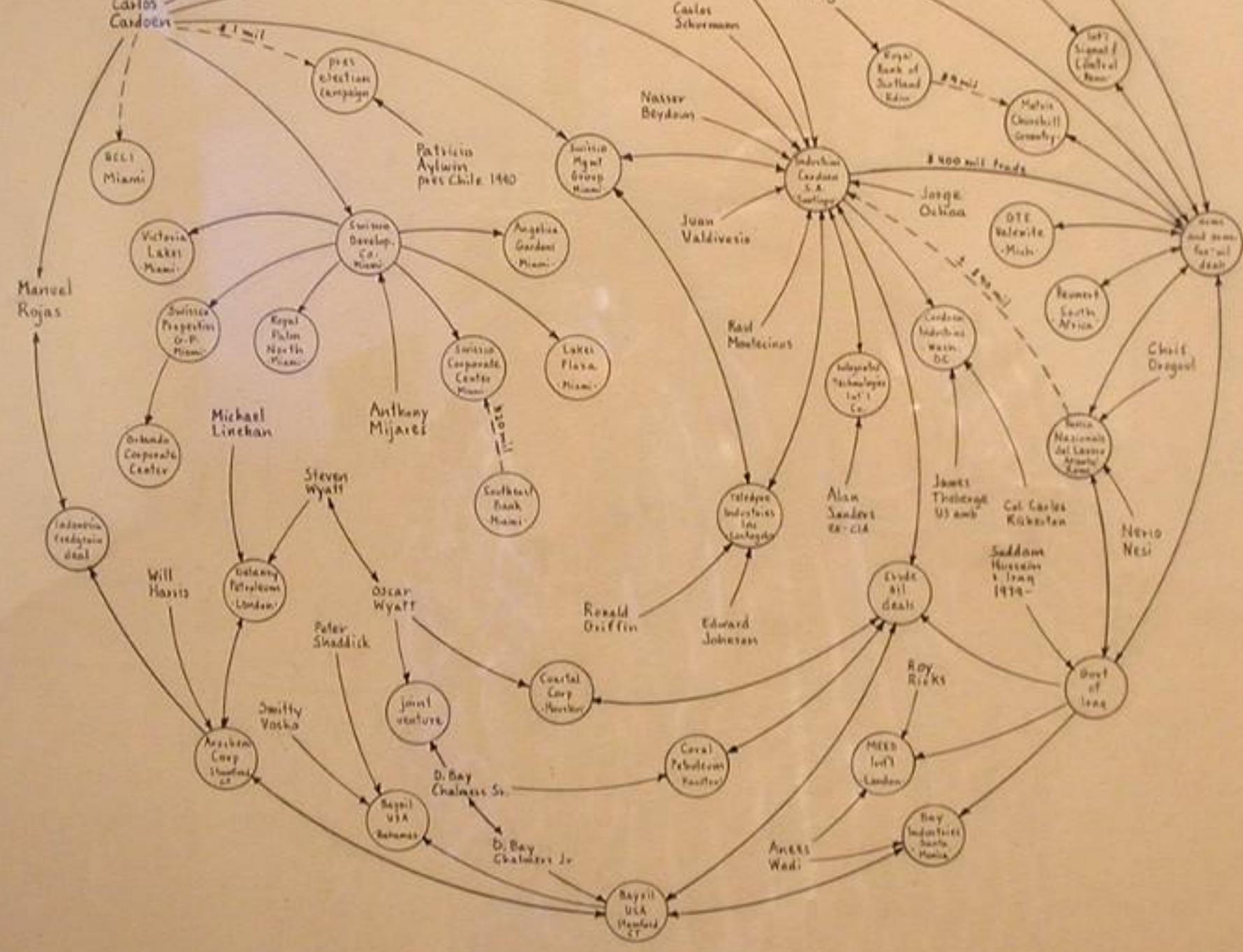
THE UNIVERSITY
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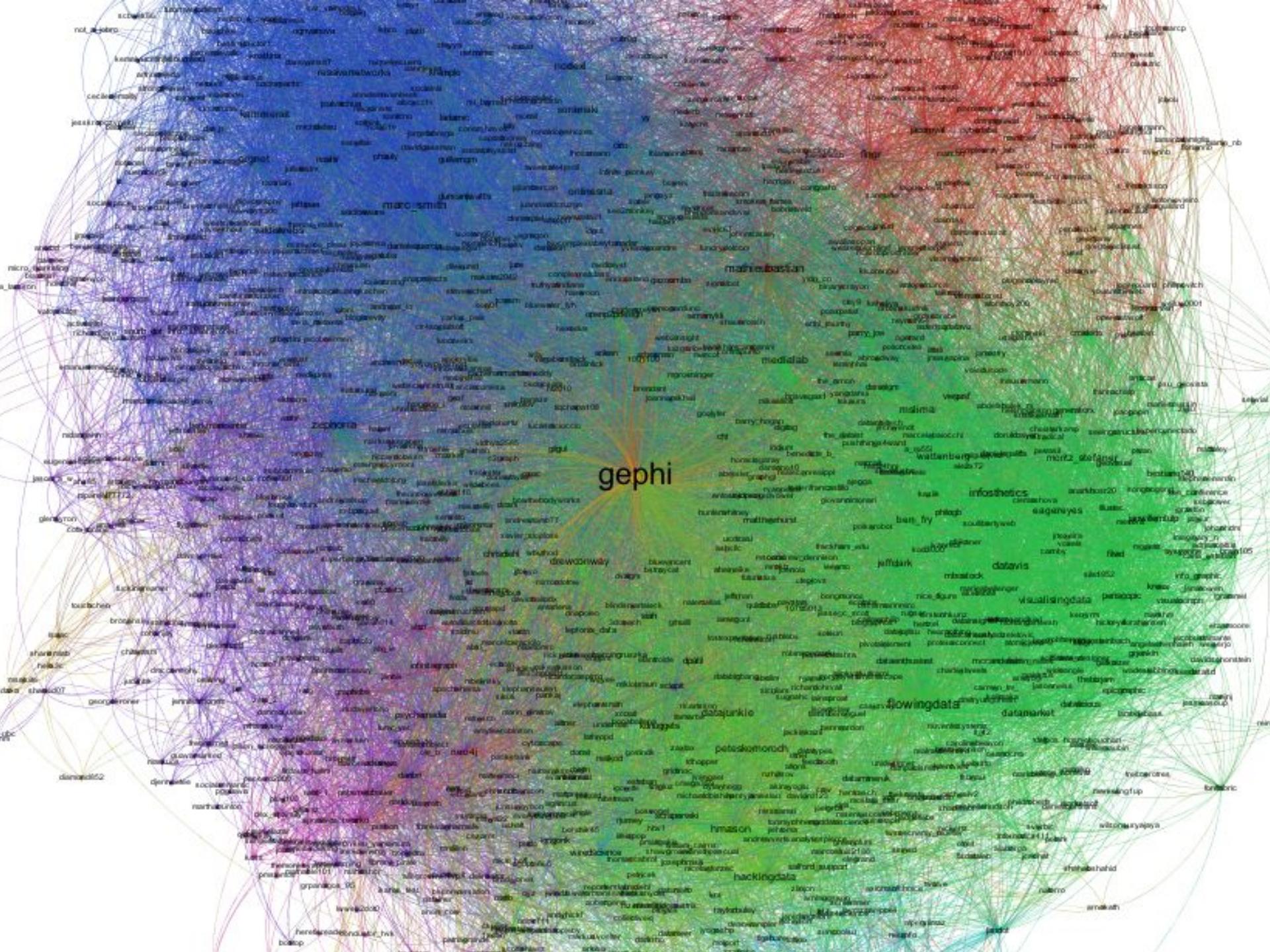
Benjamin Bach

June 2020

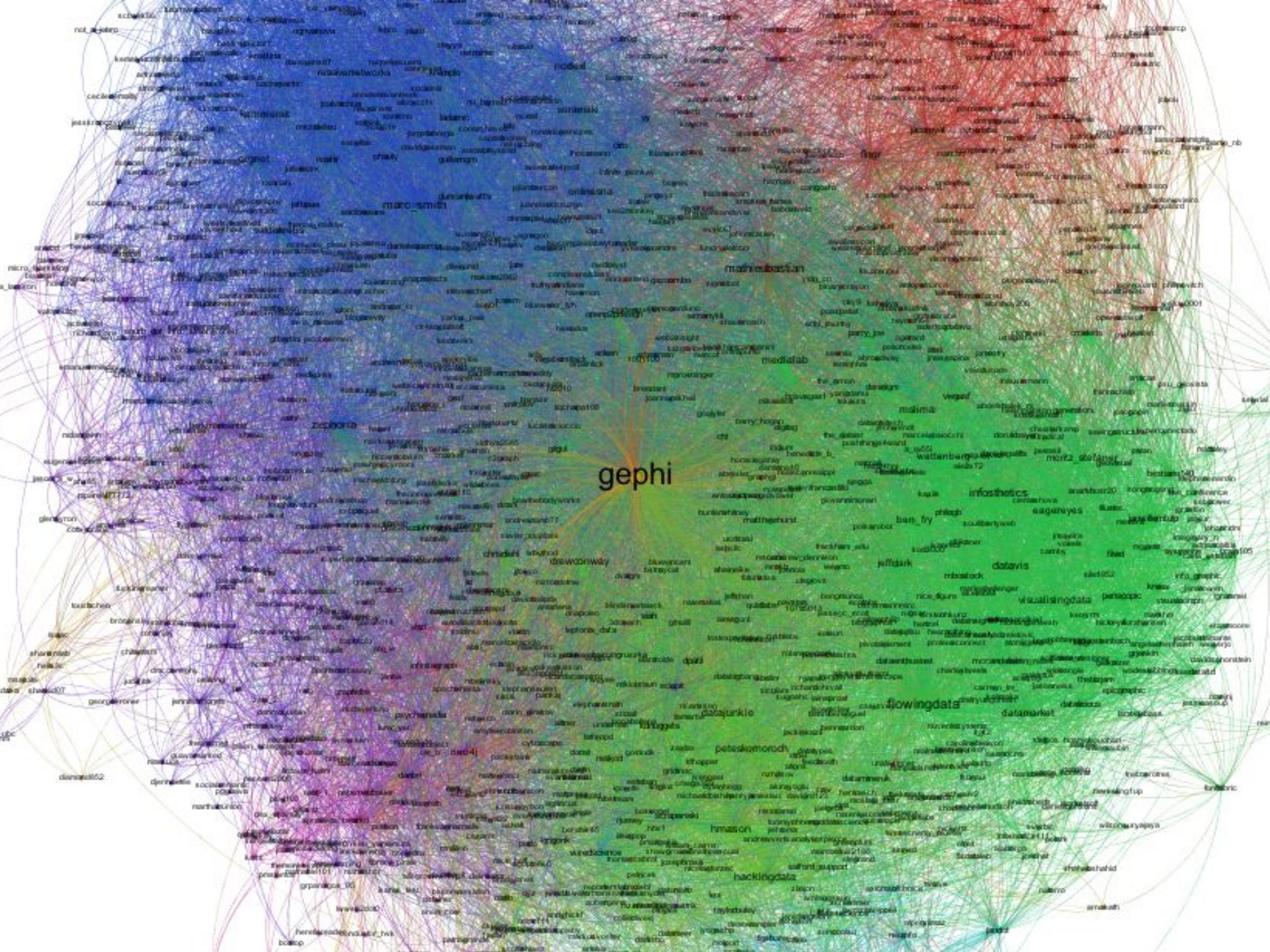
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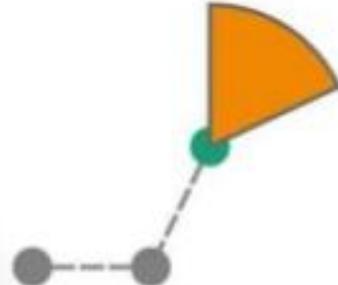


Graph density =
 $|N| \times |N| - |N| / |E|$

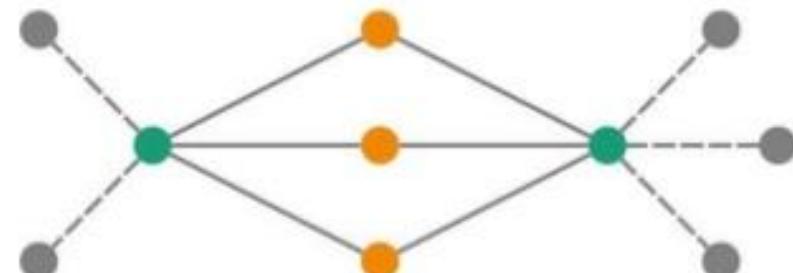


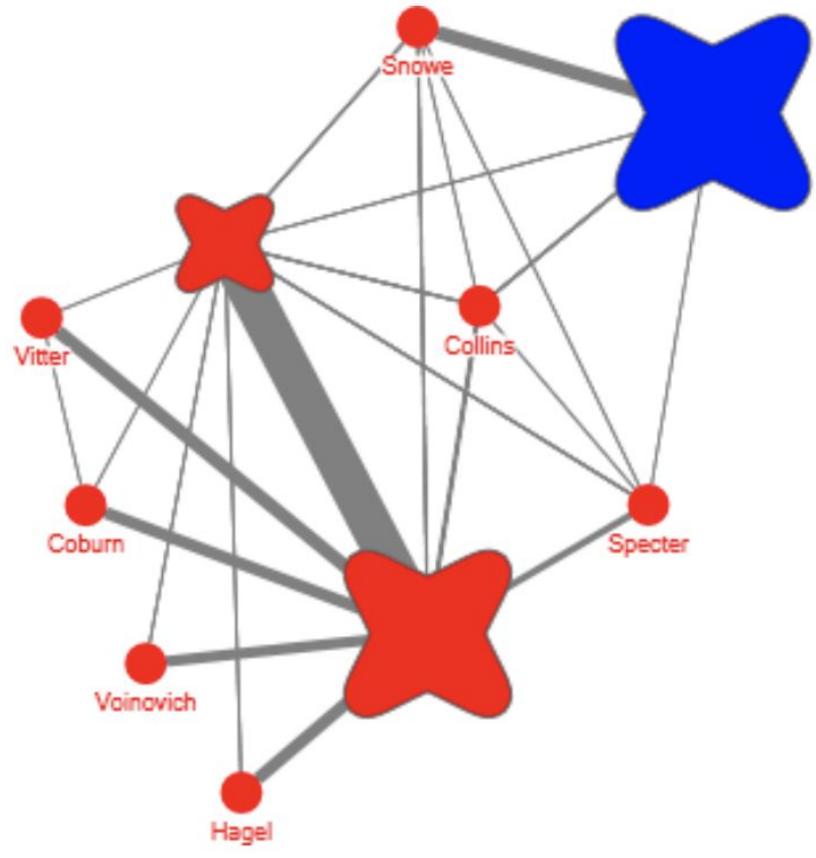
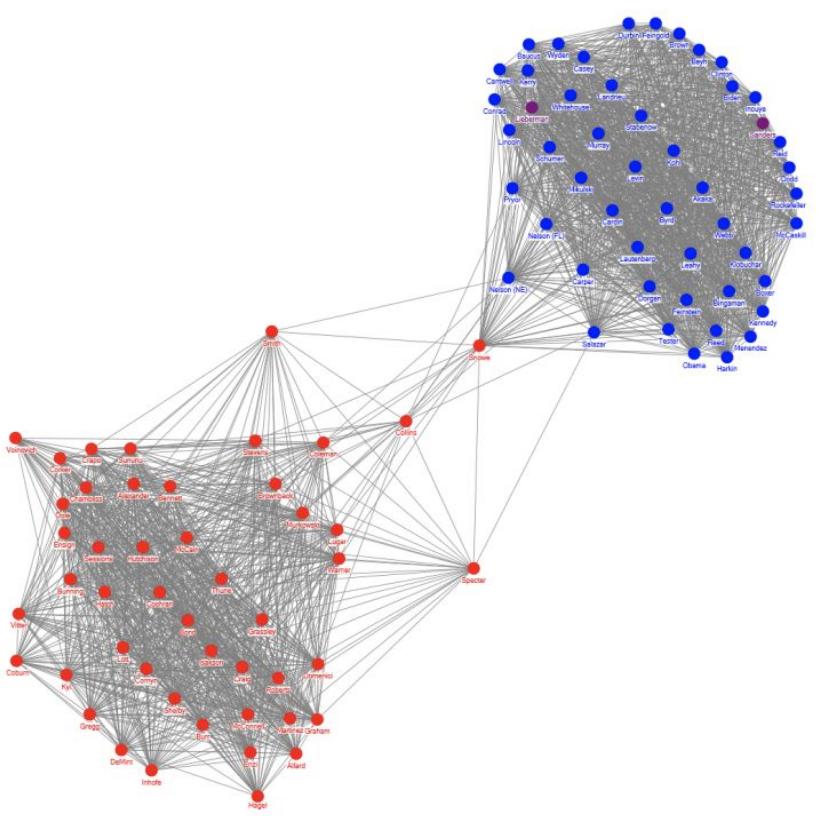
Motif Simplification

Fan Motif

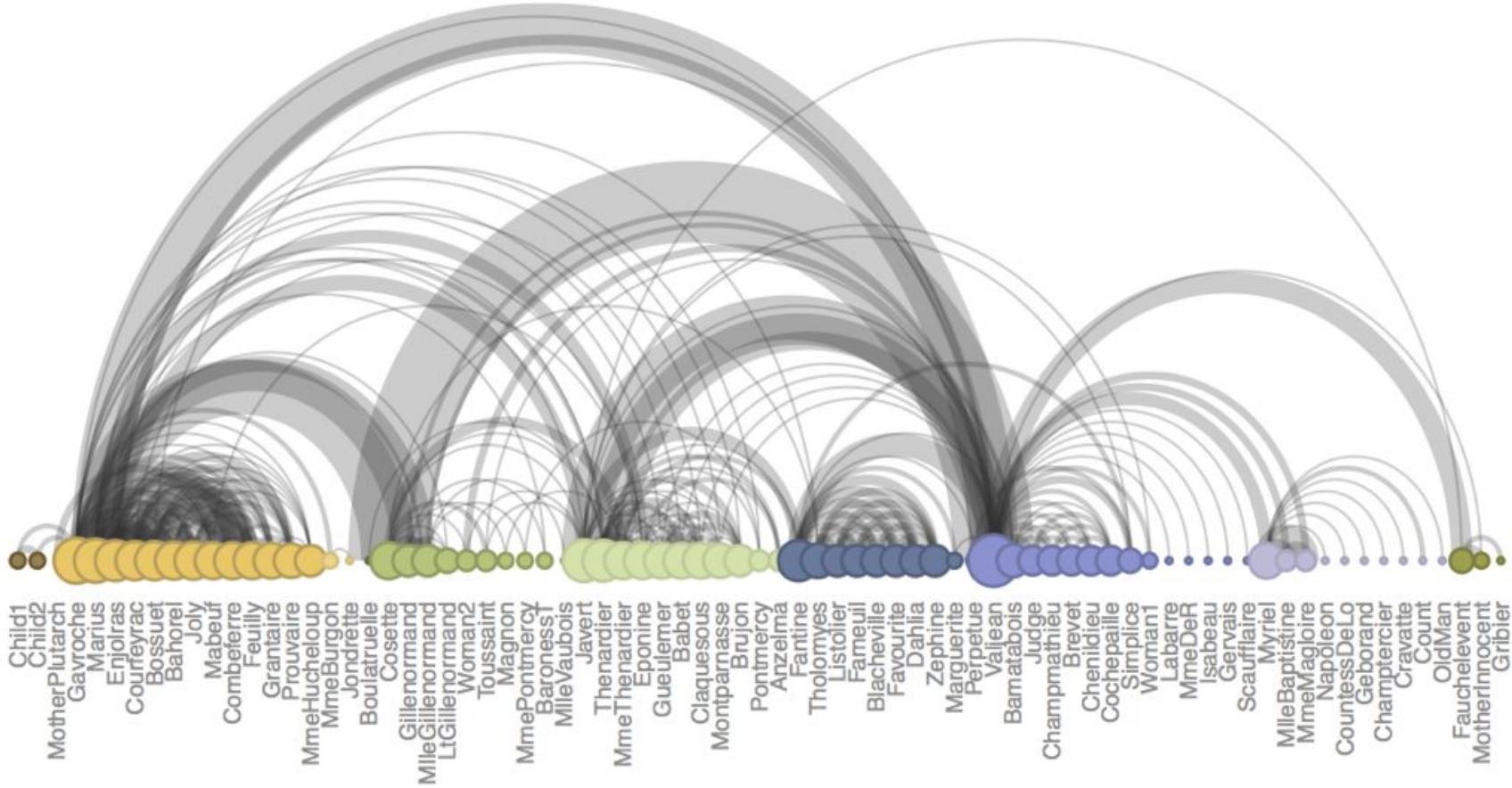


2-Connector Motif





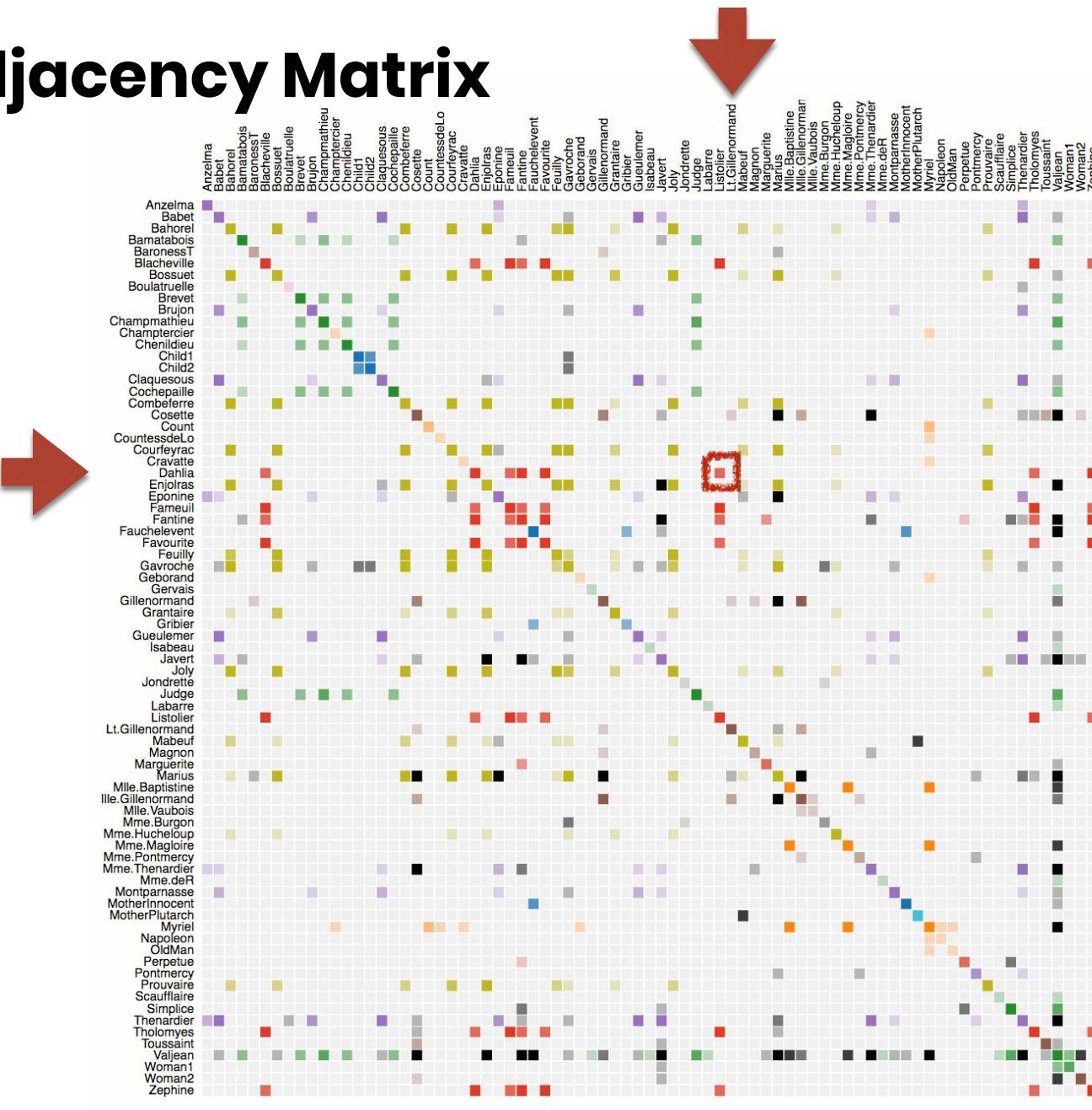
Arc Diagram



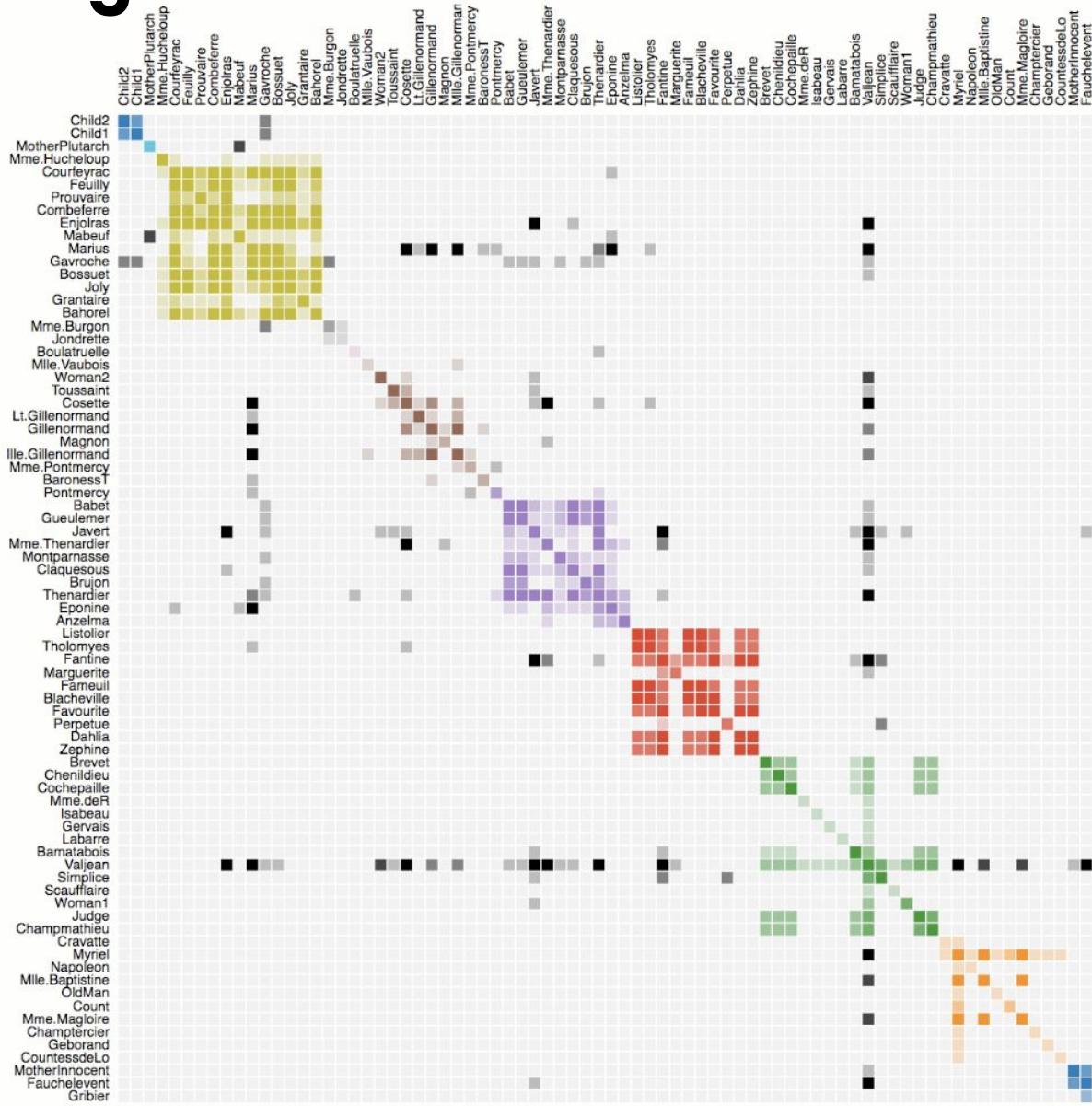
- + Node ordering
- + Node groups
- Requires meaningful ordering
- Does not scale with density

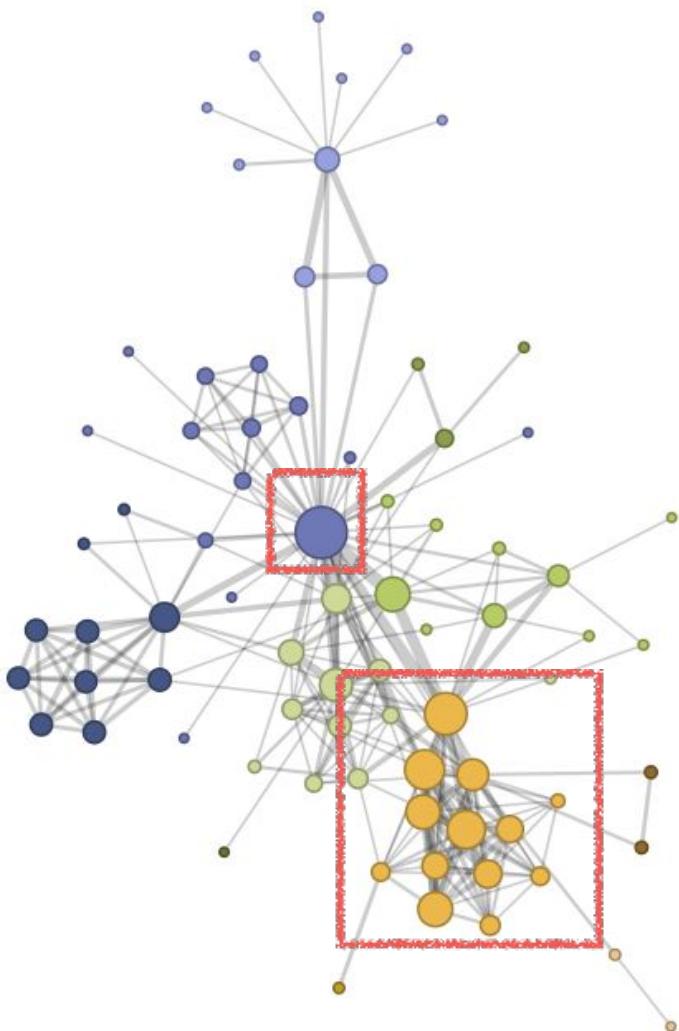
Wattenberg, Martin. "Arc diagrams: Visualizing structure in strings." *Information Visualization, 2002. INFOVIS 2002. IEEE Symposium on.* IEEE, 2002.

Adjacency Matrix

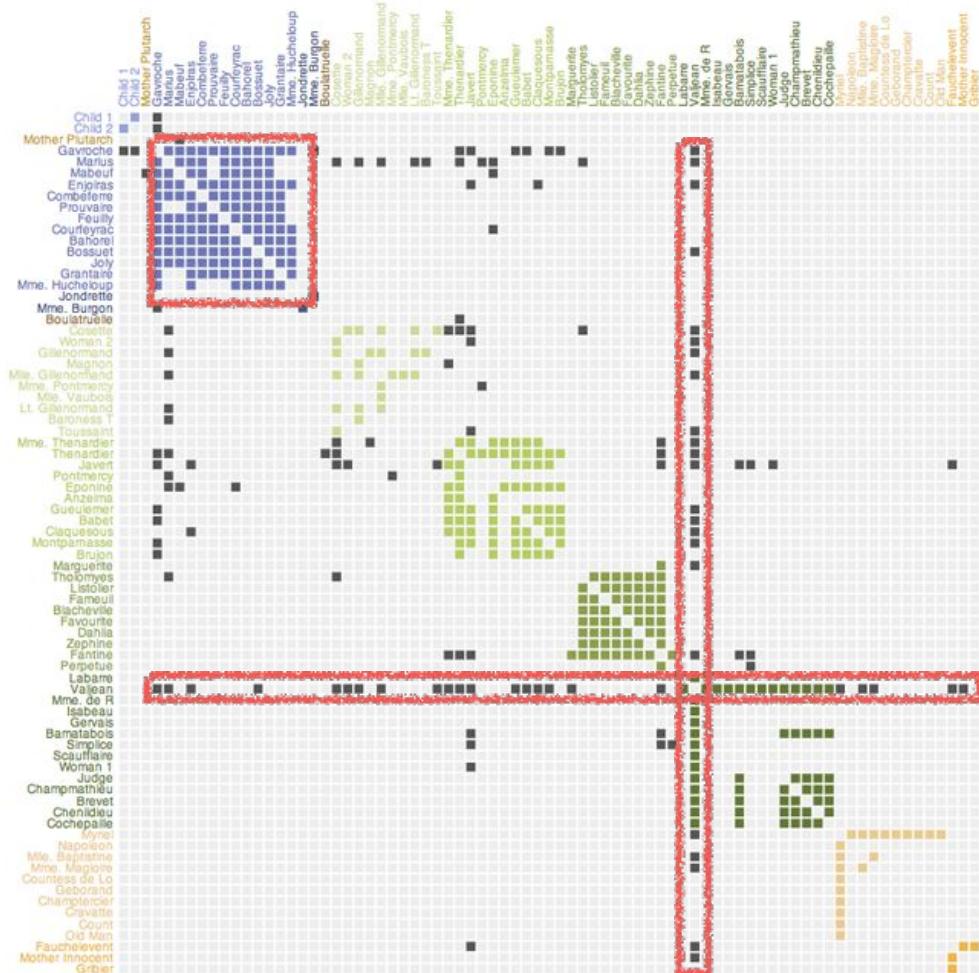


Ordering





Node Link



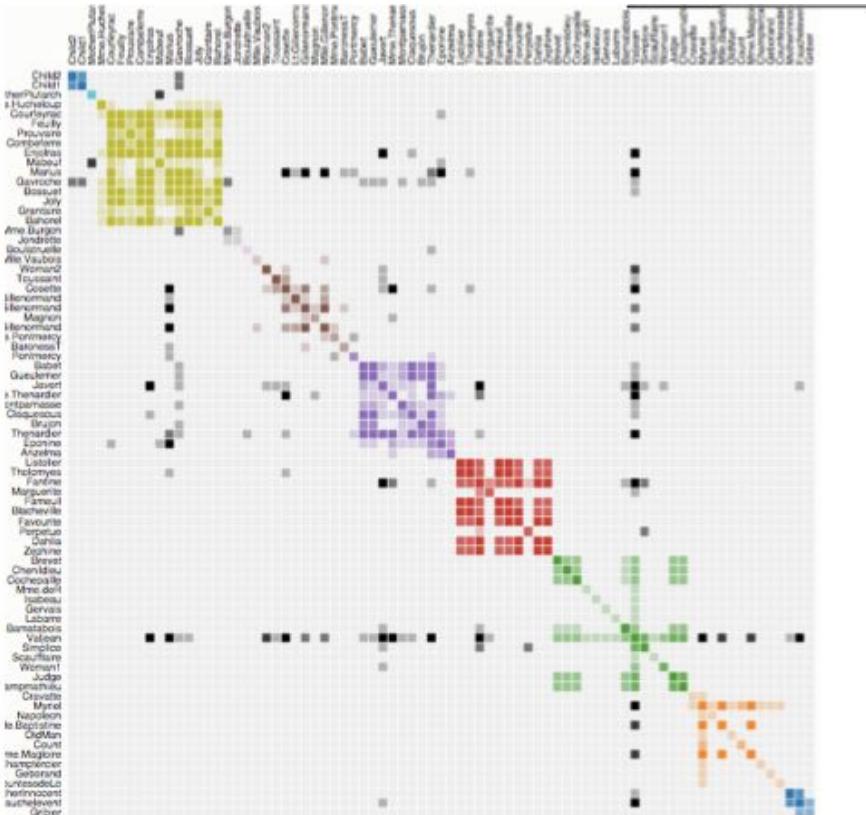
Matrices

Adjacency Matrix



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

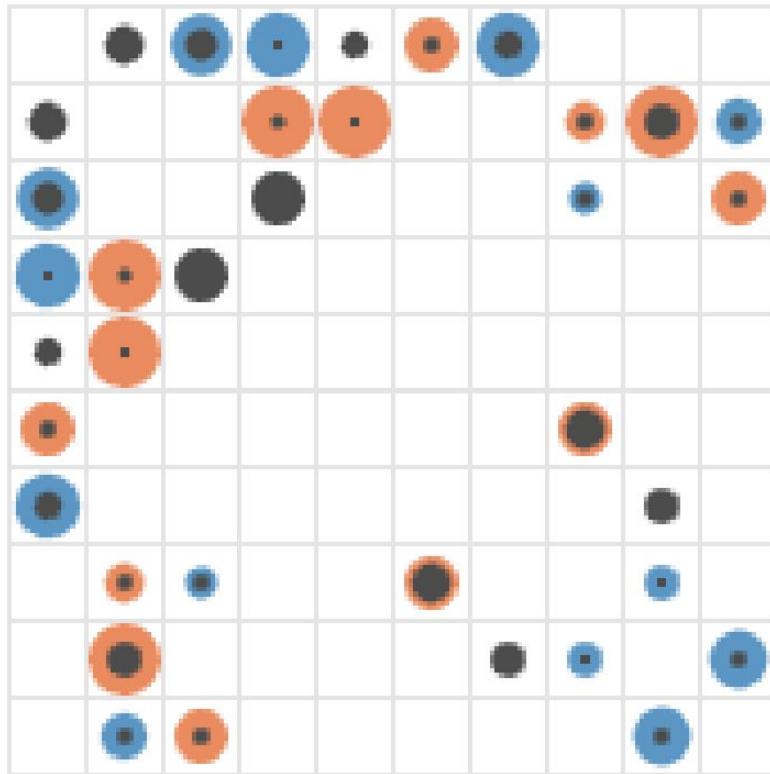
=> Sparse networks



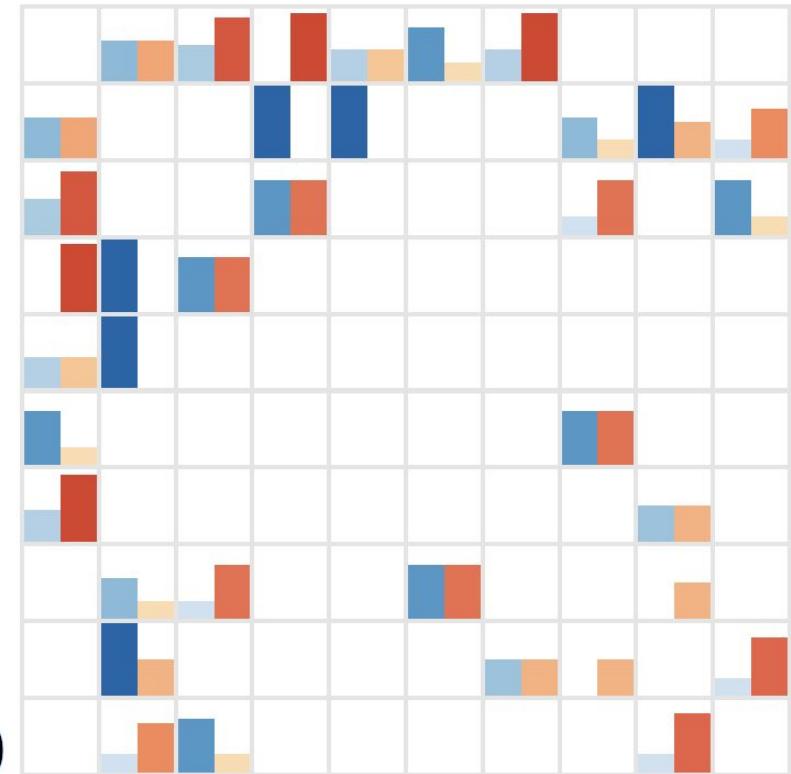
- + Clusters
 - + Missing links in clusters
 - + Highly connected nodes

=> Dense networks

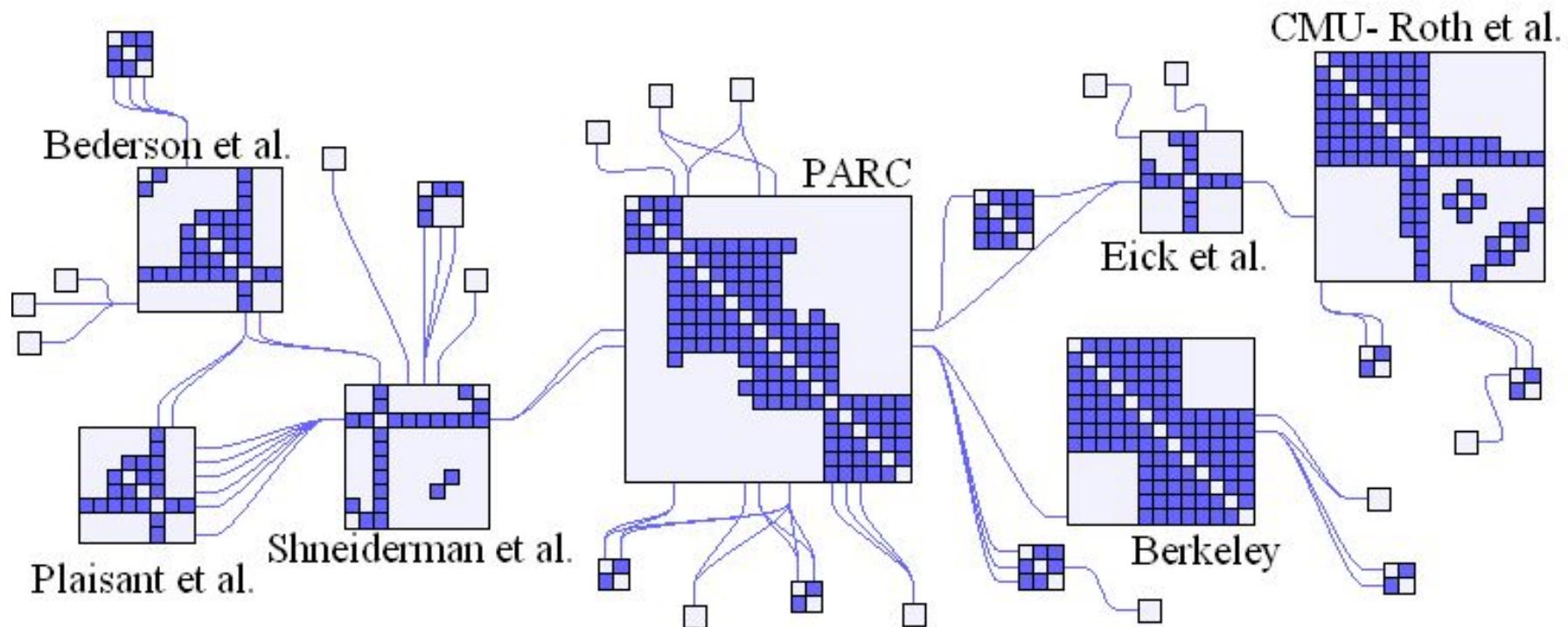
Matrix Cells



(d)

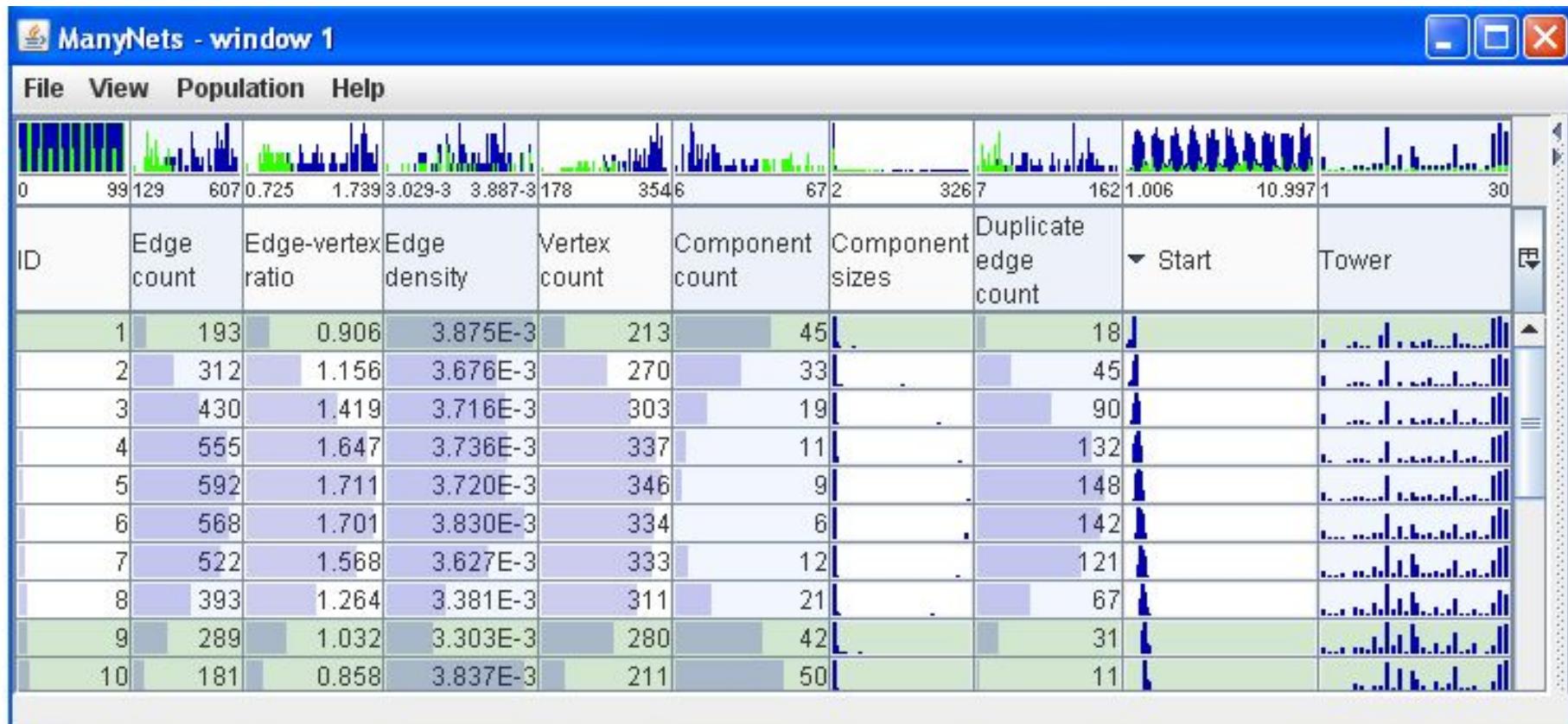


Nodetrix

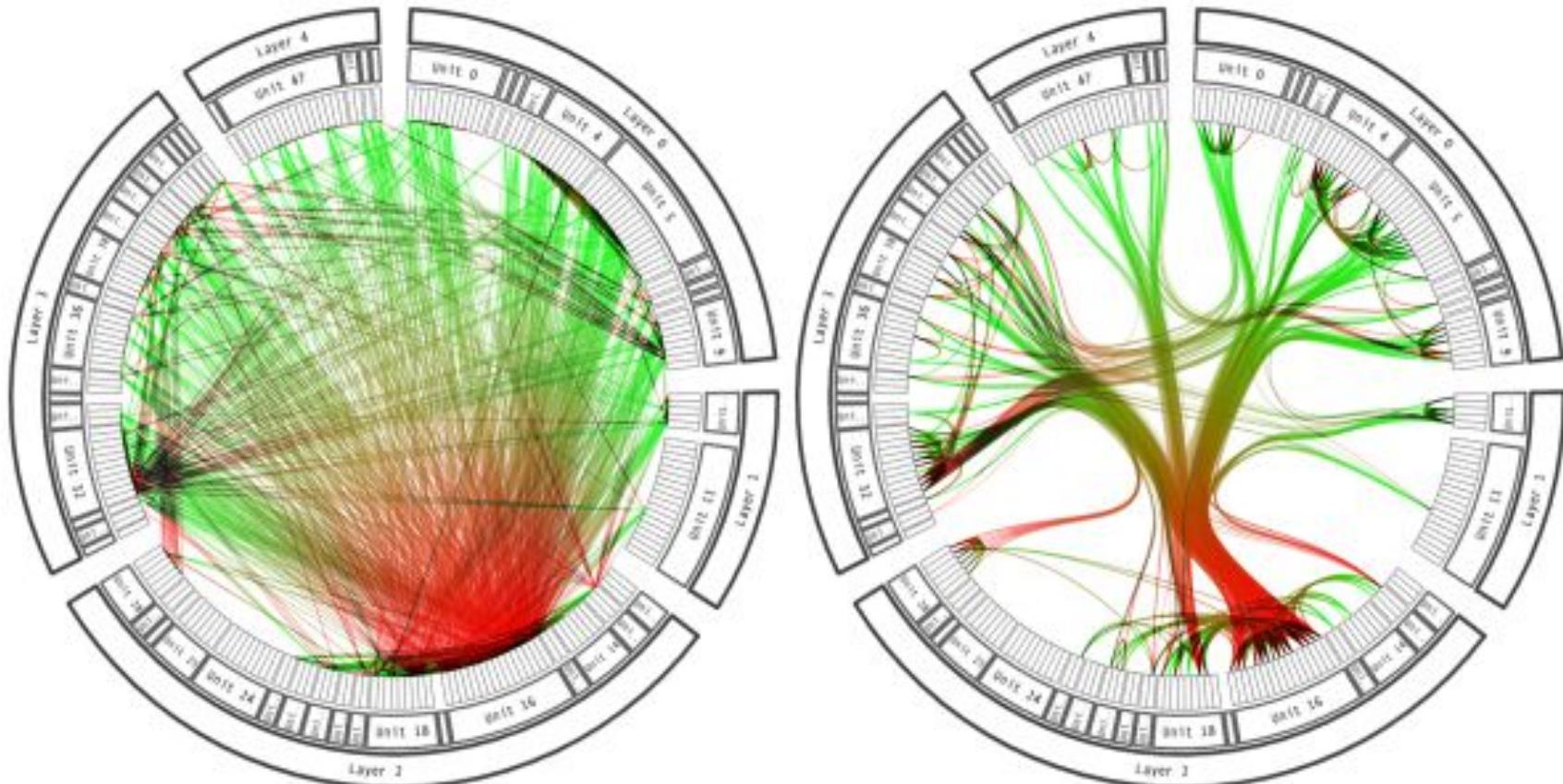


Henry, N., Fekete, J. D., & McGuffin, M. J. (2007). NodeTrix: a hybrid visualization of social networks. *IEEE transactions on visualization and computer graphics*, 13(6), 1302-1309.

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.

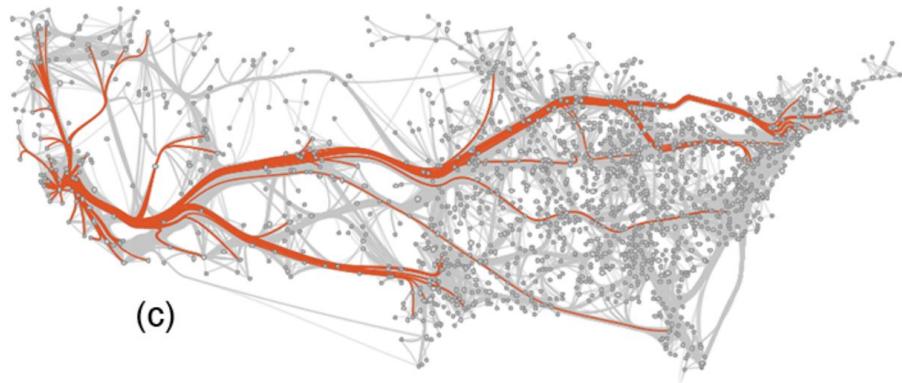
Edge Bundling



(a)



(b)



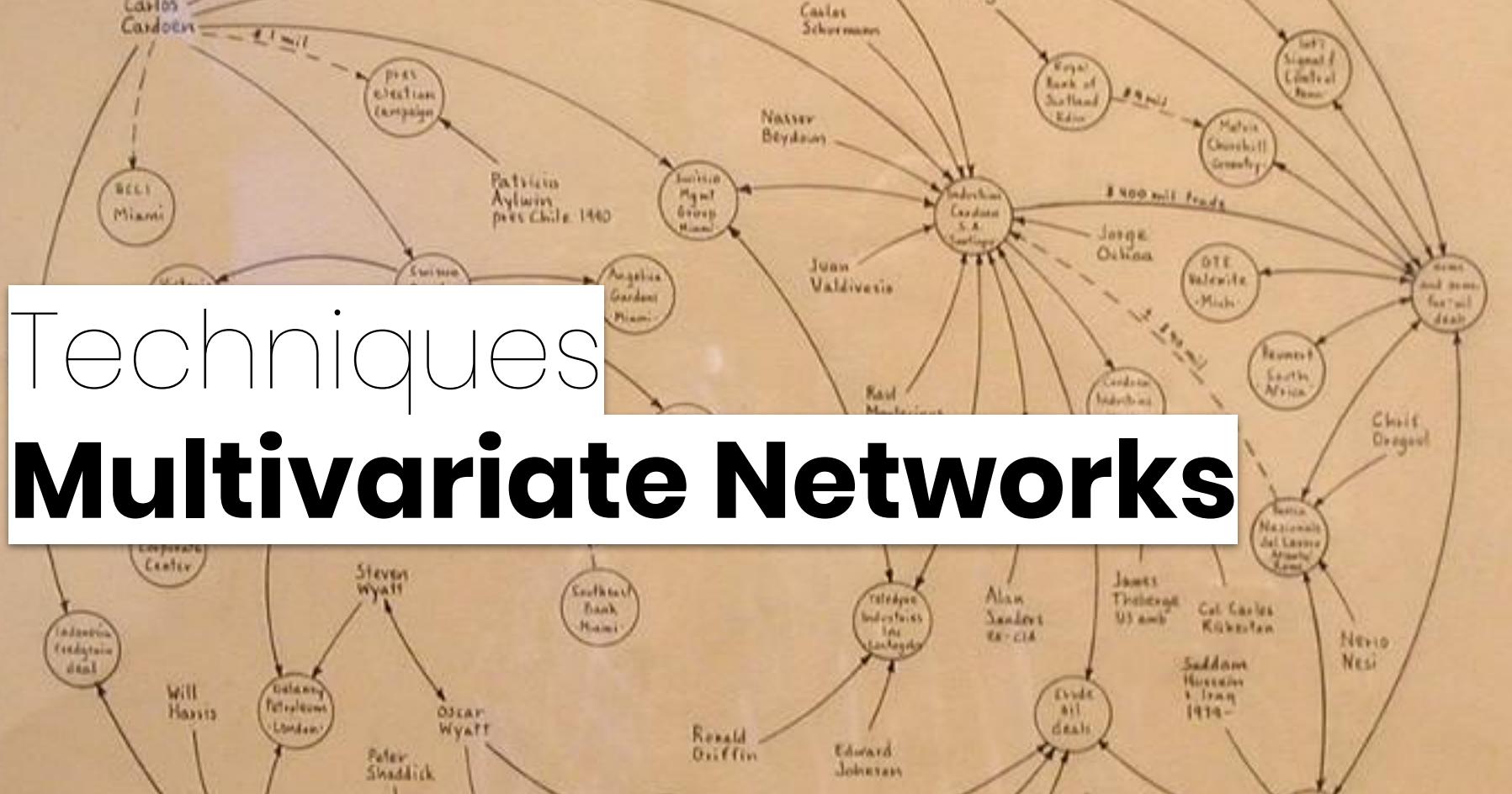
(c)



(d)

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.



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Node-link Diagram



Directed Link



Multiple Links



Link Types



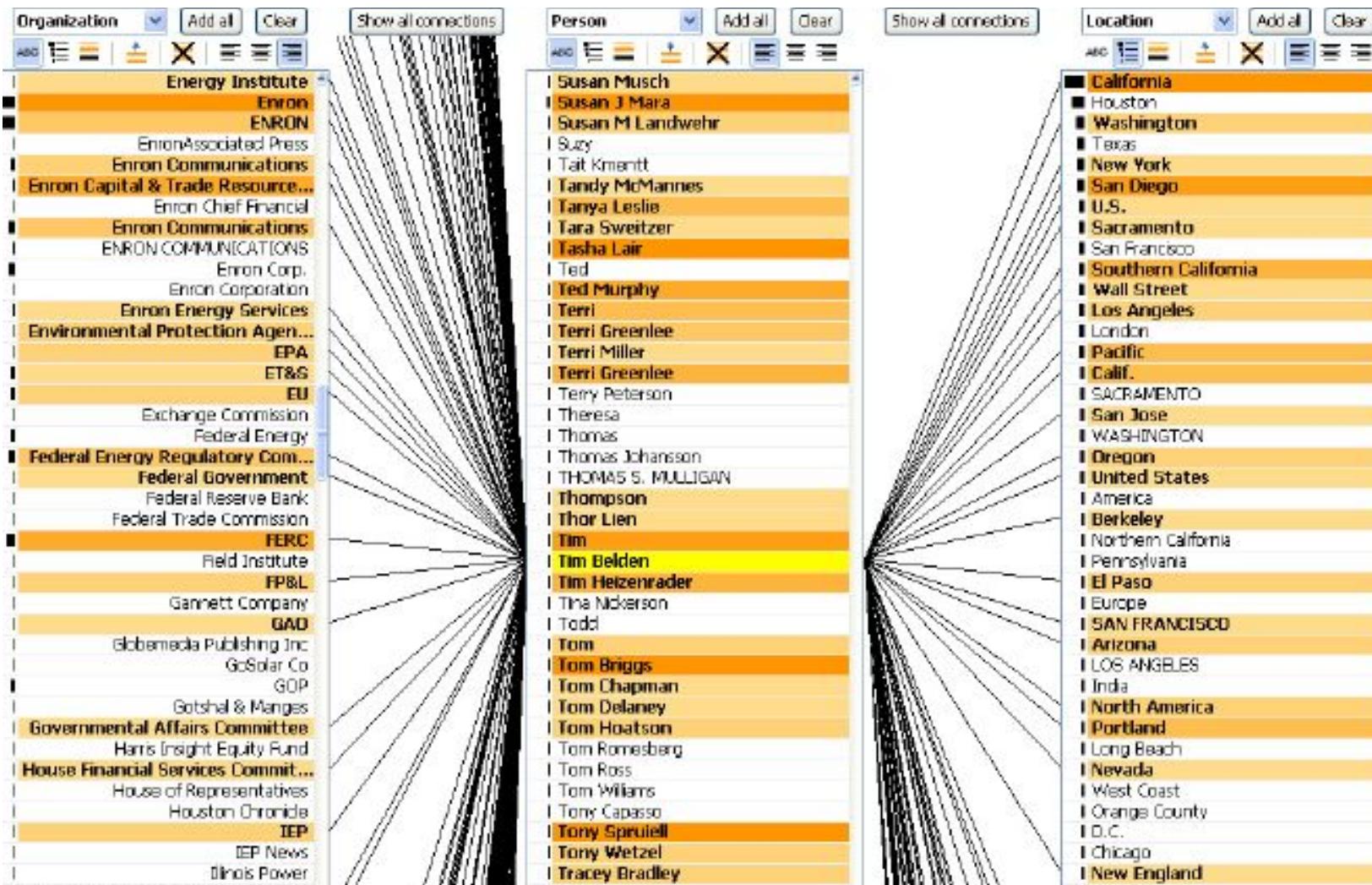
Node type



Weighted link

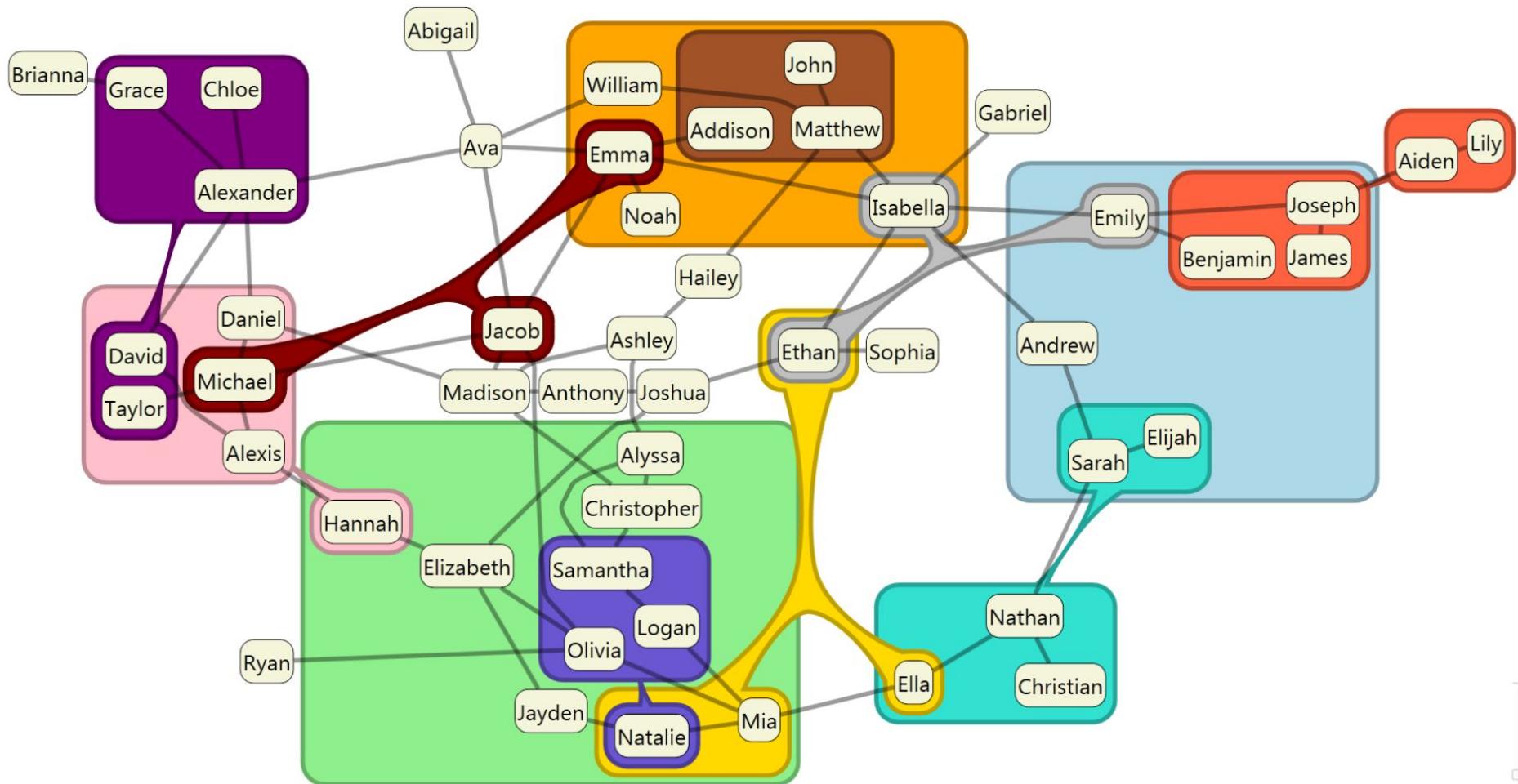


Jigsaw



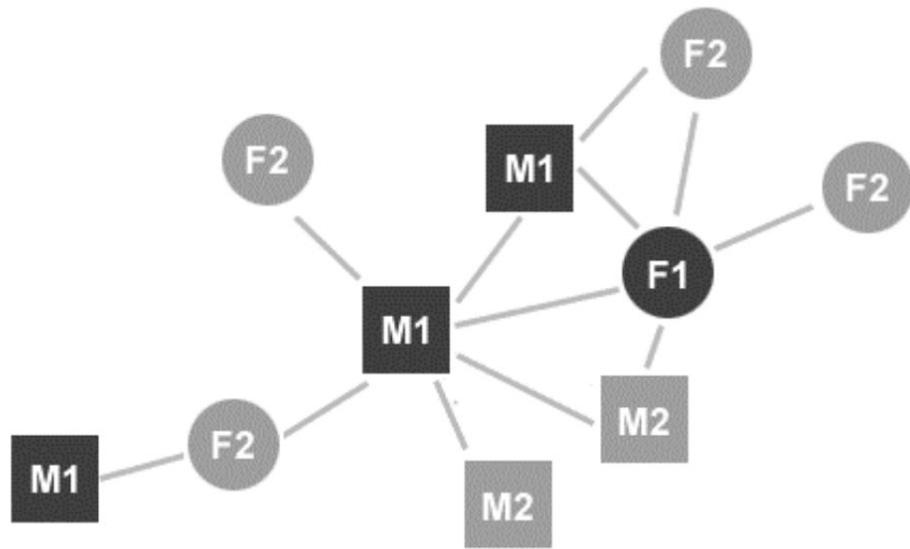
Stasko, J., Görg, C., & Liu, Z. (2008). Jigsaw: supporting investigative analysis through interactive visualization. *Information visualization*, 7(2), 118-132.

Networks and Sets



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

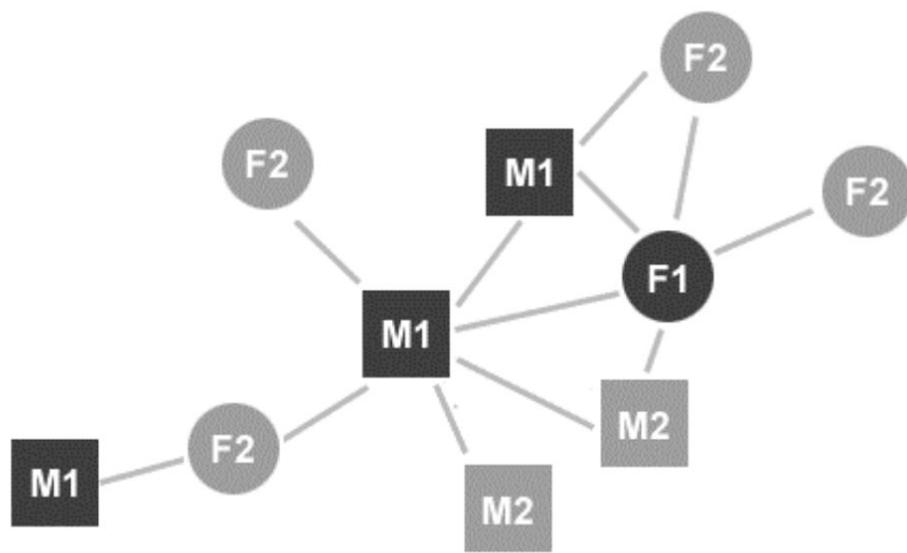
Pivot Graphs



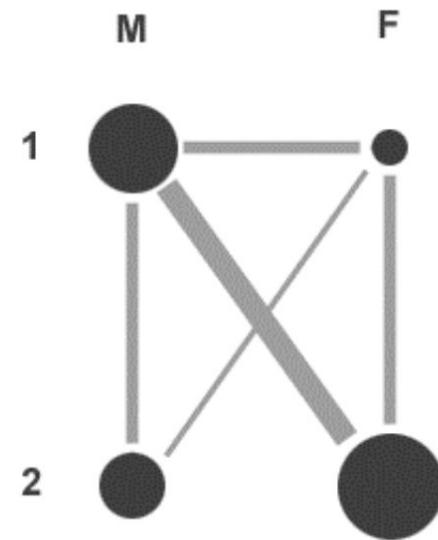
Node and Link Diagram

Wattenberg, M. (2006, April). Visual exploration of multivariate graphs. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 811-819). ACM.

Pivot Graphs



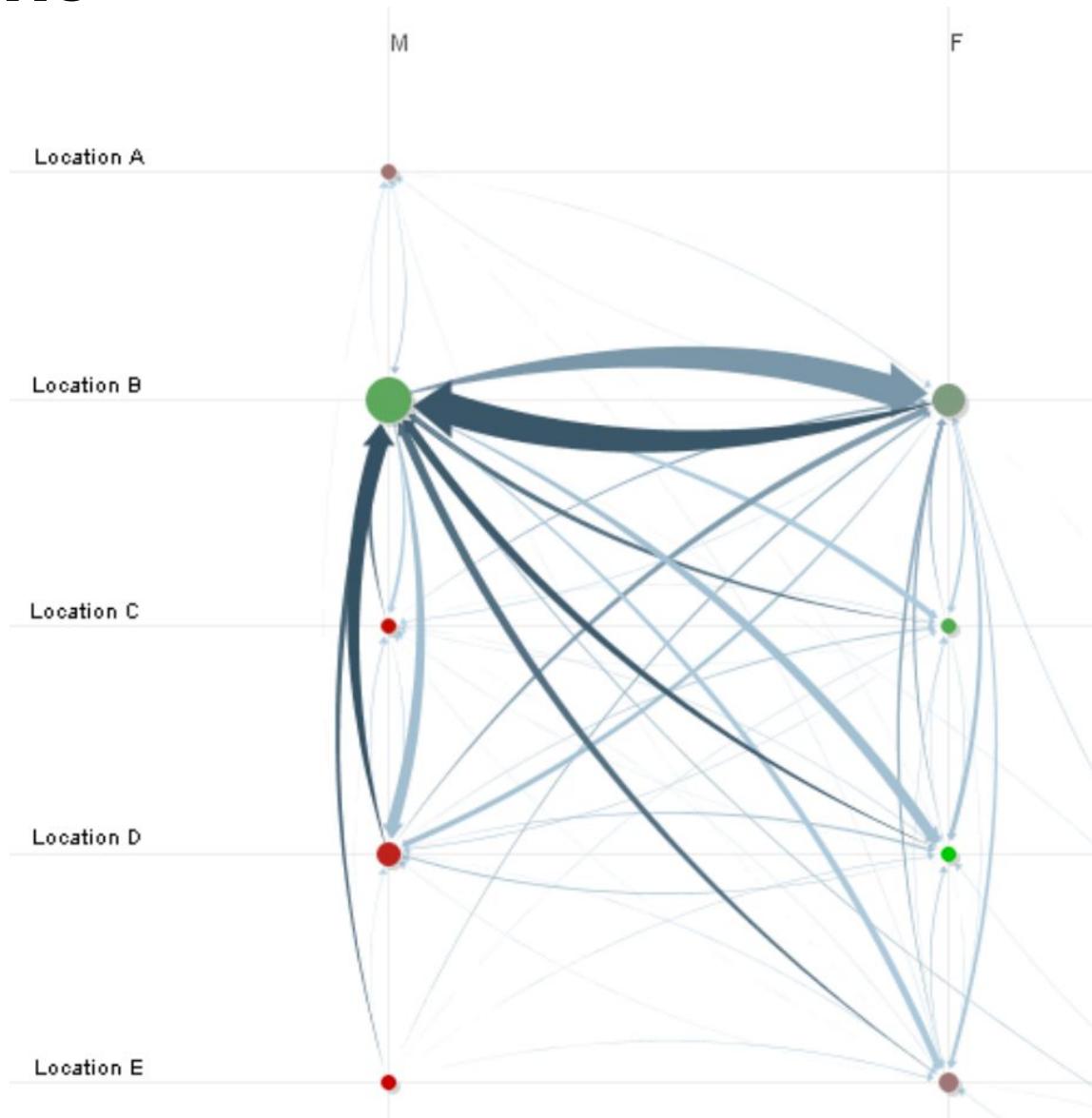
Node and Link Diagram

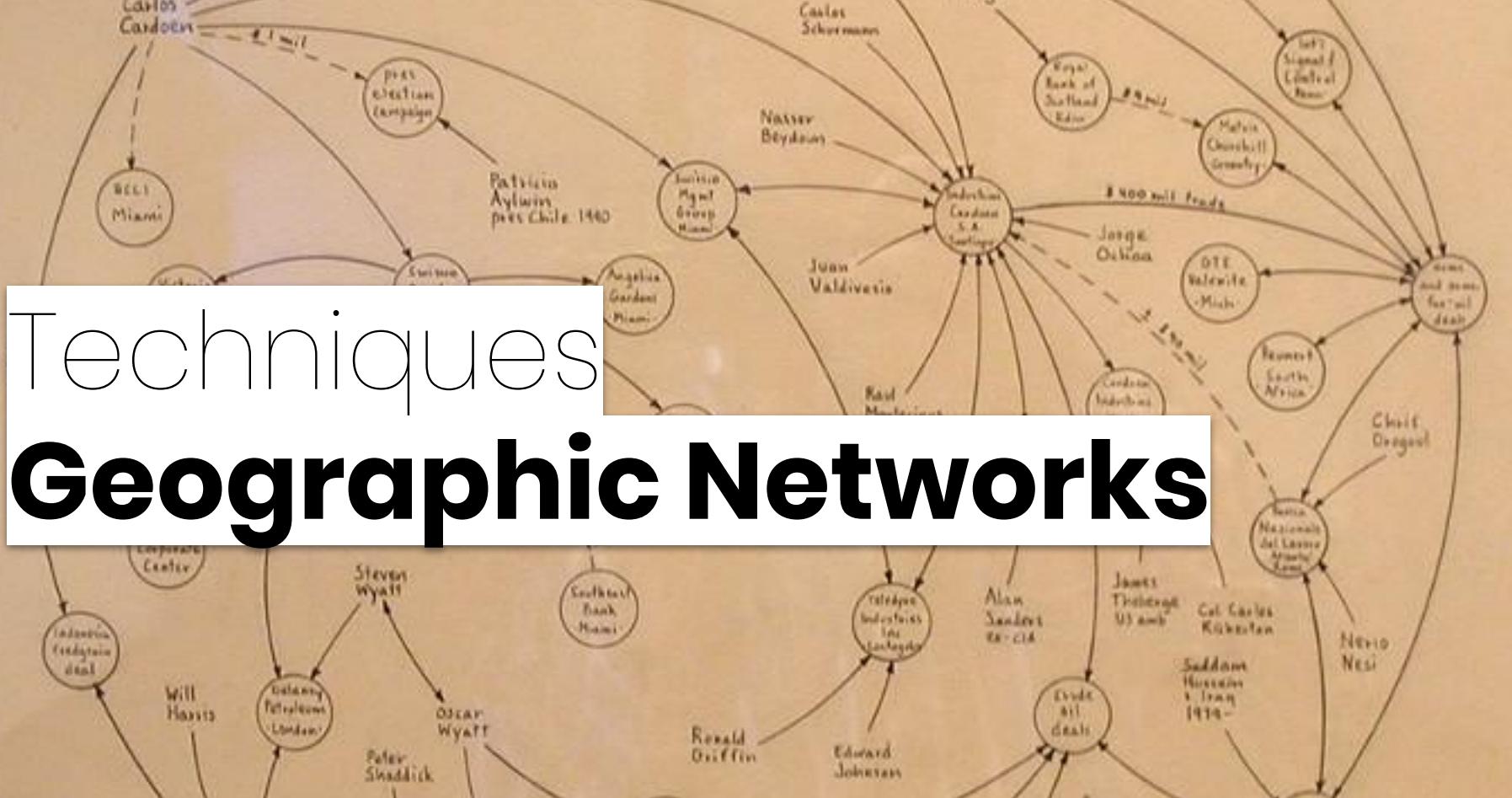


PivotGraph Roll-up

Wattenberg, M. (2006, April). Visual exploration of multivariate graphs. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 811-819). ACM.

Pivot Graphs





Techniques

Geographic Networks



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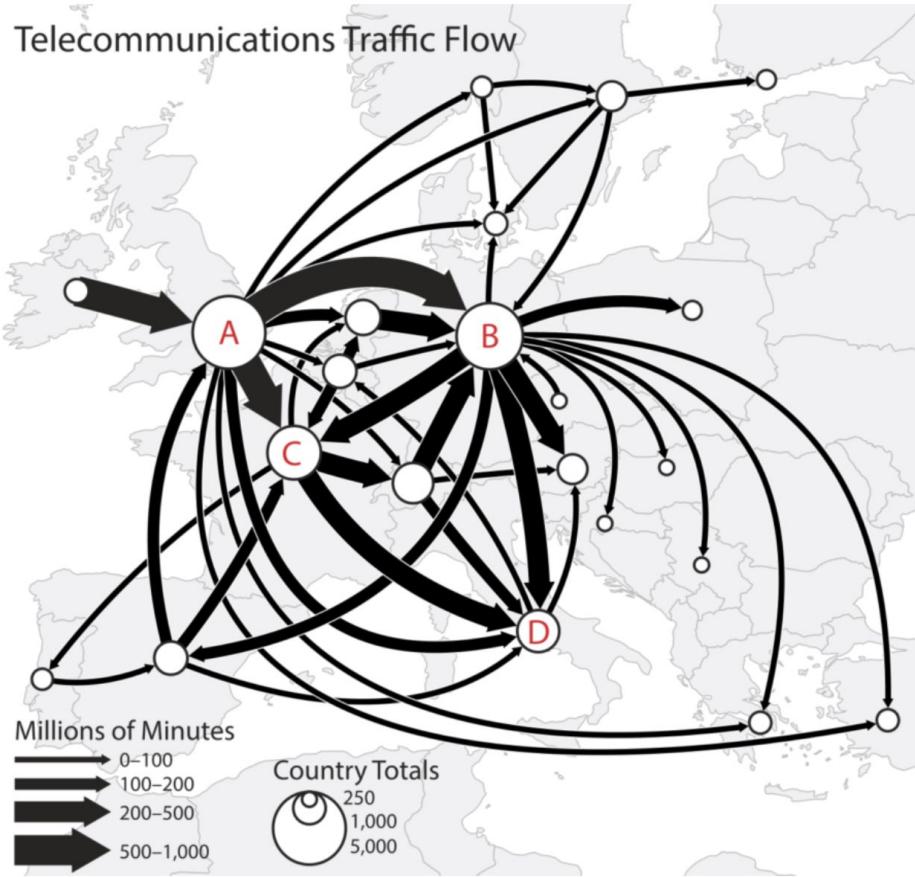
Benjamin Bach

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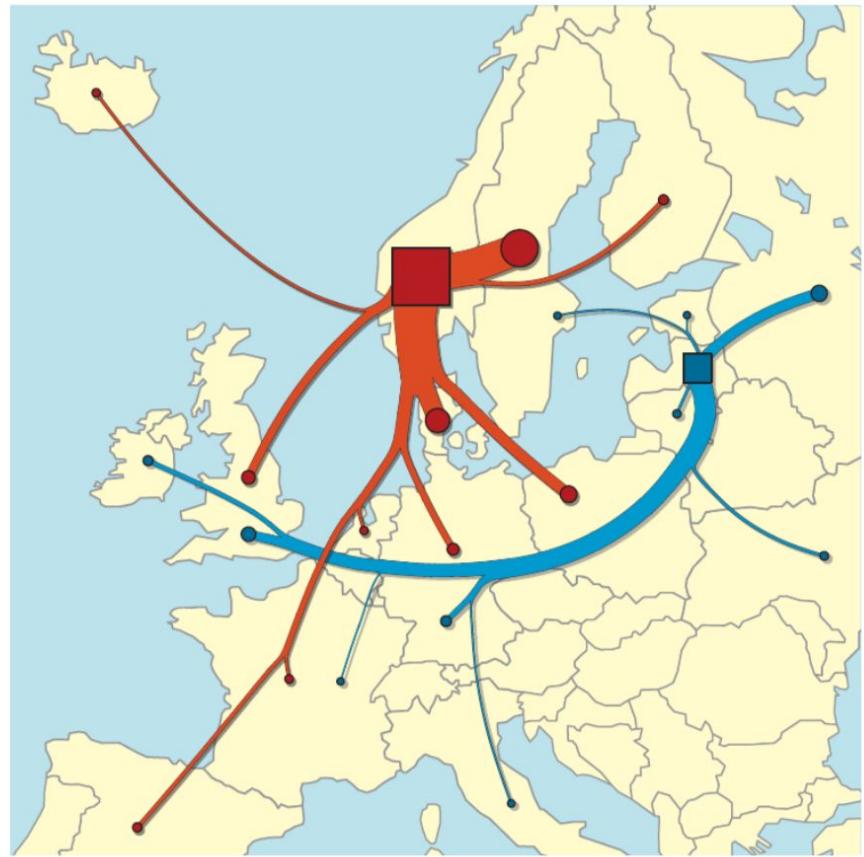
<http://benjbach.me>
<https://datavis-online.github.io>

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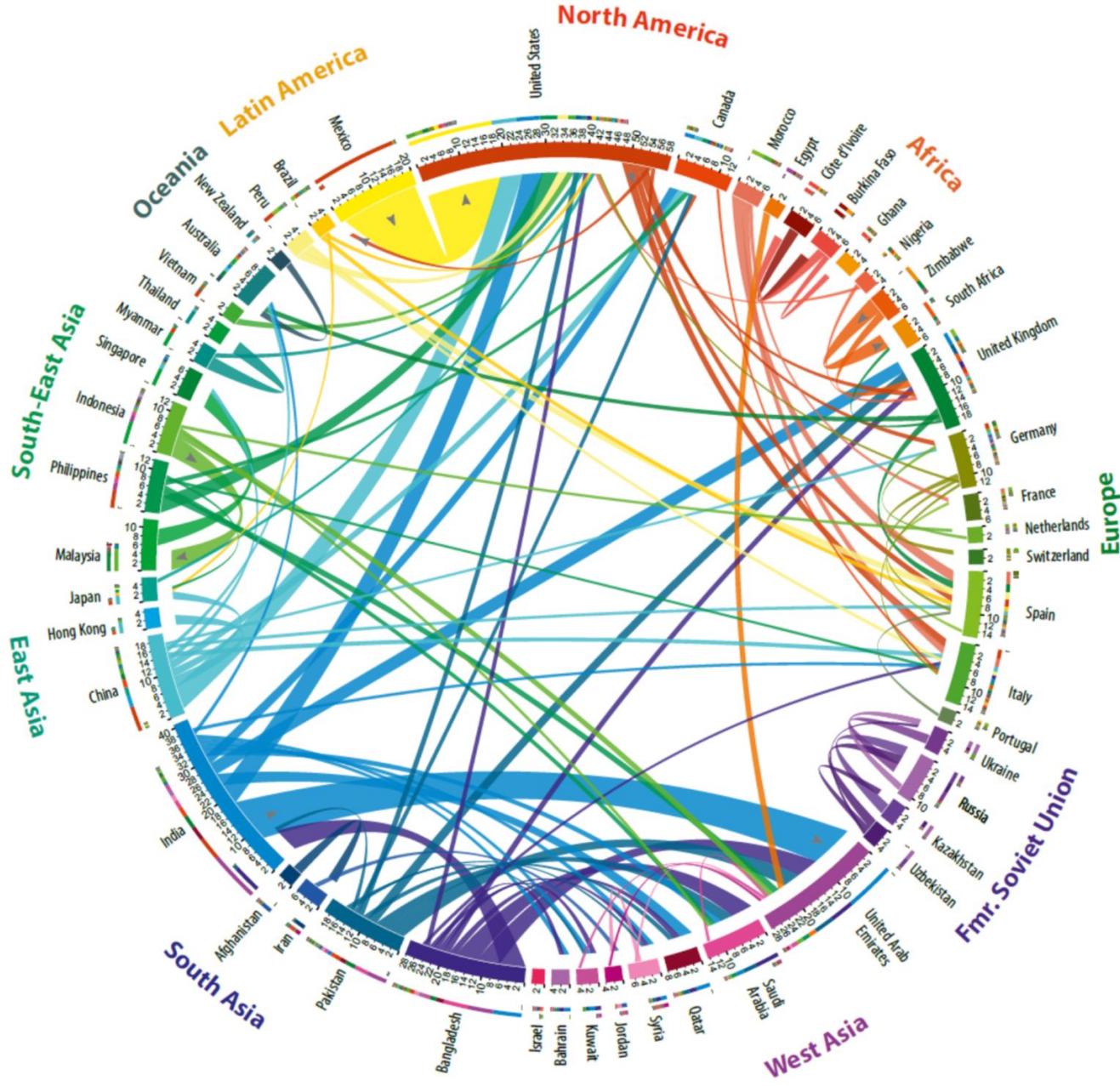
Telecommunications Traffic Flow

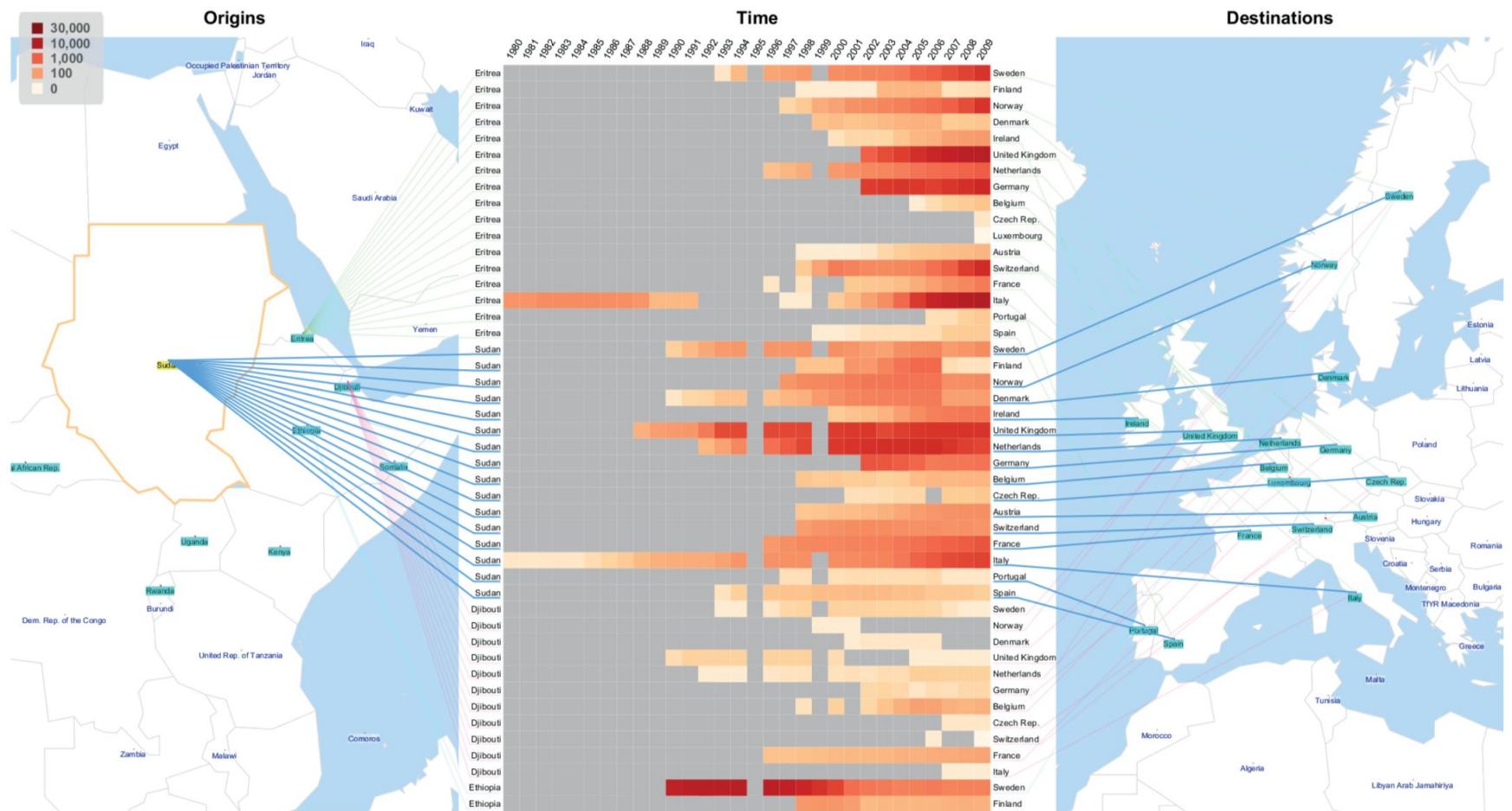


JENNY, BERNHARD, STEPHEN, DANIEL M., MUEHLENHAUS, IAN, et al.
“Design principles for origin-destination flow maps”. *Cartography and Geographic Information Science* 45.1 (Jan. 2, 2018)



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





BOYANDIN, ILYA, BERTINI, ENRICO, BAK, PETER, and LALANNE, DENIS. "Flowstrates: An Approach for Visual Exploration of Temporal Origin-Destination Data". *Computer Graphics Forum* 30.3 (2011)

GEOGRAPHIC NETWORK VISUALISATION

About • Poster • Read the abstract

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61 techniques (show all)

Geography Representation

Map	Distorted Map	Abstract
-----	---------------	----------



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]

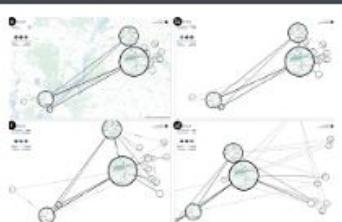
map abstract-abstract balanced
required-interaction



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



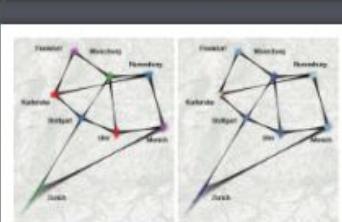
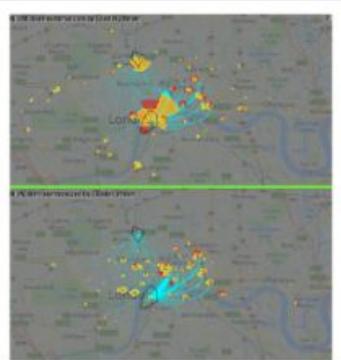
Shifted Maps: Revealing spatio-temporal topologies in movement data

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

map abstract-explicit balanced
required-interaction

Network Representation

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



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; Baciu, George; Wang, Yunzhe (2017) [DOI Link]

map abstract-explicit balanced
required-interaction

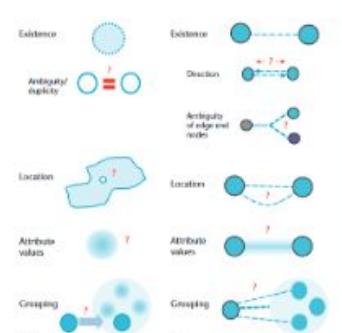


Figure 2. Overview and comparison of (a) node and (b) edge uncertainty. Node uncertainty encompasses the uncertainties that might affect individual nodes, whereas edge uncertainty is directly connected to and compounded by the various types of node uncertainty.

Integration

Geography as Basis	Balanced	Network as Basis
--------------------	----------	------------------

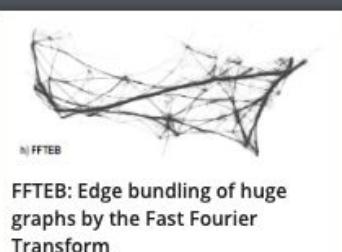
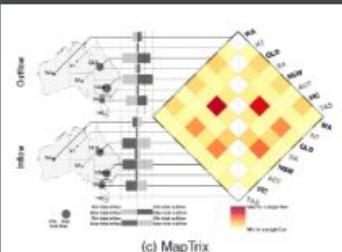
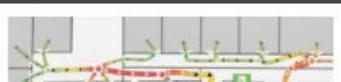
Interaction

No Interaction	Optional Interaction
Required Interaction	Interaction Technique

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



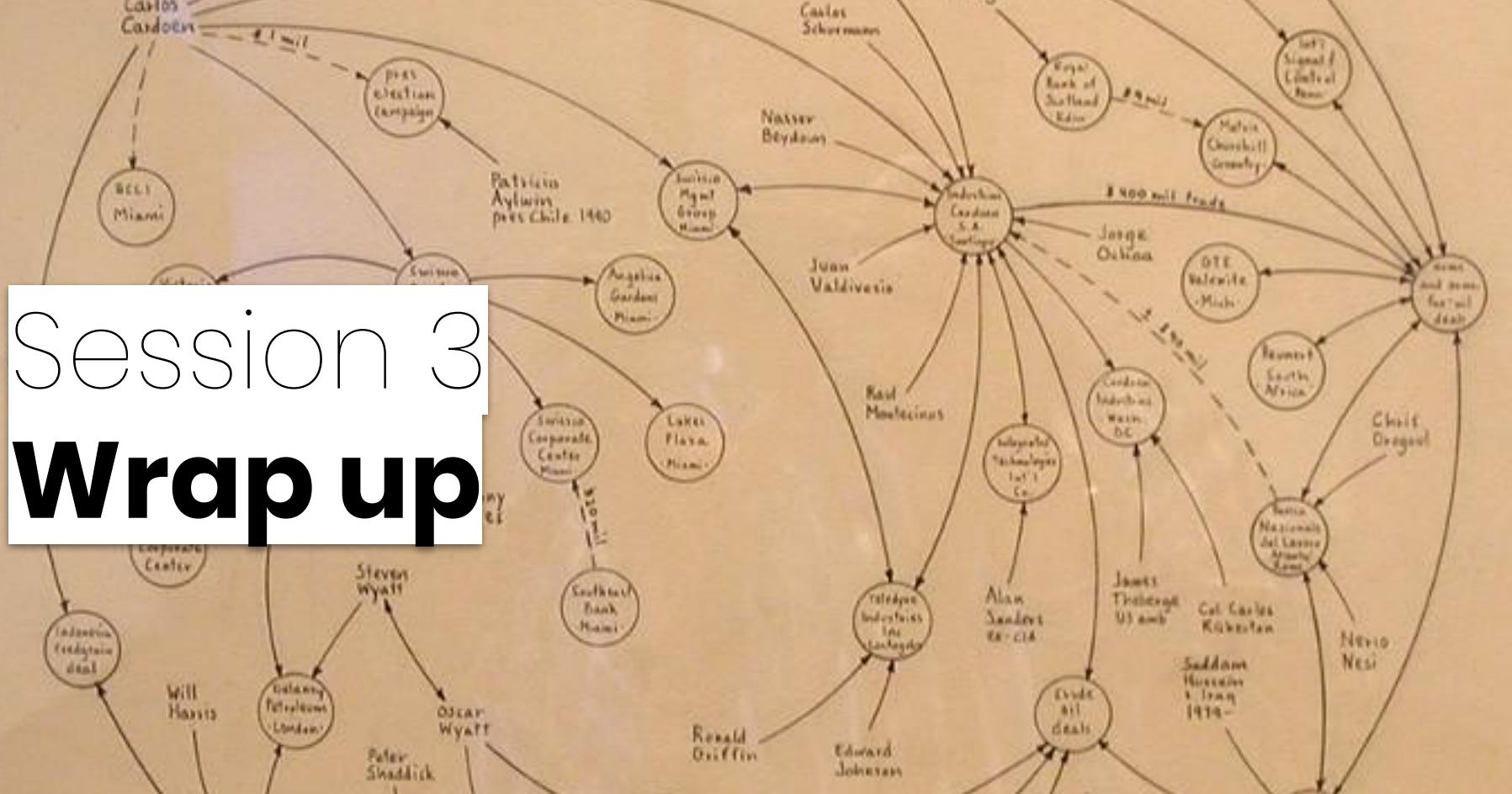
FFTEB: Edge bundling of huge graphs by the Fast Fourier Transform

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

Session 3 Wrap up



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June 2020

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Outline

- Sparse networks vs. dense networks
- Dense networks: adjacency matrices, motif simplification
- Multivariate networks: color, shape, pivot graphs
- Geographic networks: abstract geography

Outline

- Sparse networks vs. dense networks
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Outline

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Outline

- Sparse networks vs. dense networks
- Dense networks: adjacency matrices, motif simplification
- Multivariate networks: color, shape, pivot graphs
- Geographic networks: abstract geography

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.
- 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/>

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.
- Hadlak, Steffen, Heidrun Schumann, and Hans-Jörg Schulz. "A Survey of Multi-faceted Graph Visualization." *EuroVis (STARs)*. 2015.
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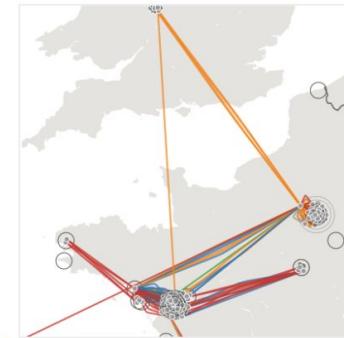
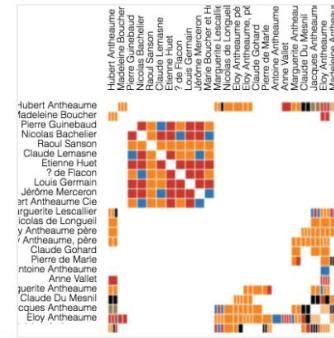
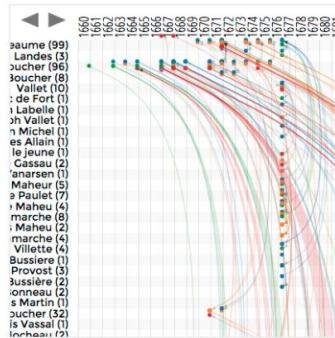
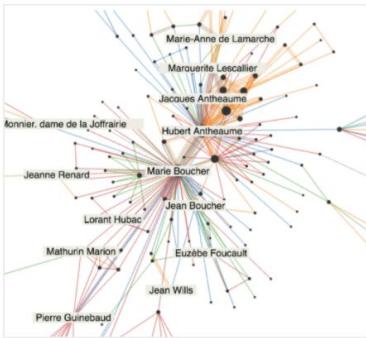
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