

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

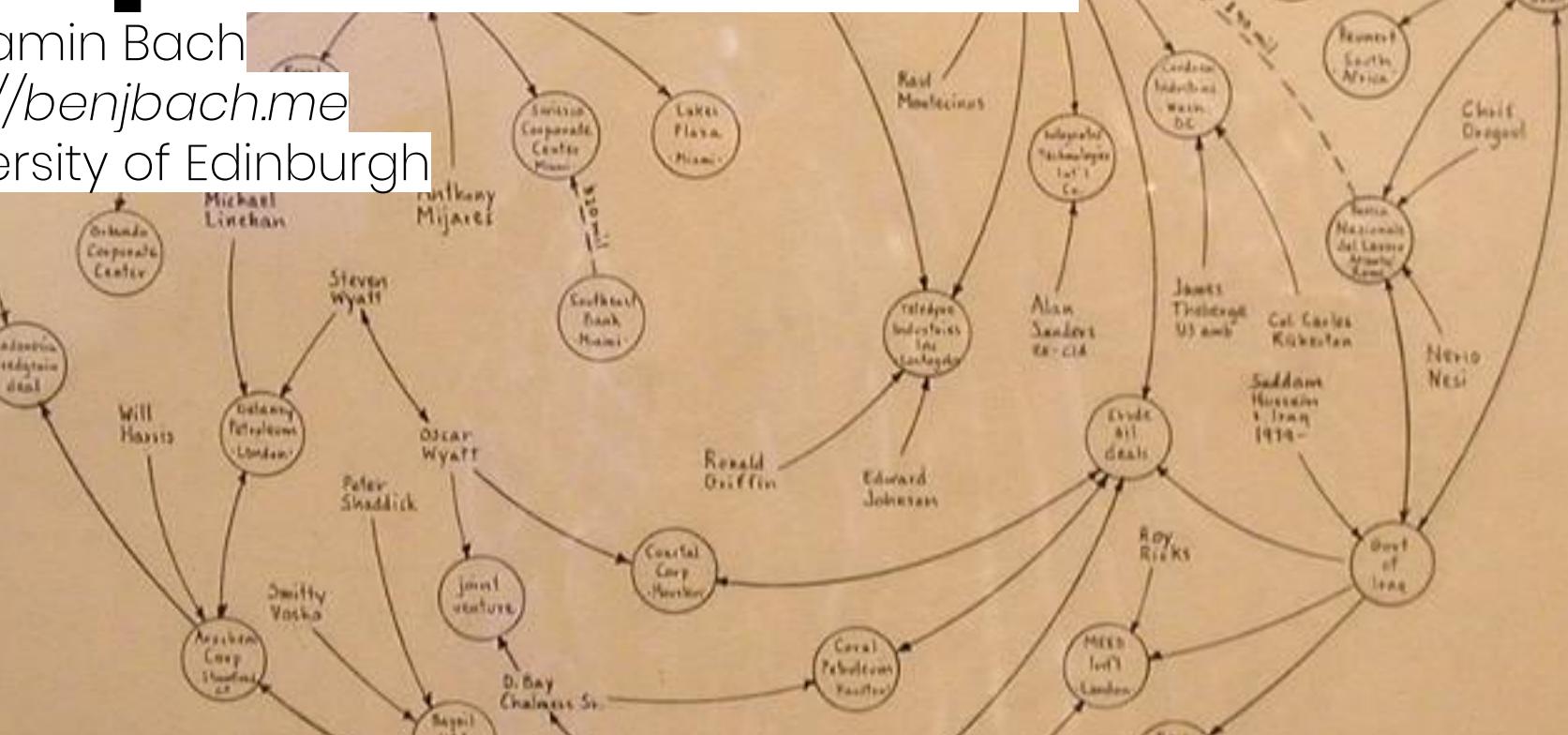
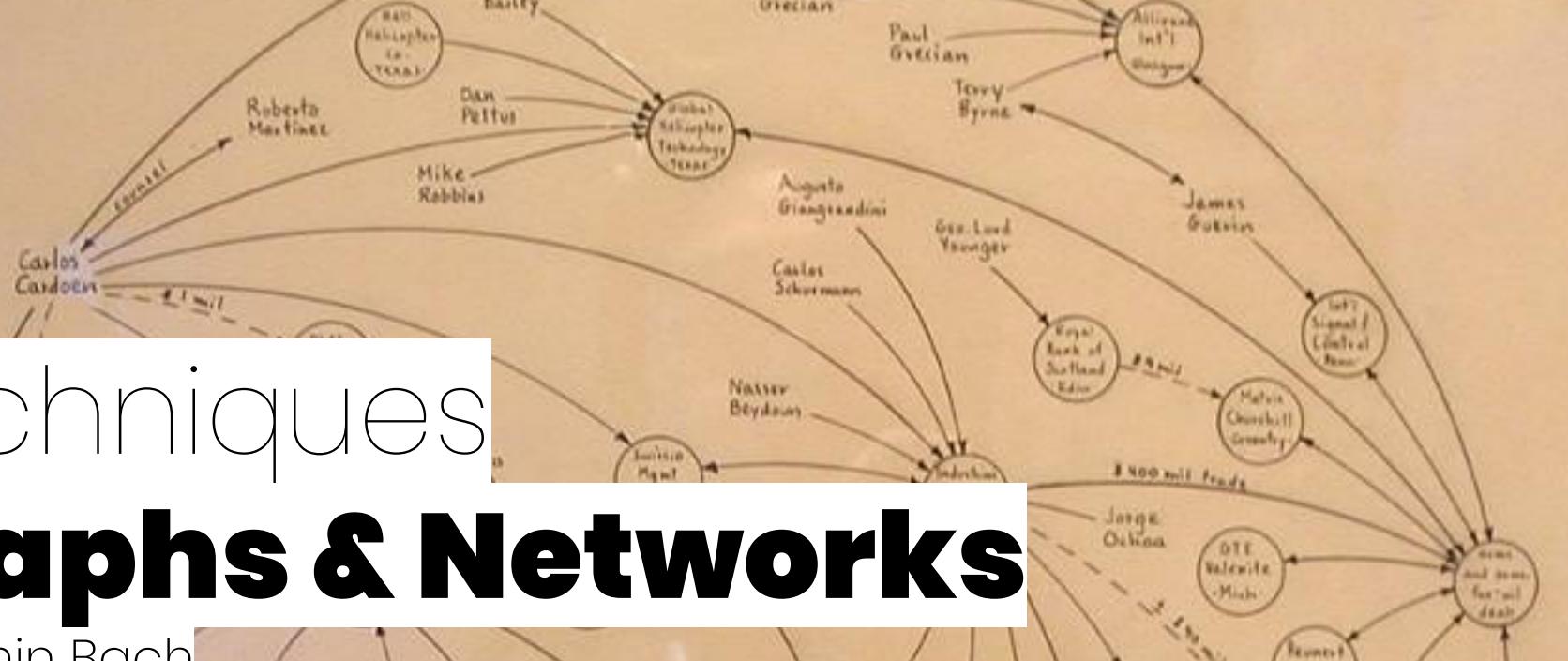
# Assignment 2

- 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

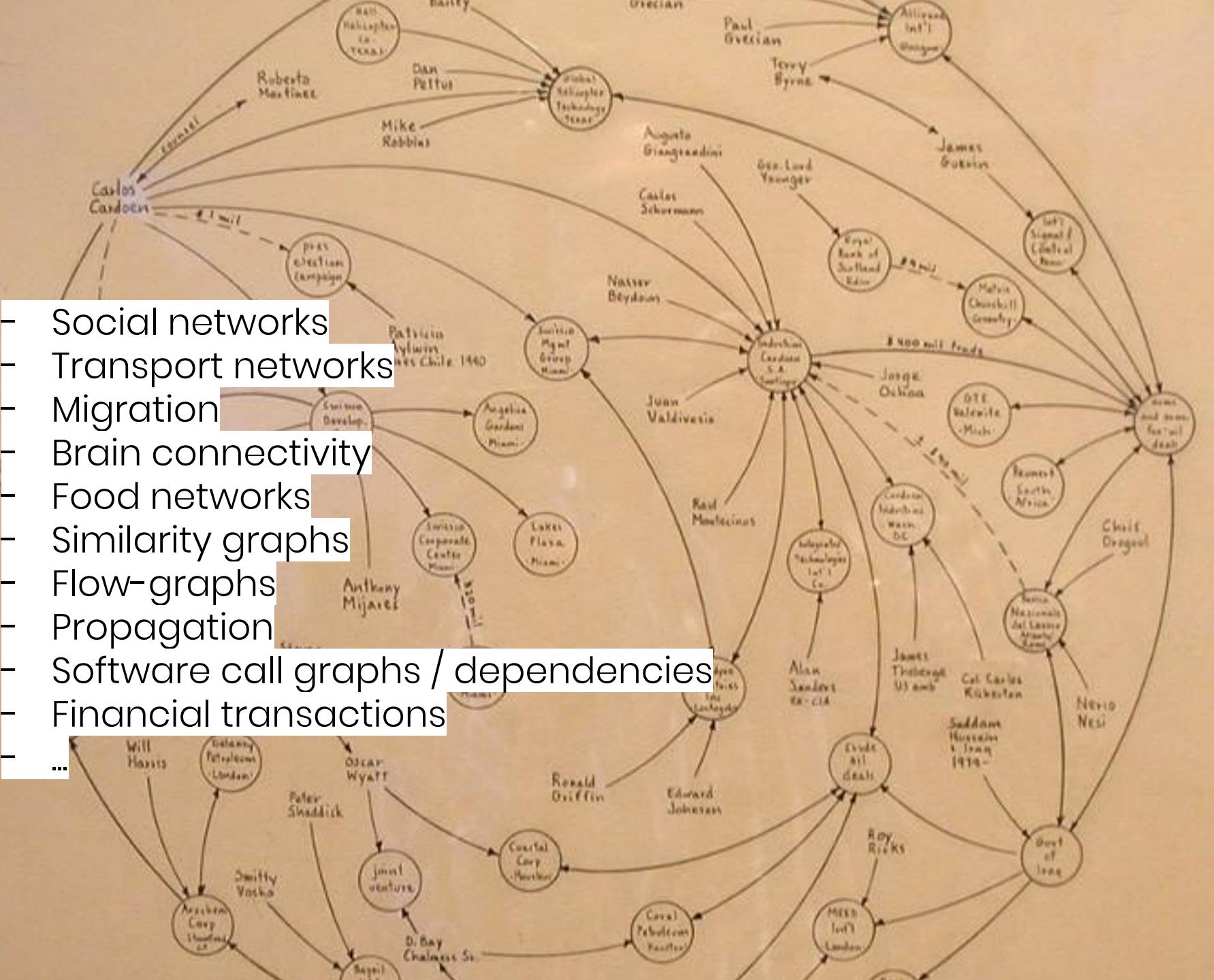
# Techniques Graphs & Networks

Benjamin Bach  
<http://benjbach.me>

University of Edinburgh  
2020



- Social networks
- Transport networks
- Migration
- Brain connectivity
- Food networks
- Similarity graphs
- Flow-graphs
- Propagation
- Software call graphs / dependencies
- Financial transactions



# Graph $G = (N, V)$

Point

Actor

Vertex

Nodes



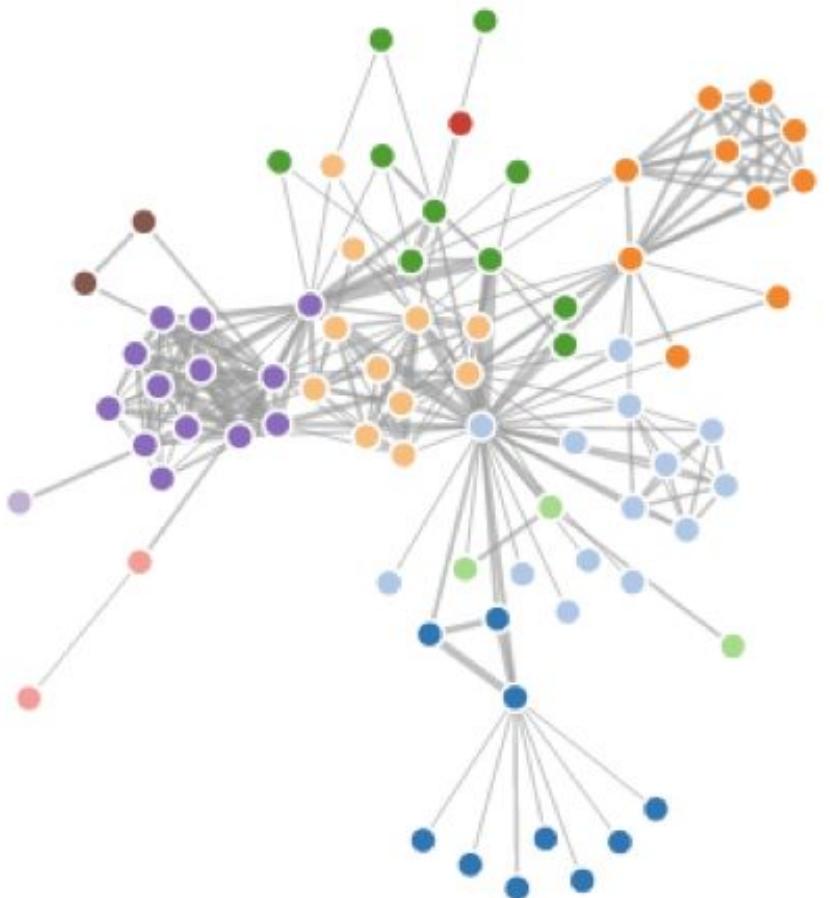
Link

Arc

Relation(ship)

Connection

# Node-link Diagram



Directed  
Link



Multiple  
Links



Link  
Types



Node  
type

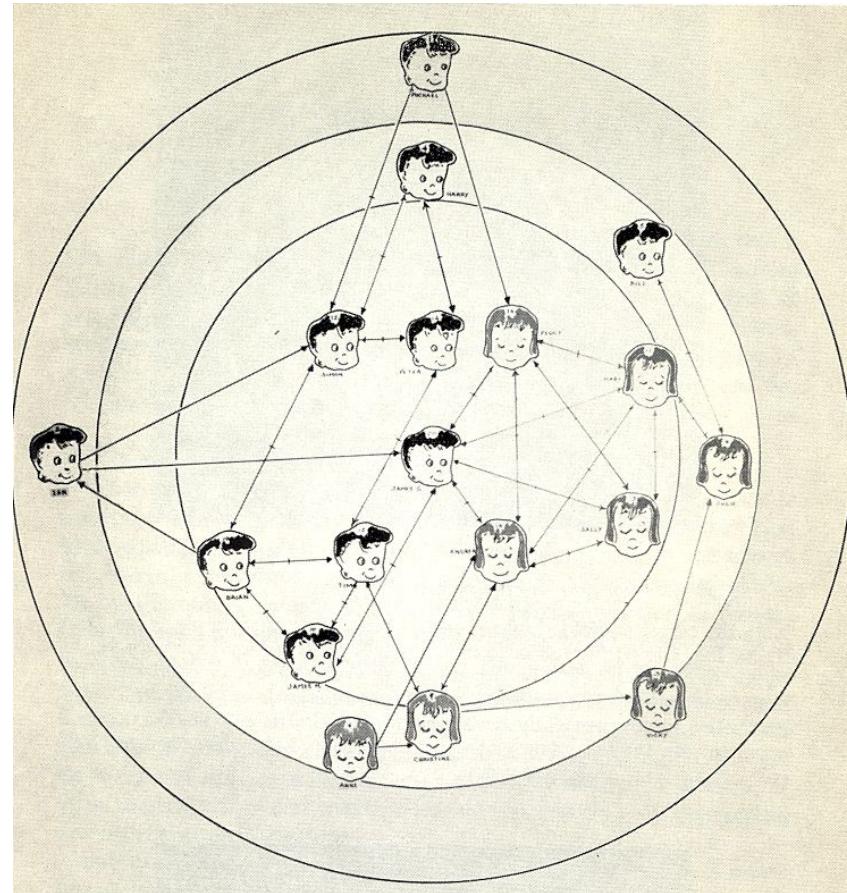


Weighted  
link



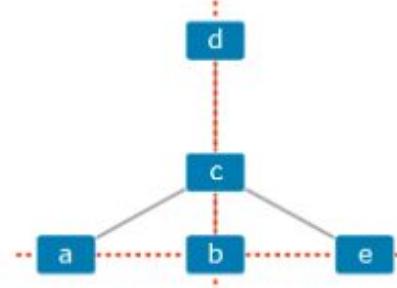
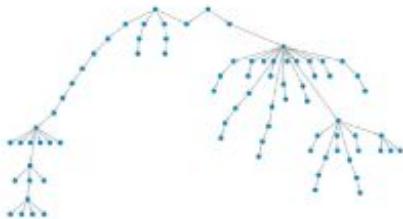
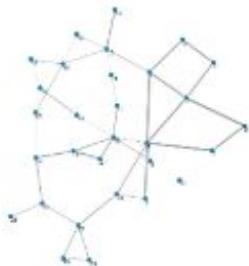
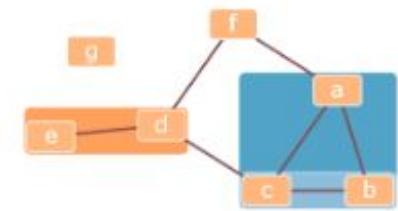
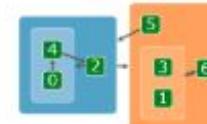
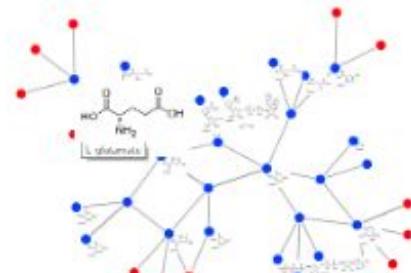
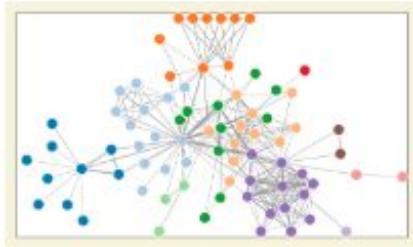
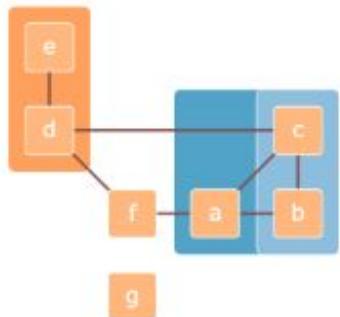
# Visualizing Networks

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

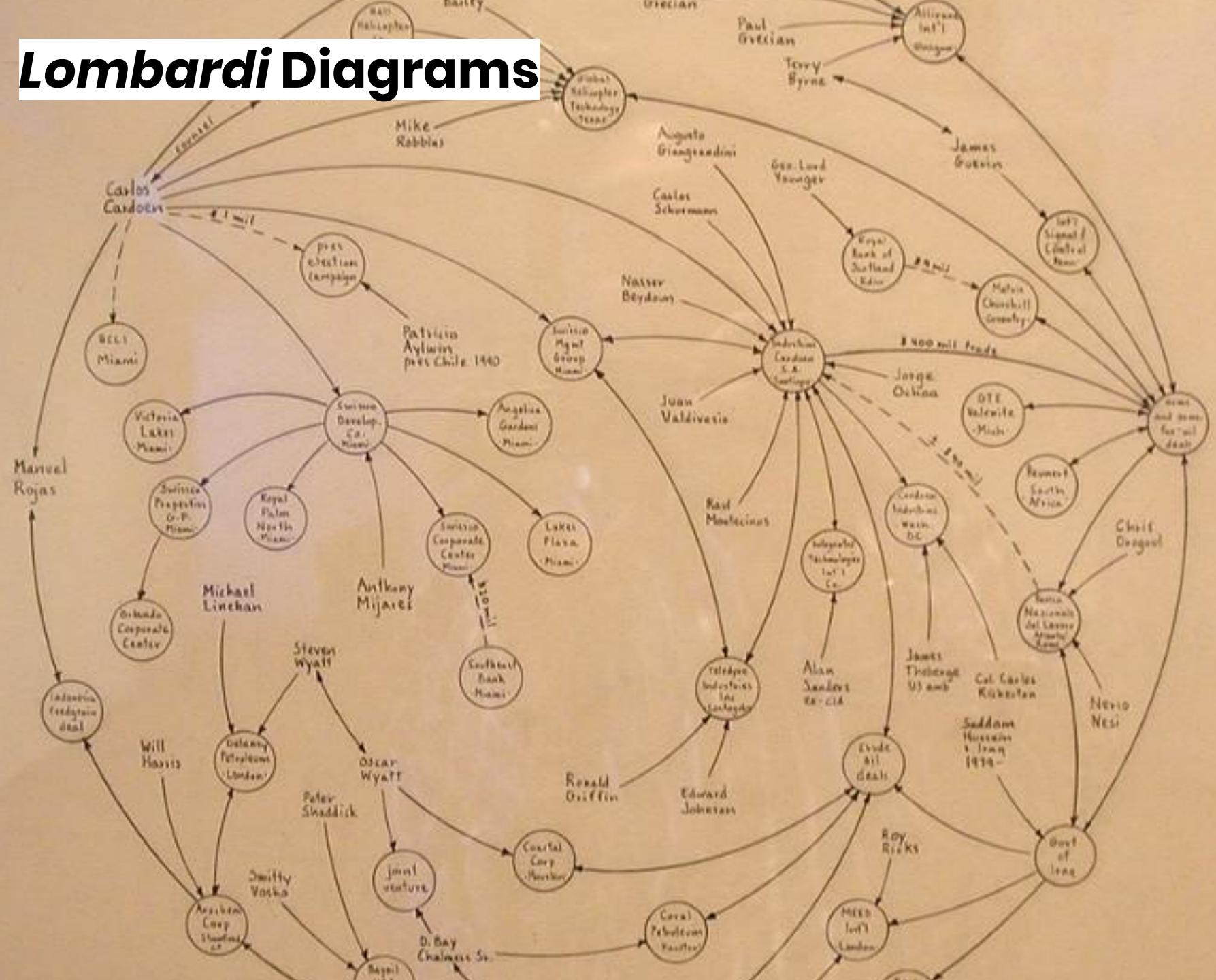


**Sociograms:**  
**Jacob Levy Moreno**  
**(1889 – 1974)**

# More layouts with web-cola:



# **Lombardi Diagrams**



# Why do we visualize networks?

## - Topology

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

## - Attributes

- Node attributes
- Link attributes

## - Browse

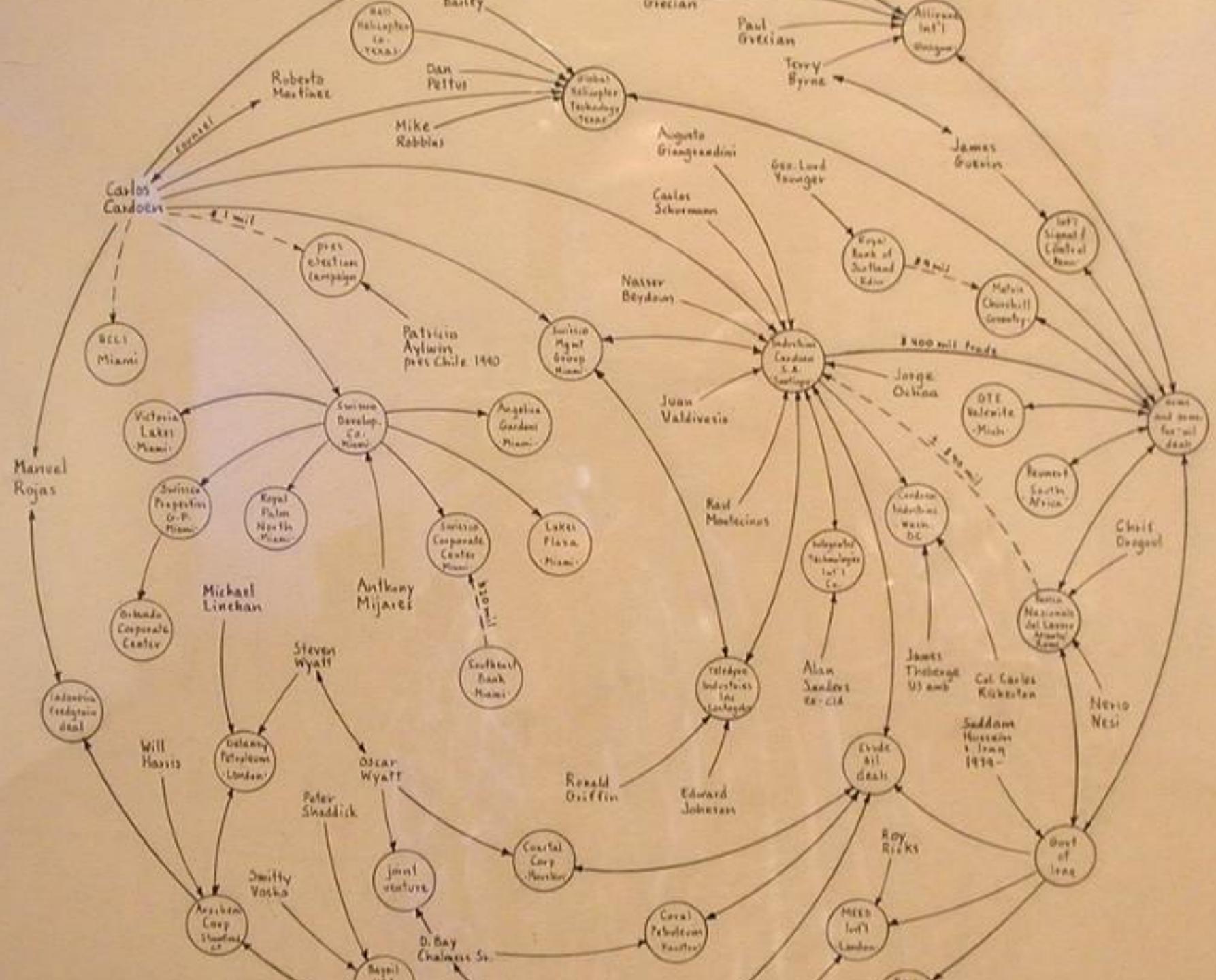
- Follow links
- Discover
- Overview

## - High level

## - High-level

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

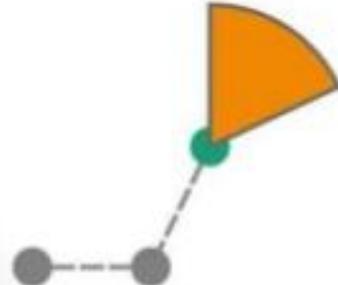
Lee, Bongshin, et al. "Task taxonomy for graph visualization." *Proceedings of the 2006 AVI workshop on BEyond time and errors: novel evaluation methods for information visualization.* 2006.



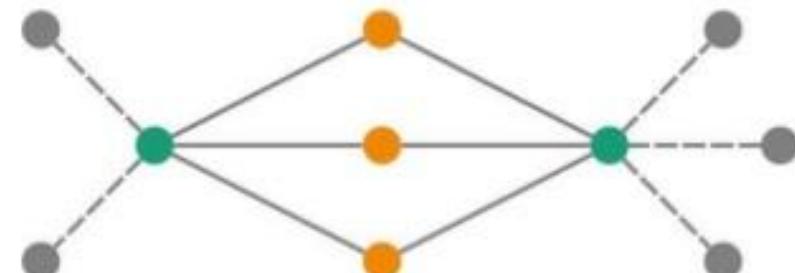
**Graph density =**  
 **$|N| \times |N| - |N| / |E|$**

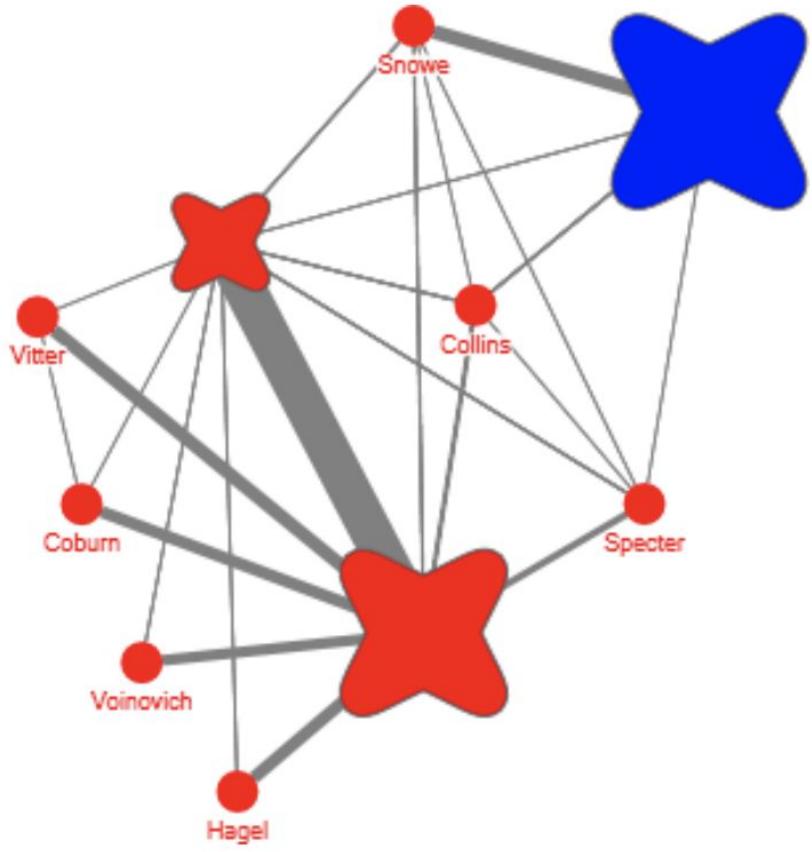
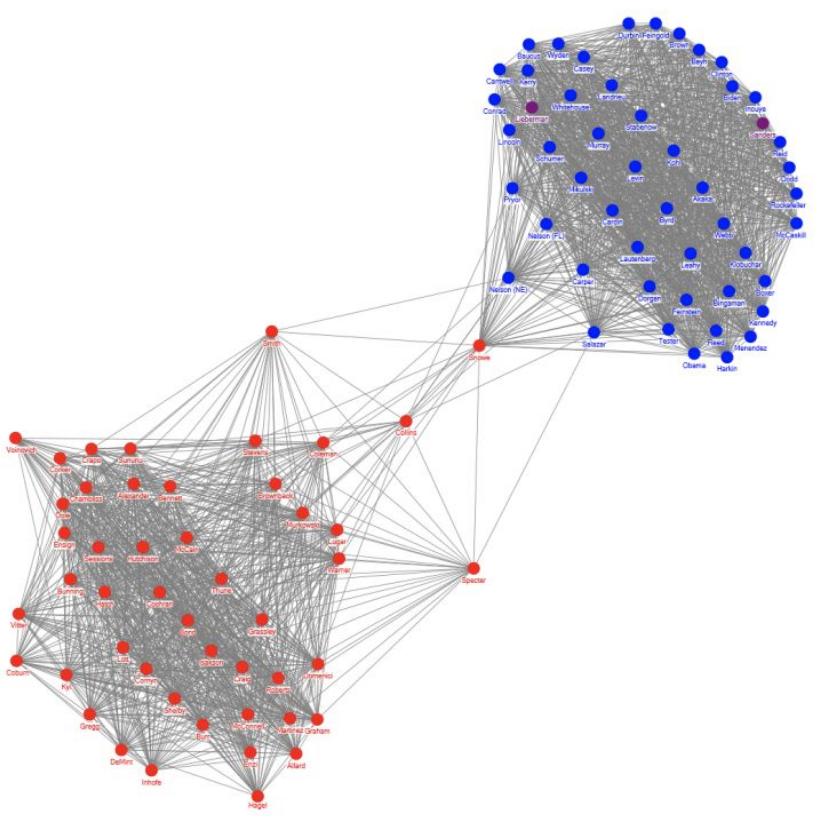
# Motif Simplification

Fan Motif

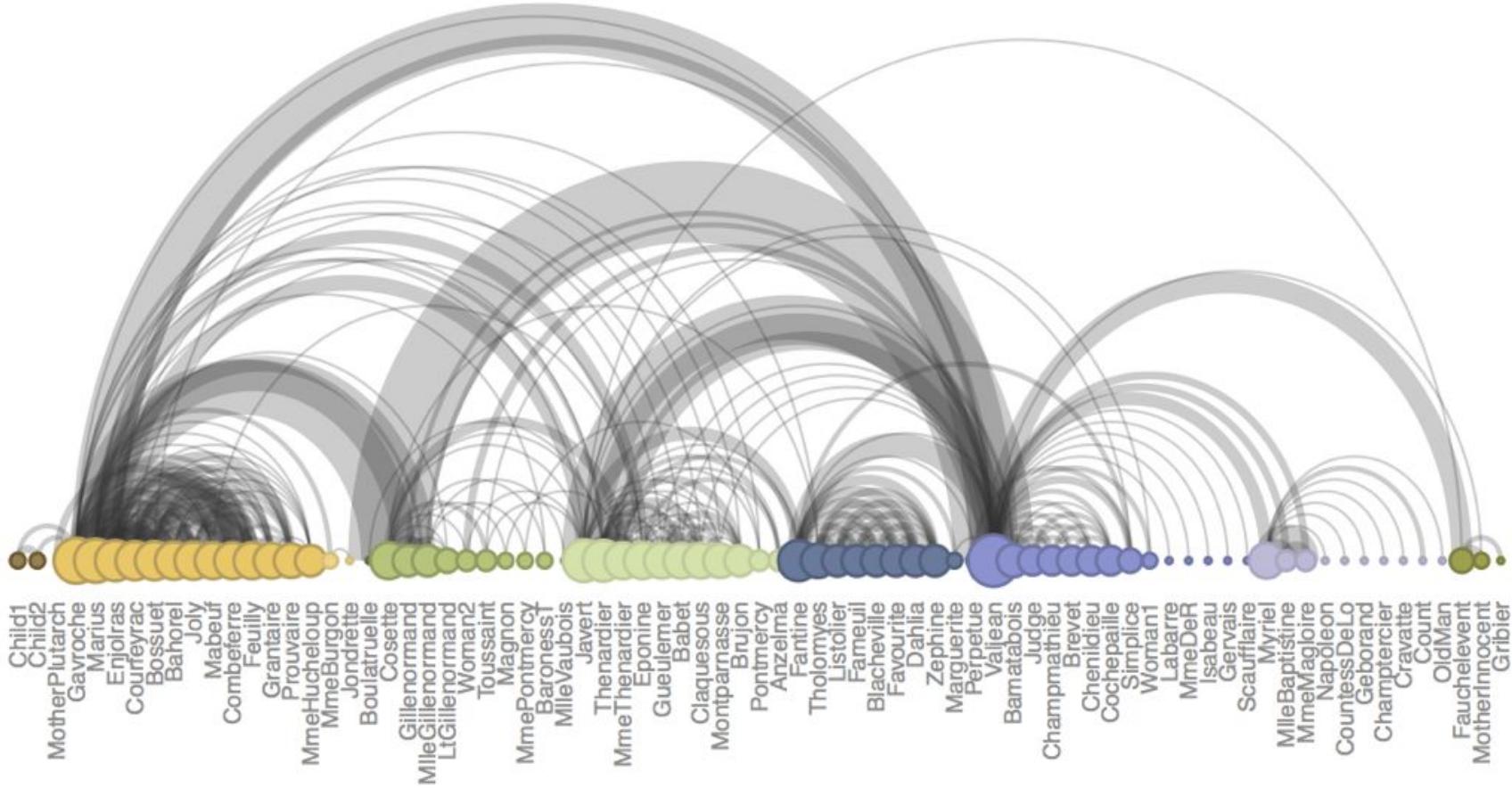


2-Connector Motif





# Arc Diagram



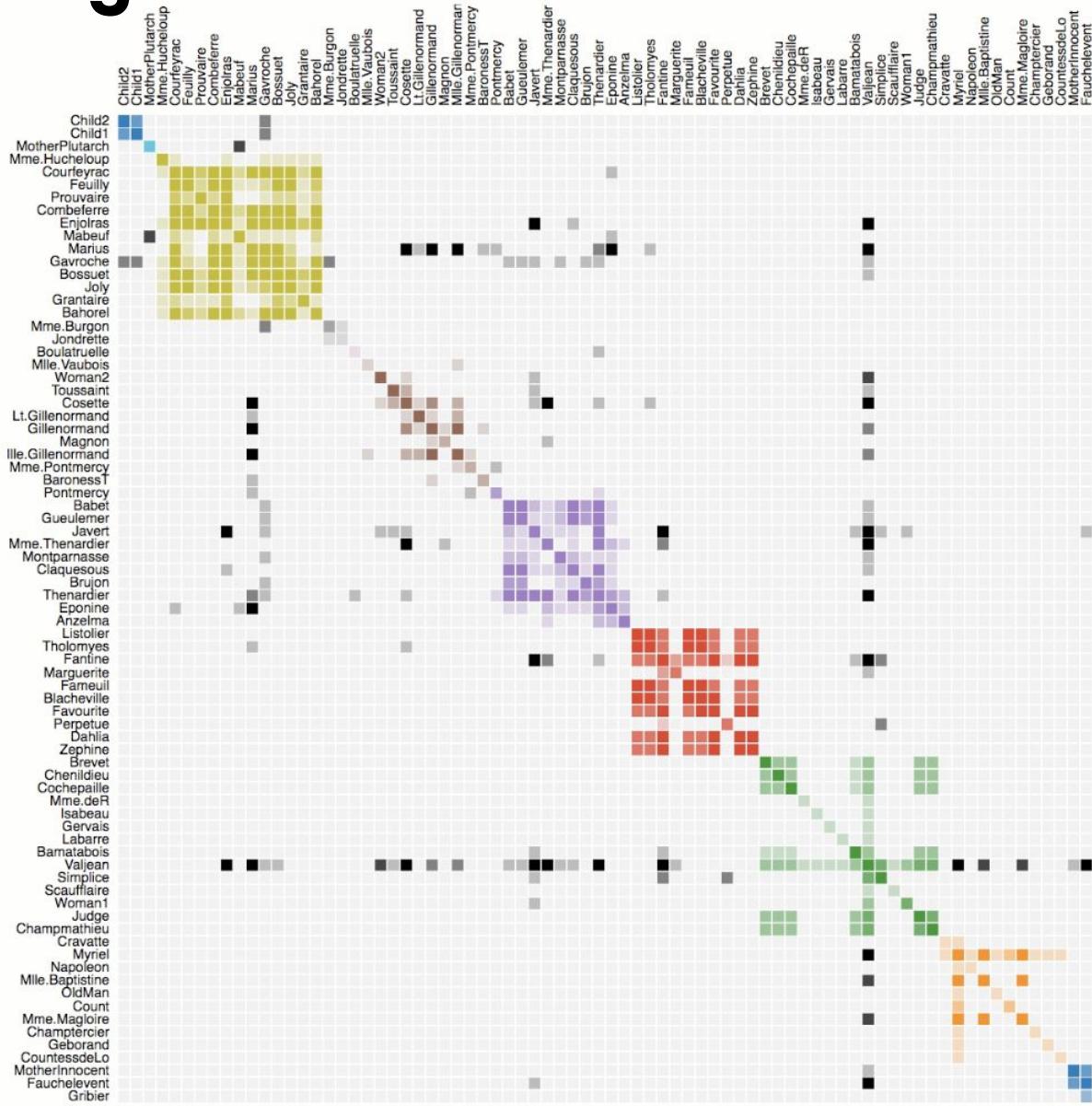
- + Node ordering
- + Node groups
- Requires meaningful ordering
- Does not scale with density

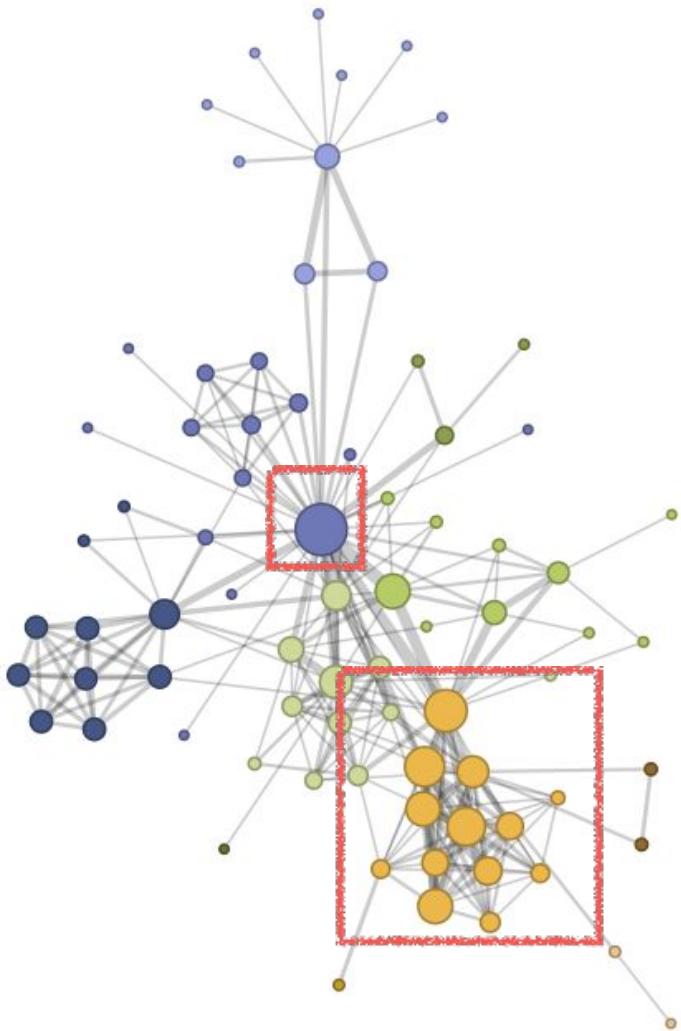
Wattenberg, Martin. "Arc diagrams: Visualizing structure in strings." *Information Visualization, 2002. INFOVIS 2002. IEEE Symposium on*. IEEE, 2002.

# Adjacency Matrix

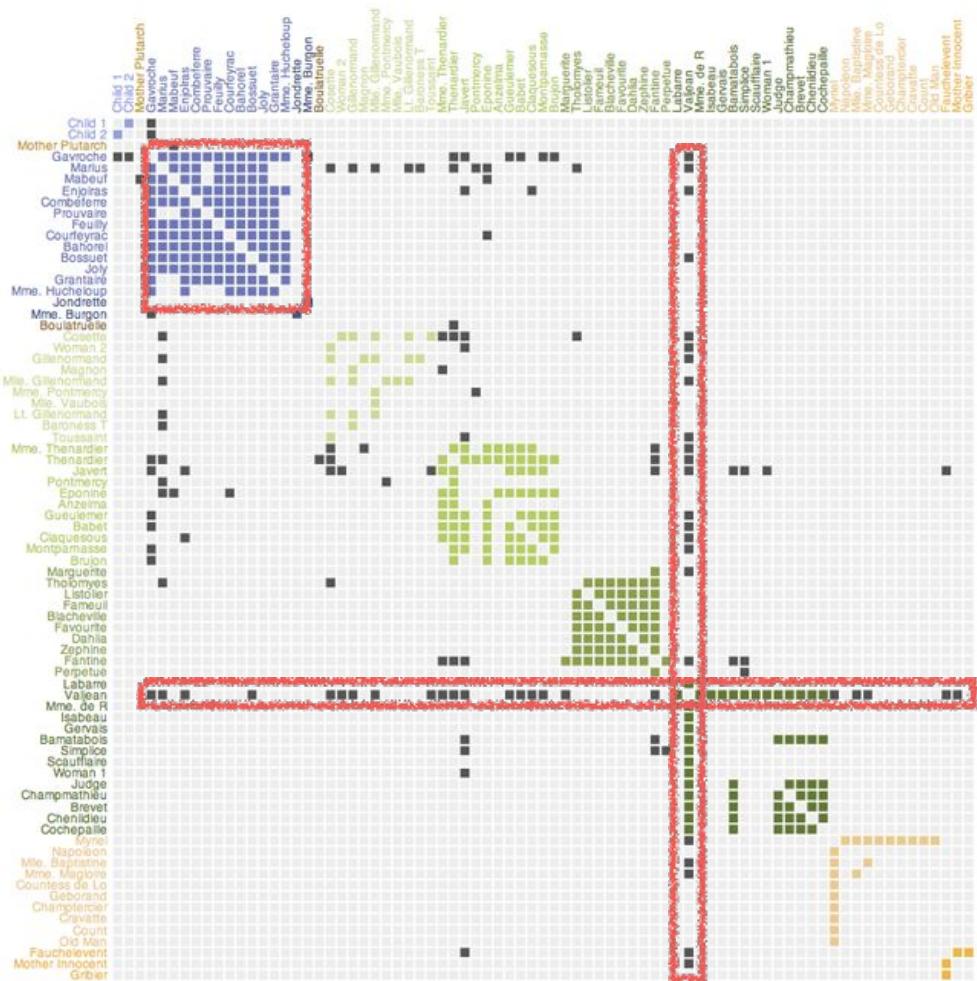


# Ordering





Node  
Link



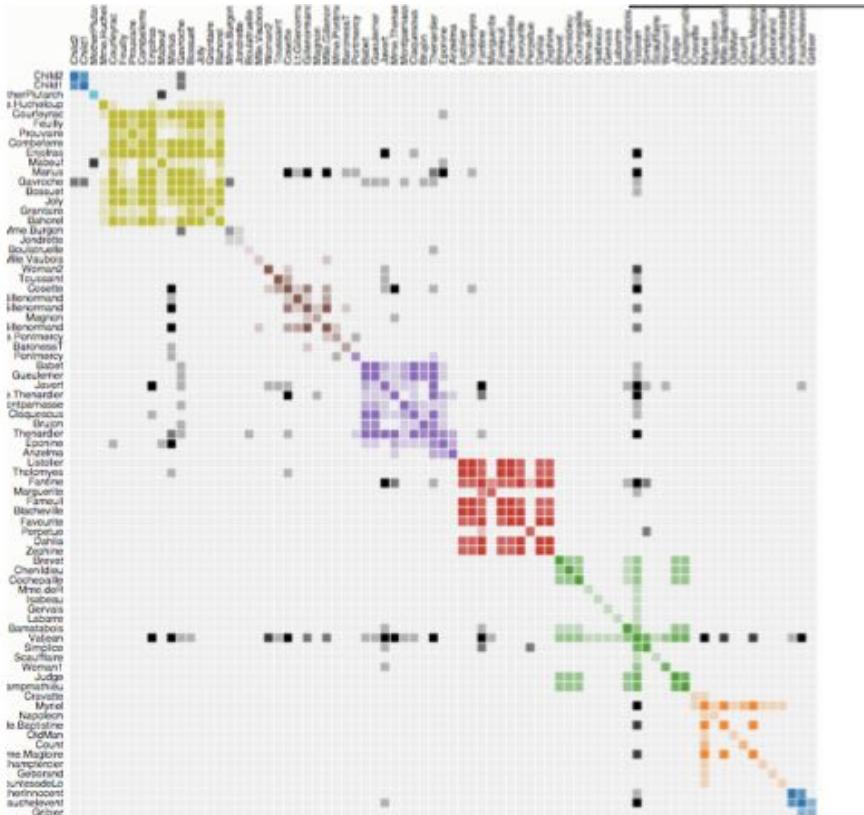
Matrice  
S

# Adjacency Matrix



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

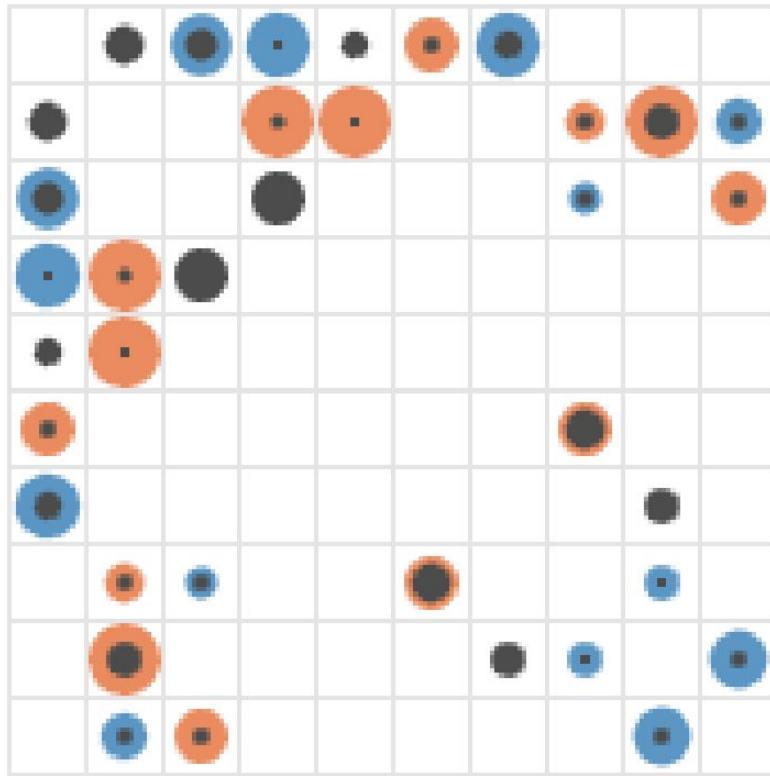
=> Sparse networks



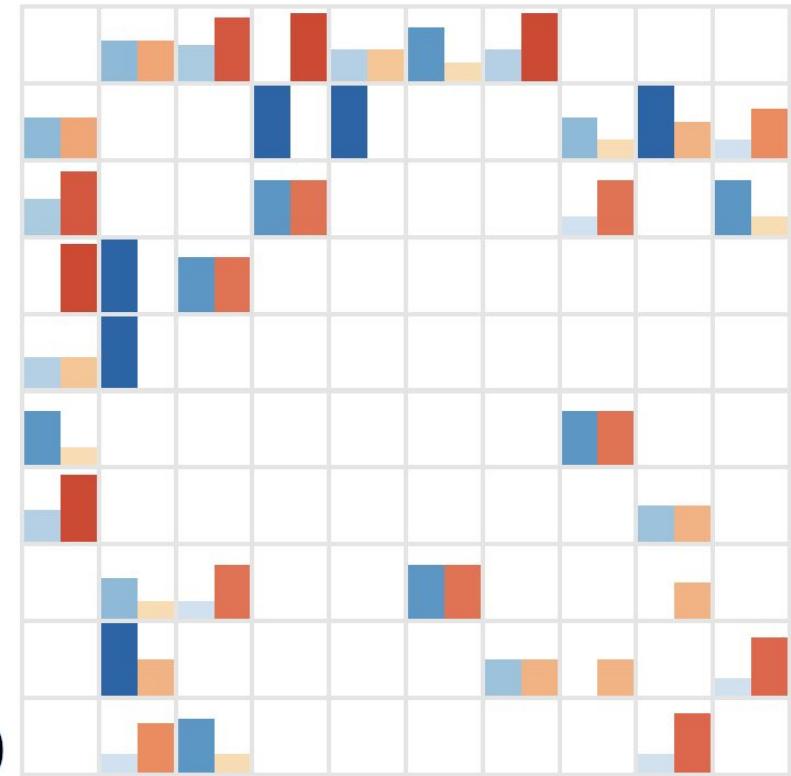
- + Clusters
- + Missing links in clusters
- + Highly connected nodes

=> Dense networks

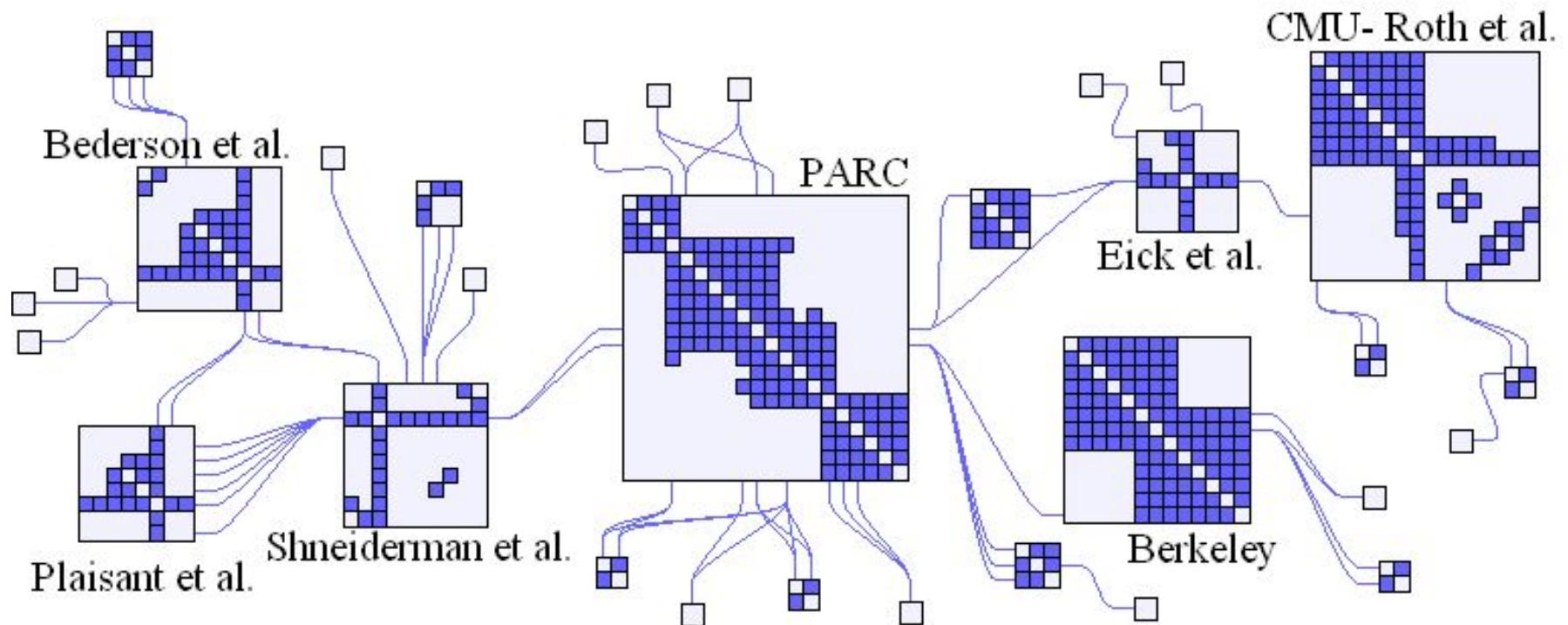
# Matrix Cells



(d)

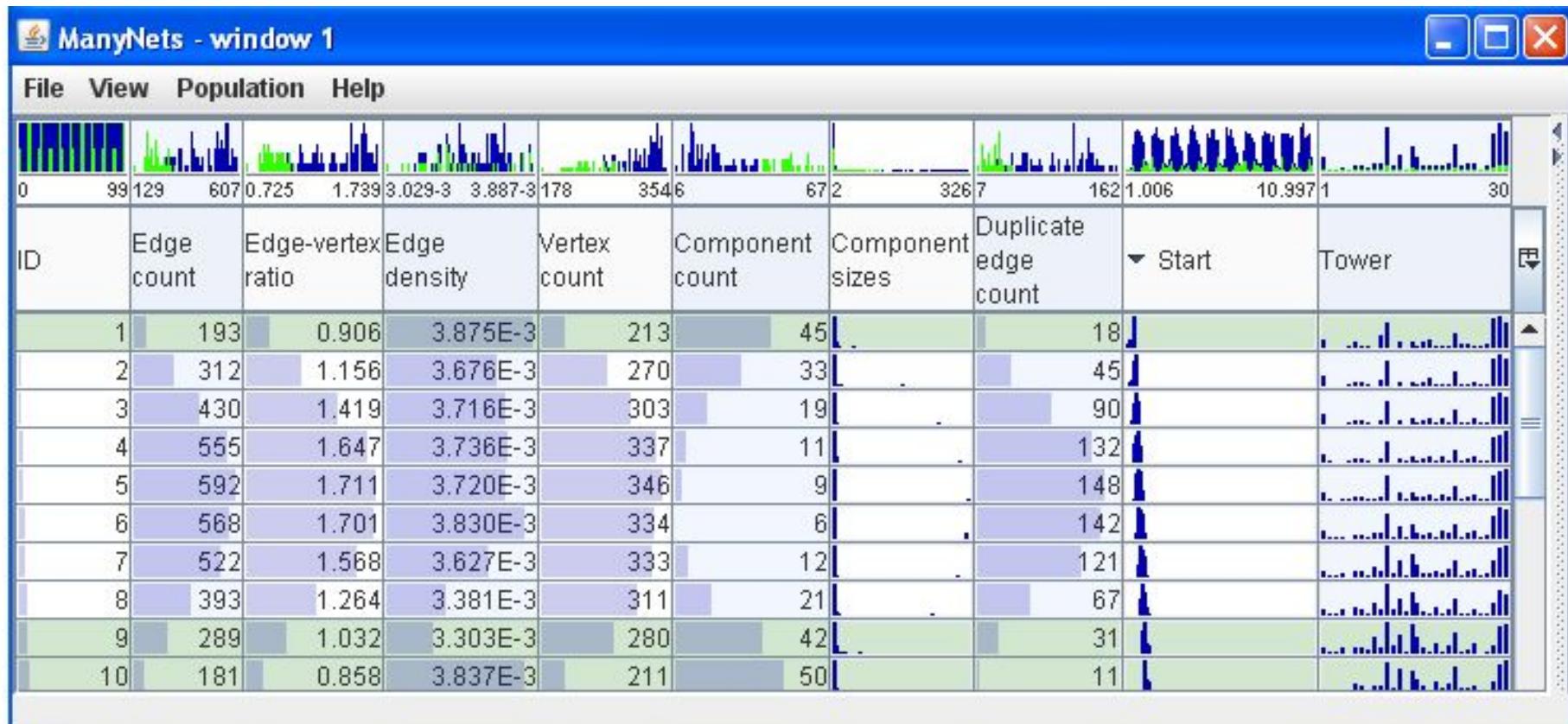


# Clusters

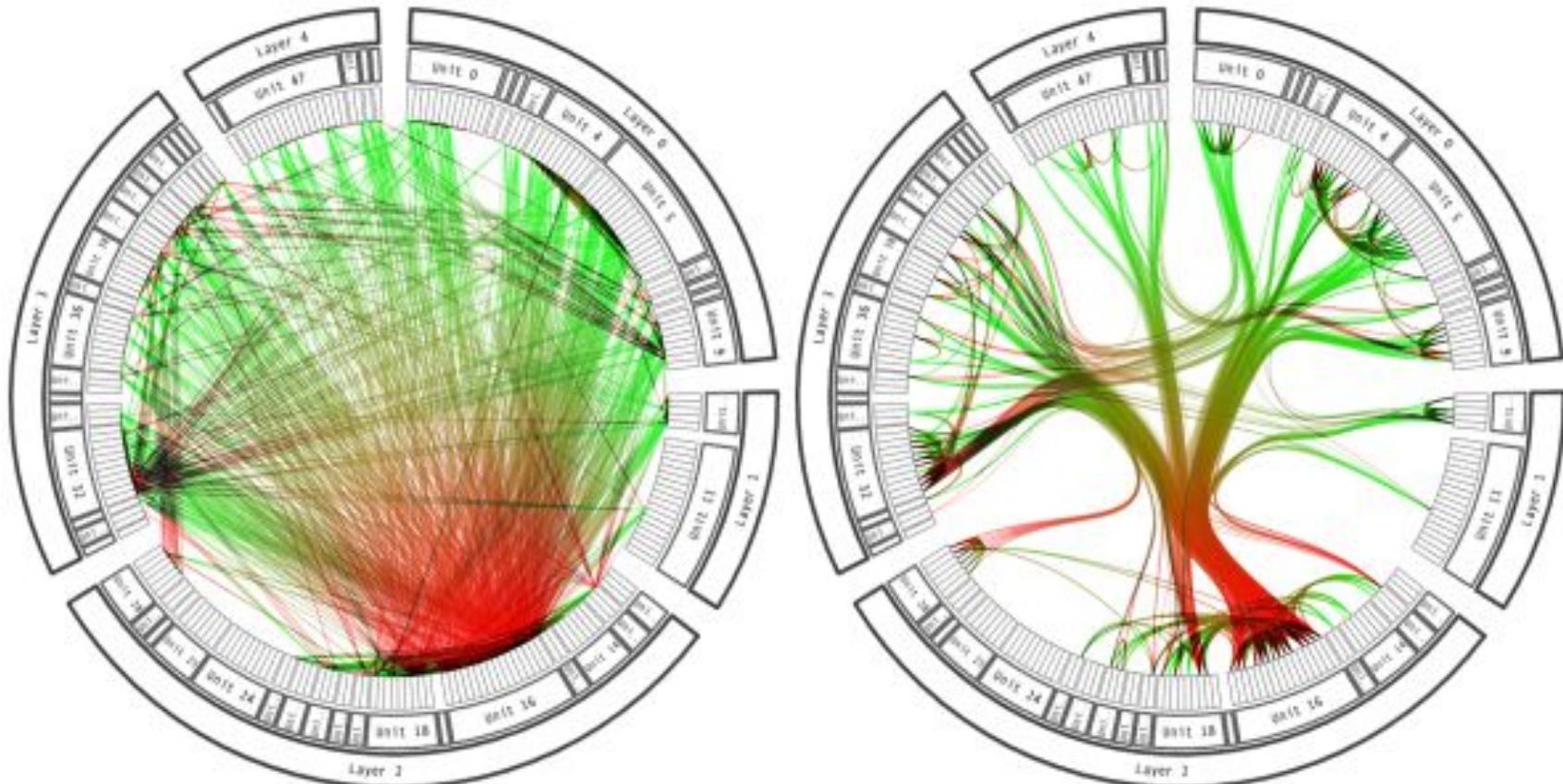


Henry, N., Fekete, J. D., & McGuffin, M. J. (2007). NodeTrix: a hybrid visualization of social networks. *IEEE transactions on visualization and computer graphics*, 13(6), 1302-1309.

# Comparing networks

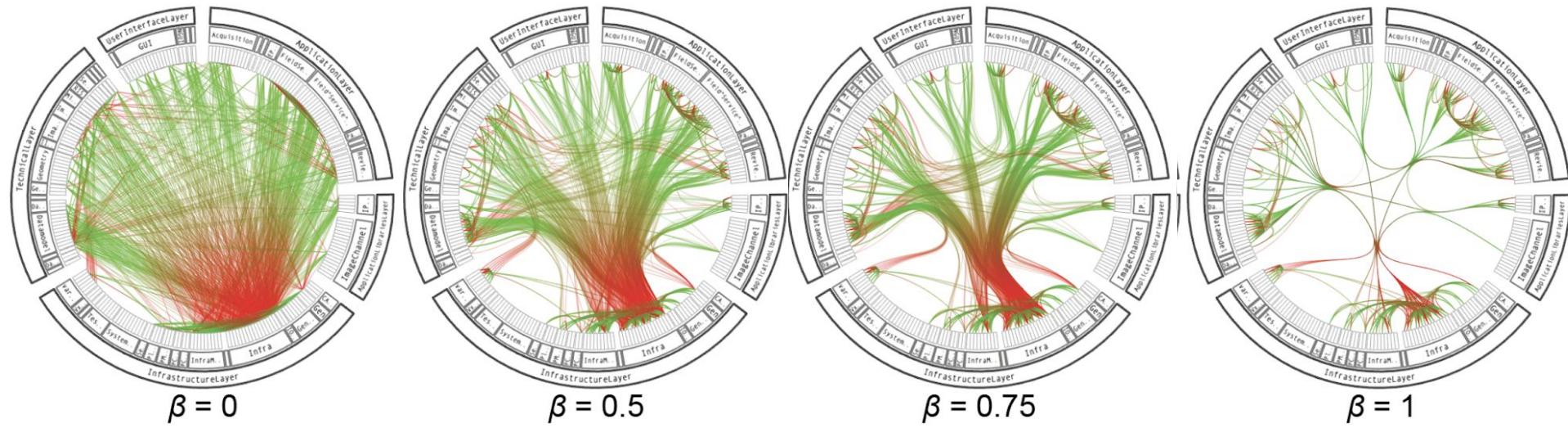


# Edge Bundling



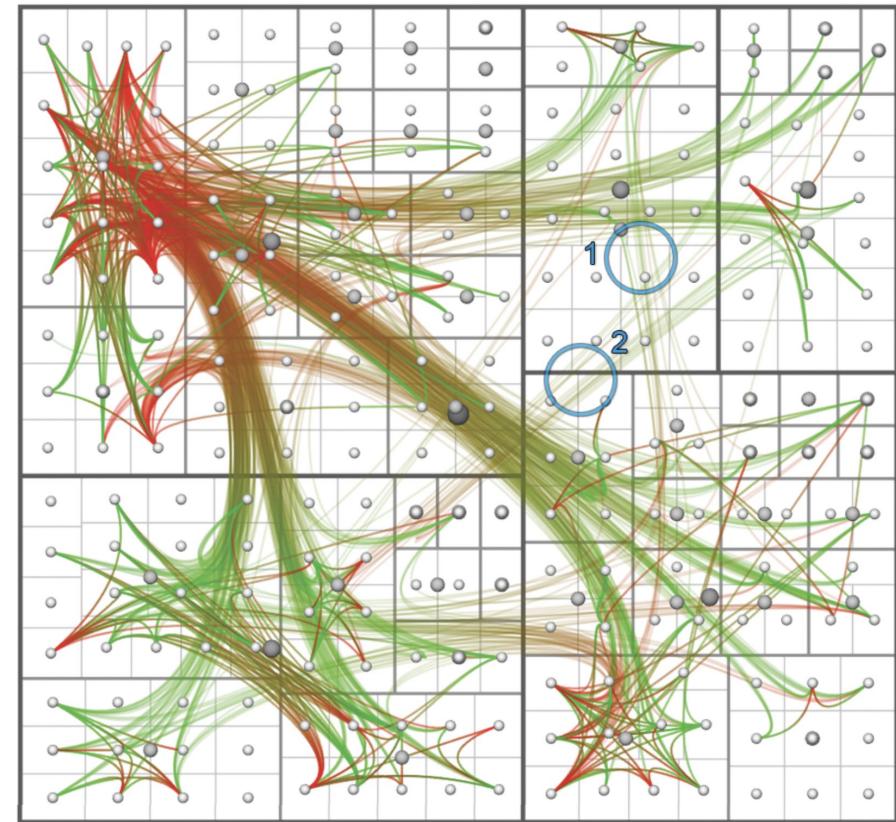
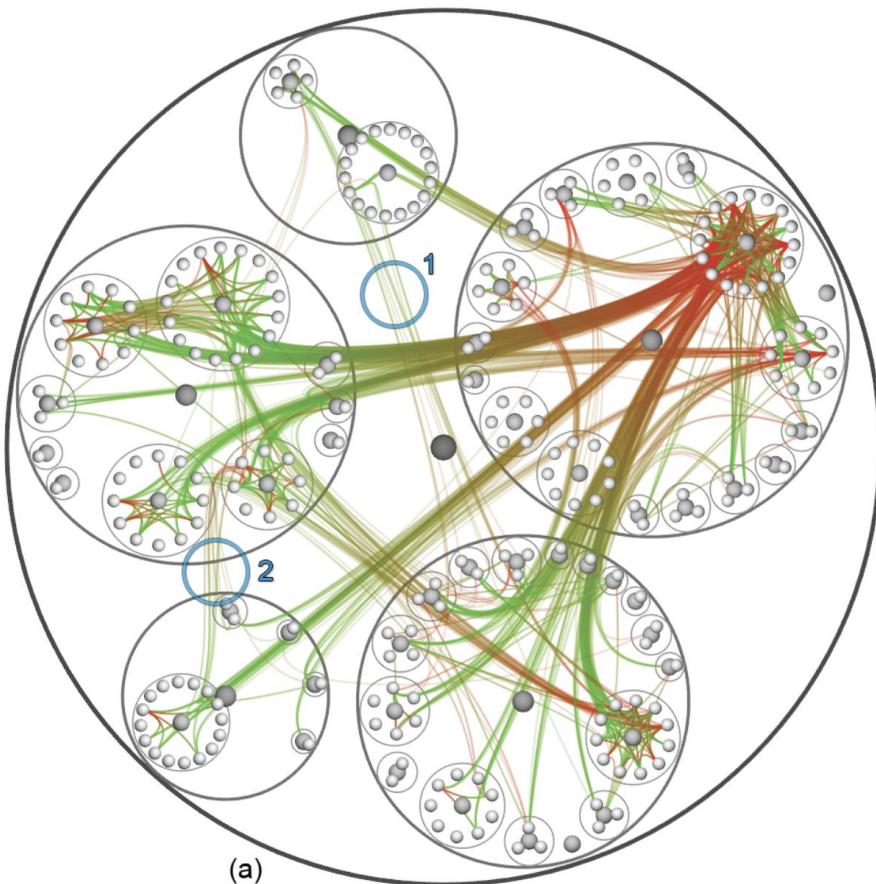
Holten, Danny. "Hierarchical edge bundles: Visualization of adjacency relations in hierarchical data." *IEEE Transactions on visualization and computer graphics* 12.5 (2006): 741-748.

# Edge Bundling: Bundling Parameter



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



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

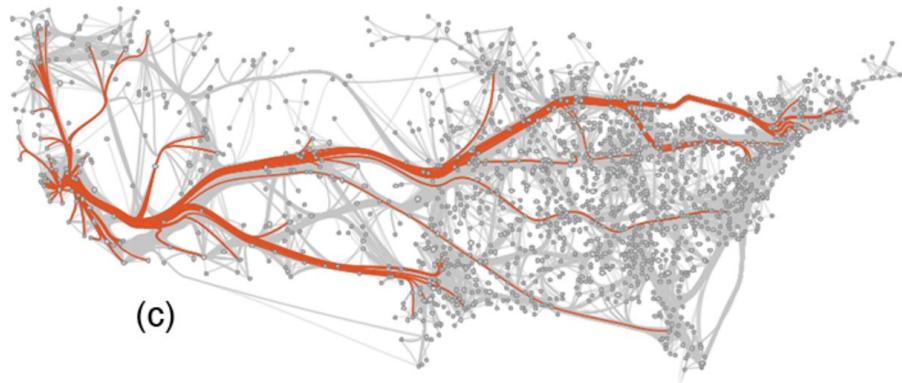
# Edge Bundling



(a)



(b)



(c)



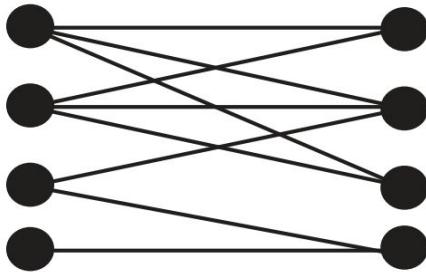
(d)

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.

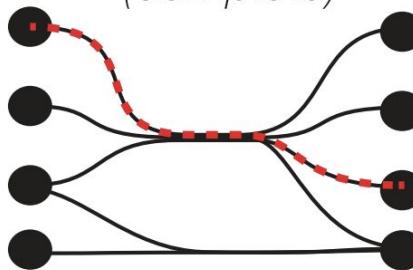
Sun, Guo-Dao, et al. "A survey of visual analytics techniques and applications: State-of-the-art research and future challenges." *Journal of Computer Science and Technology* 28.5 (2013): 852-867.

# Ambiguity

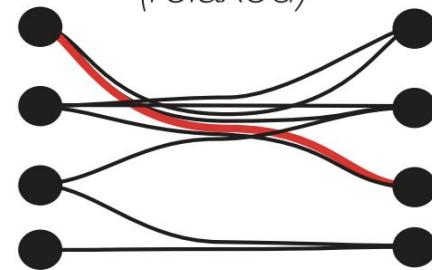
(a) No bundling



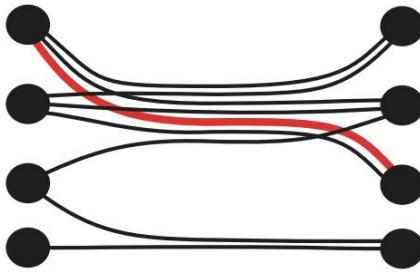
(b) Edge Bundling  
(complete)



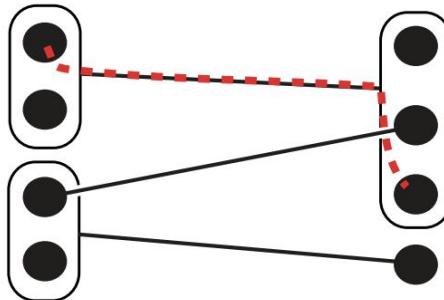
(c) Edge Bundling  
(relaxed)



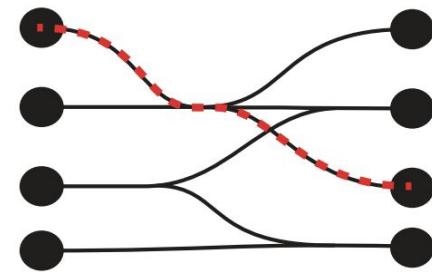
(d) Metro-Style Bundling



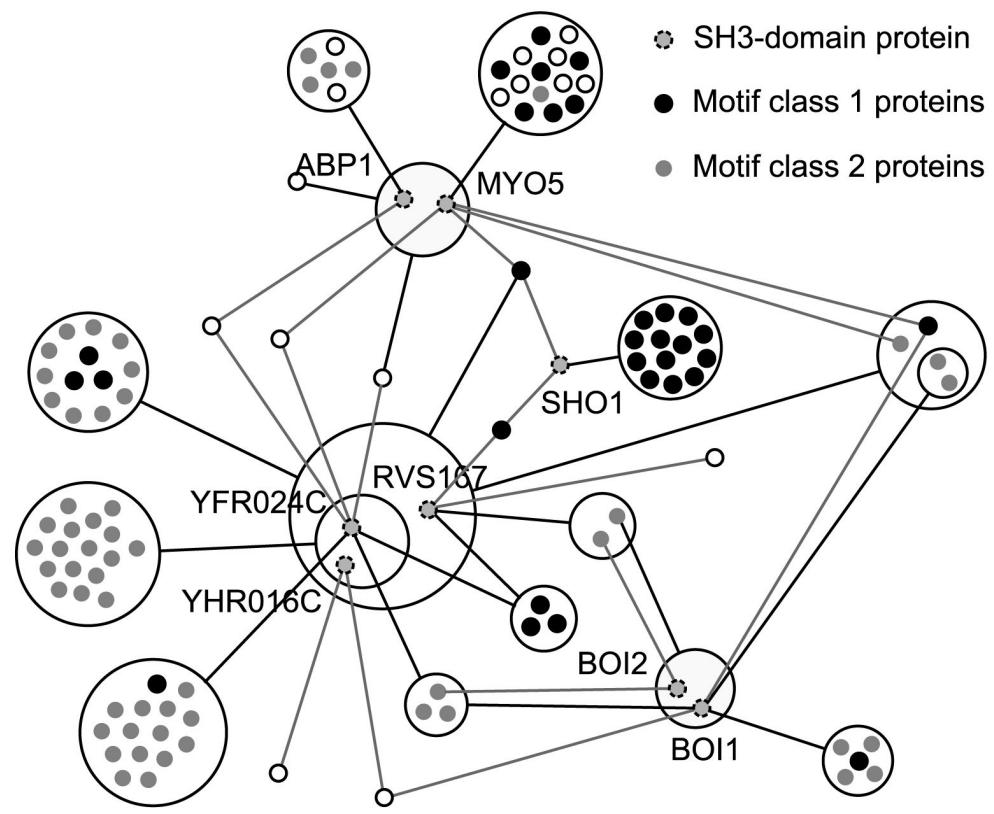
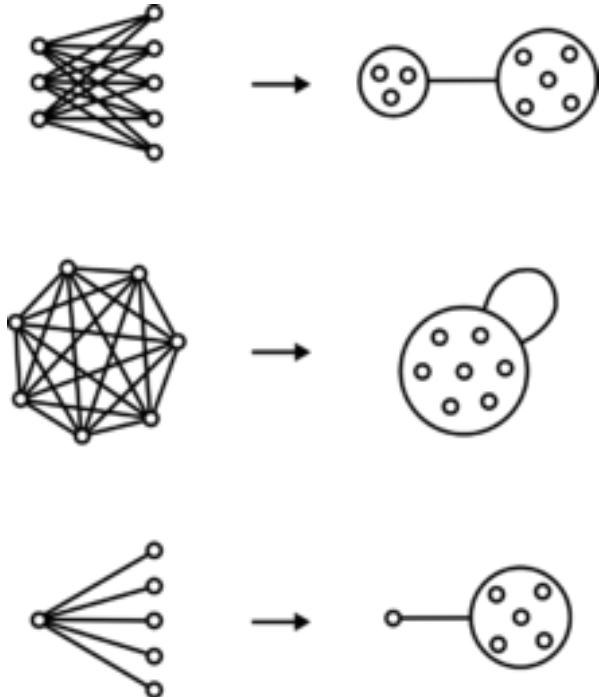
(e) Power Graphs



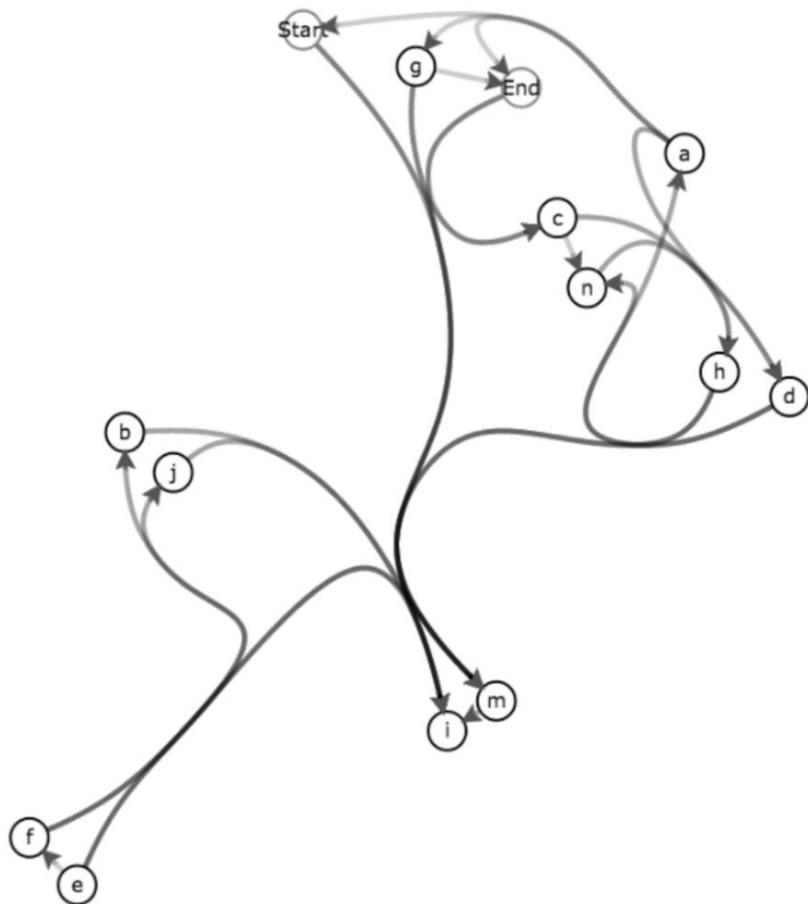
(f) Confluent Drawing



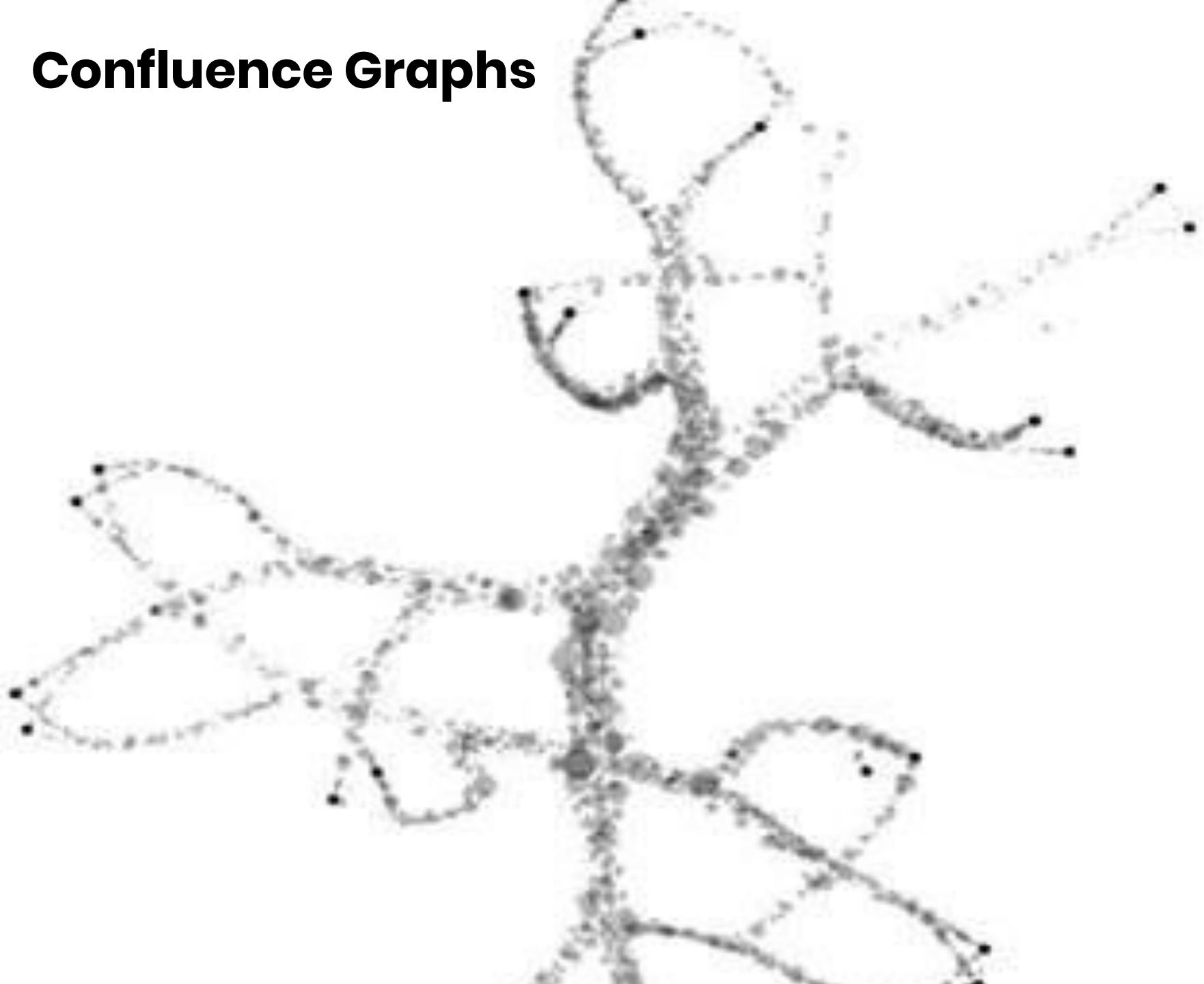
# Powergraphs



# Confluence Graphs



# Confluence Graphs



# Multivariate *(Multilayer)* Networks

# Node-link Diagram



Directed  
Link



Multiple  
Links



Link  
Types



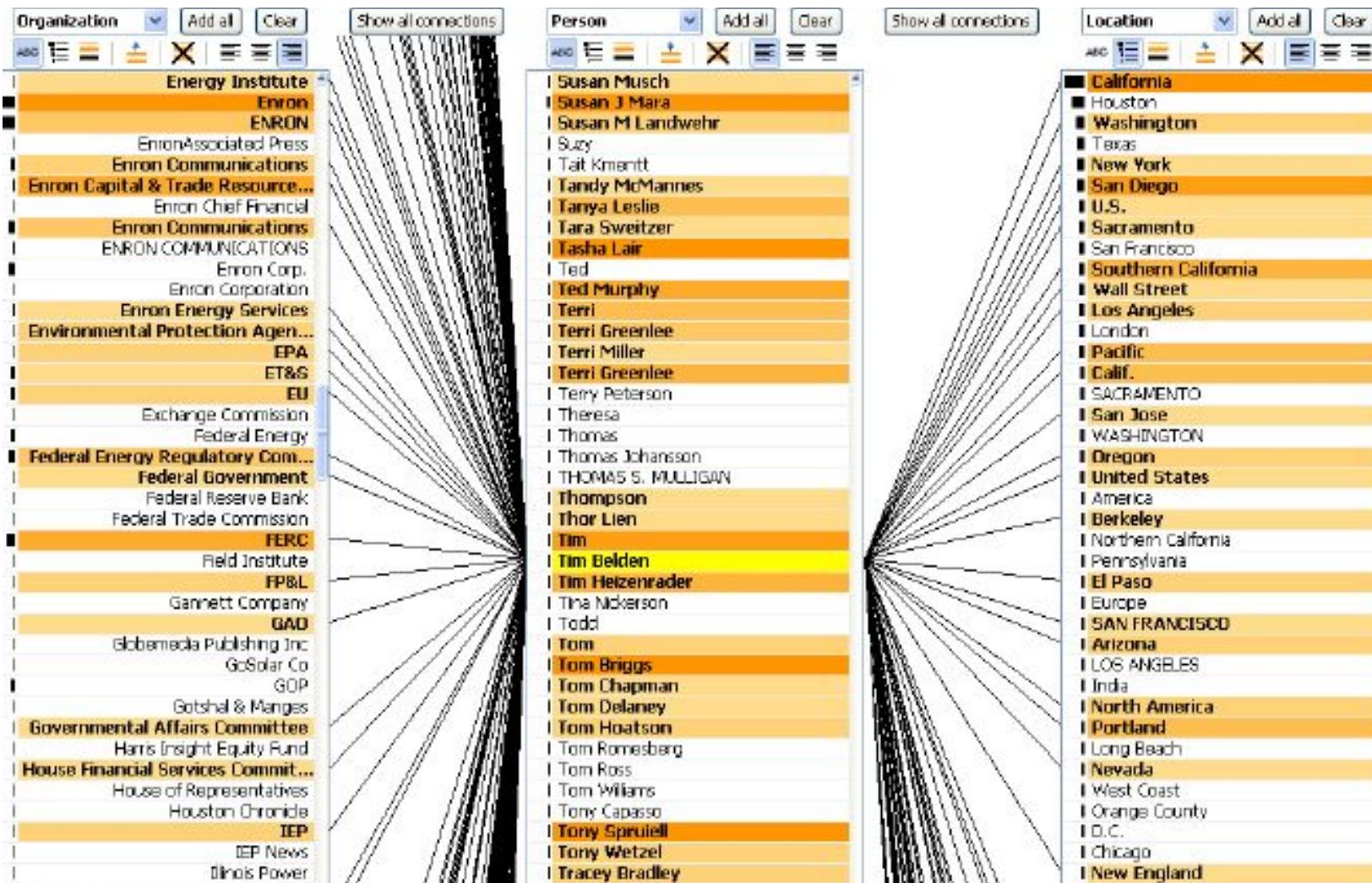
Node  
type



Weighted  
link

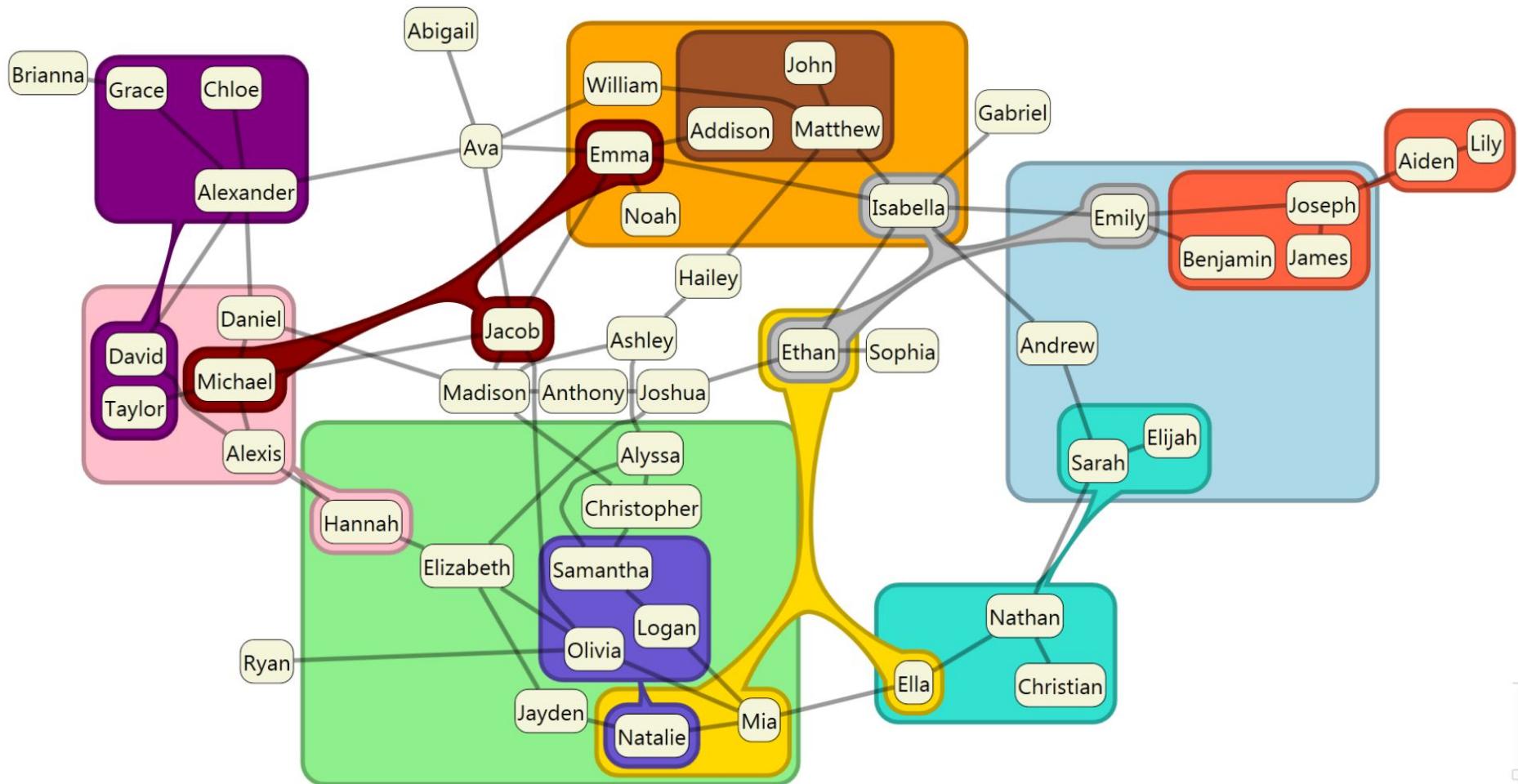


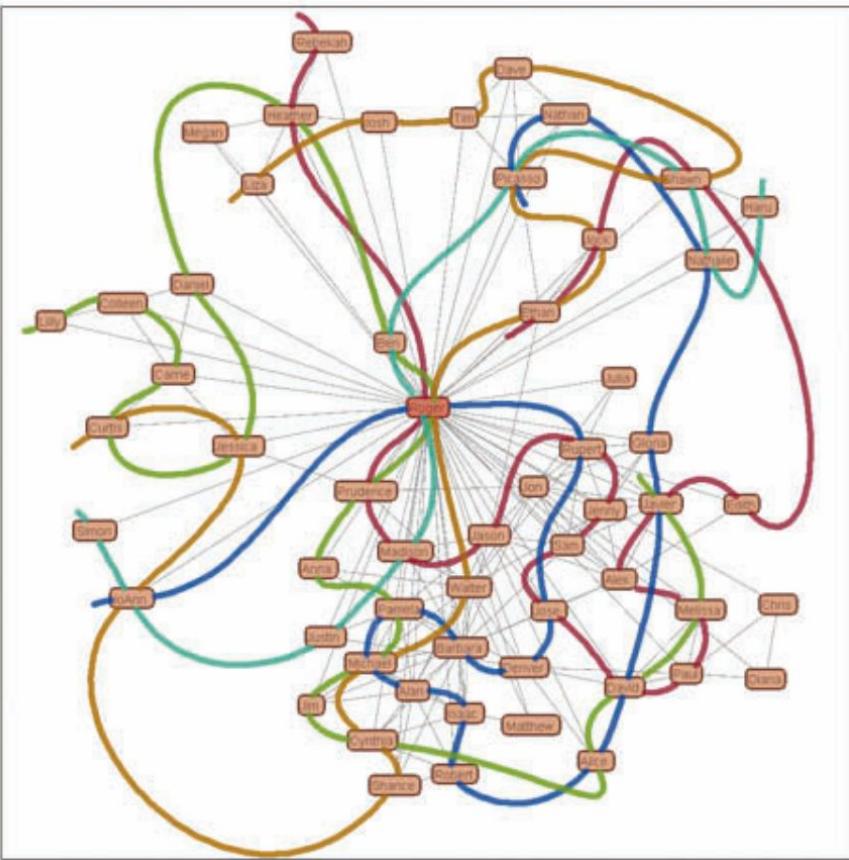
# Jigsaw



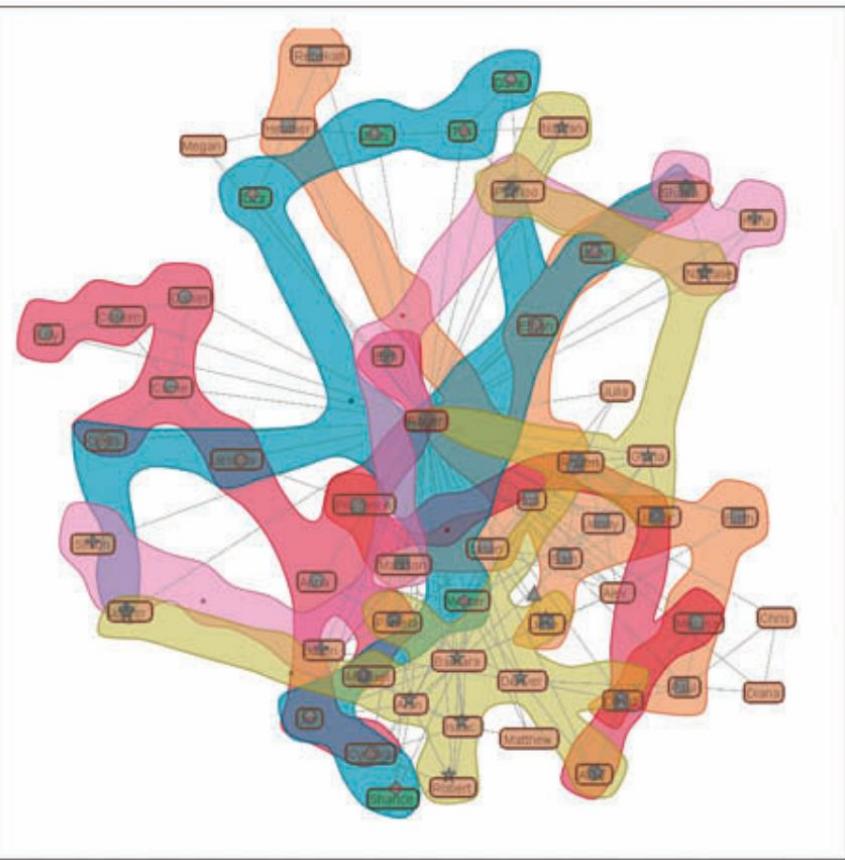
Stasko, J., Görg, C., & Liu, Z. (2008). Jigsaw: supporting investigative analysis through interactive visualization. *Information visualization*, 7(2), 118-132.

# Networks and Sets



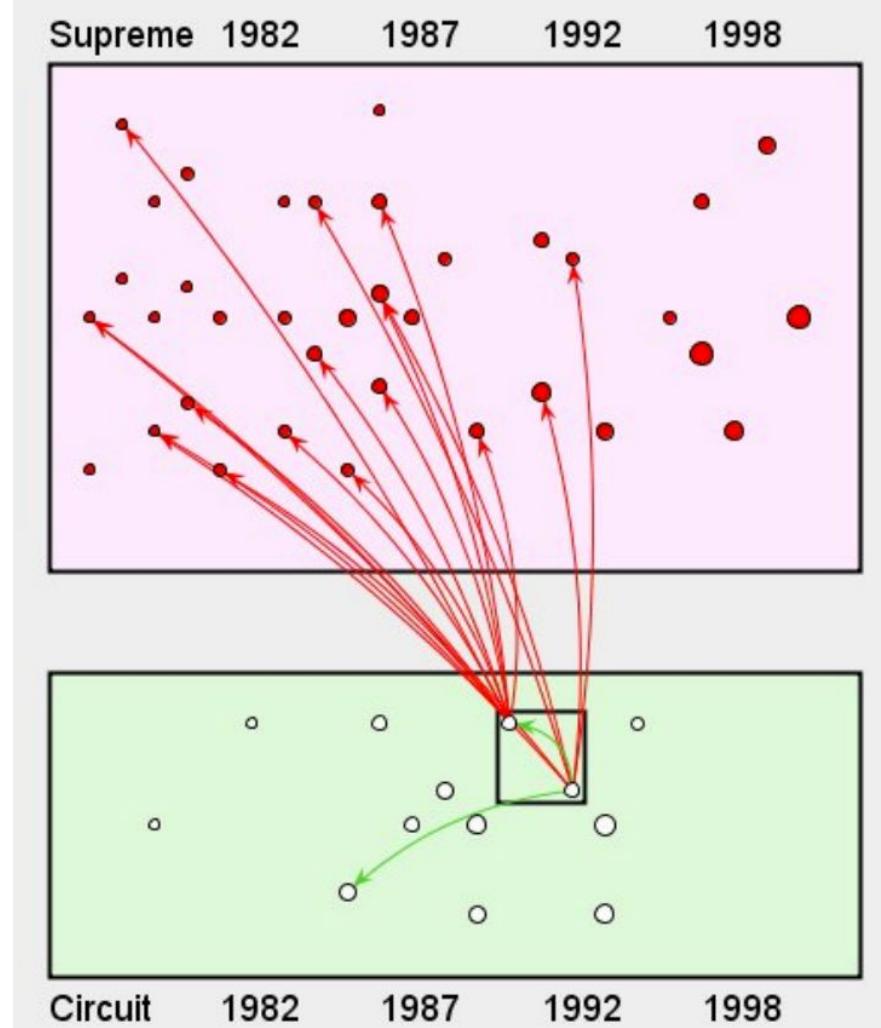
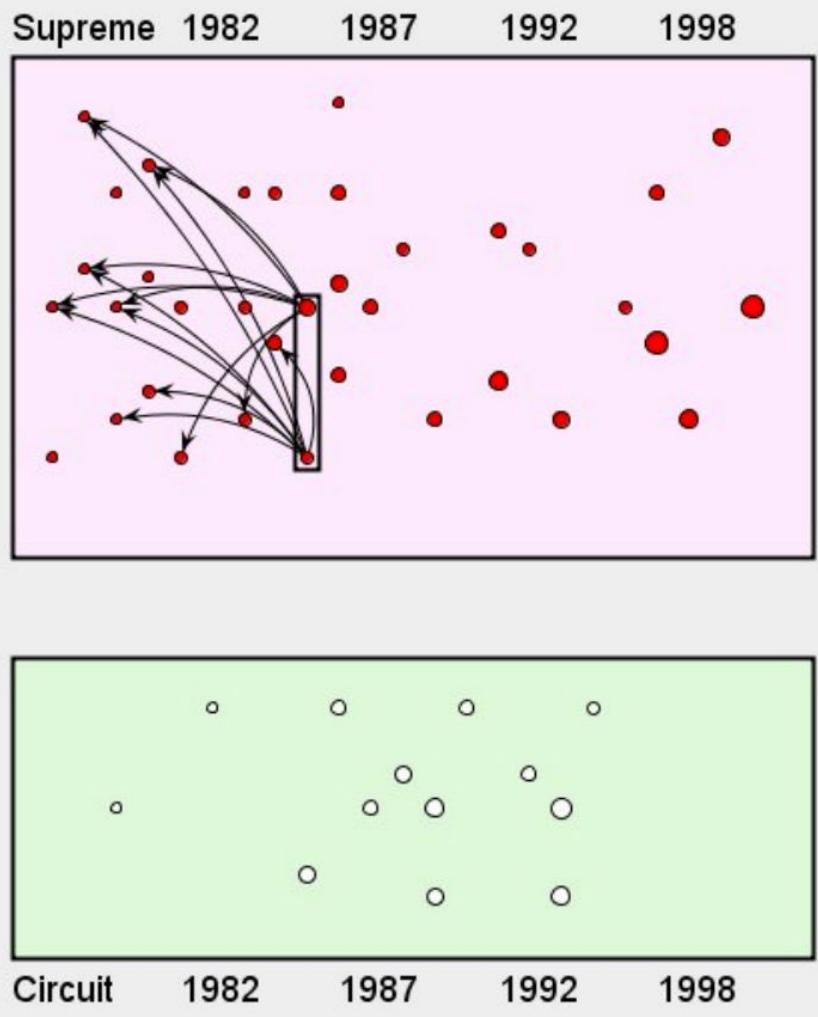


Line  
Sets

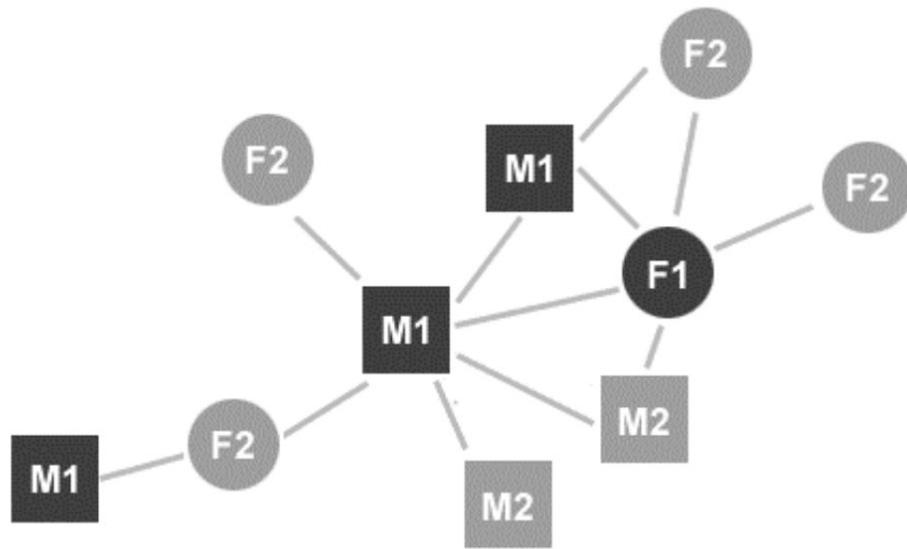


Bubble  
Sets

# Semantic Substrates



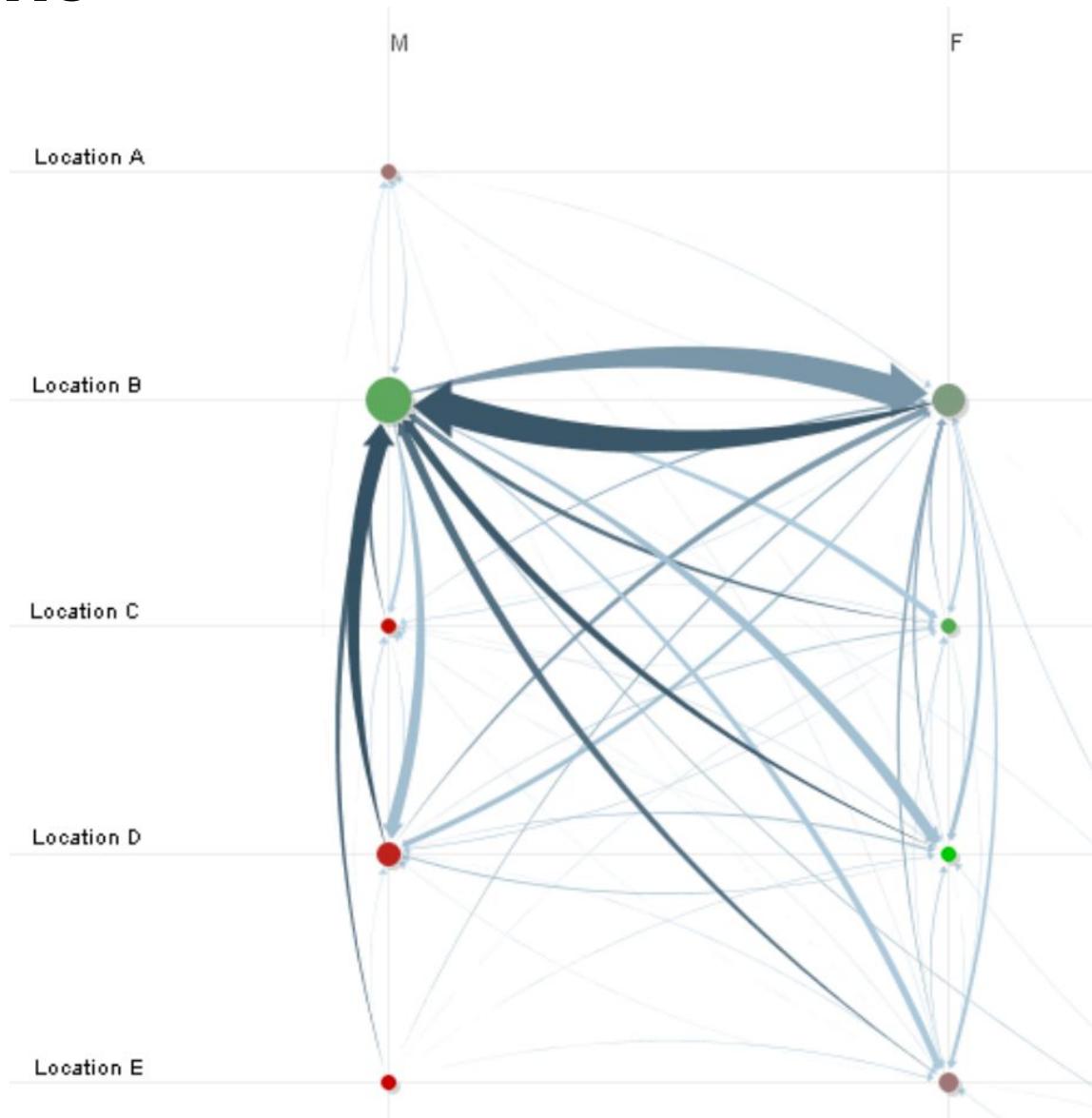
# Pivot Graphs



**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



# **Geographic Networks**

**LÉGENDE** — Quantités et couleurs pour chaque Pays de provenance.

Estate-Unis	Inde (Burdesh, Ceylan)	Egypte, Série	Béral, Inde (Indonésie)	Australie, répartition.
332.000 <sup>a</sup>	76.000 <sup>b</sup>	43.000 <sup>b</sup>	5.400 <sup>c</sup>	43.000 <sup>b</sup>
144.000 <sup>a</sup>	18.000 <sup>b</sup>	27.000 <sup>b</sup>	9.400 <sup>c</sup>	133.000 <sup>b</sup>
16.100 <sup>a</sup>	3.000 <sup>b</sup>	37.700 <sup>b</sup>	19.100 <sup>c</sup>	36.000 <sup>b</sup>
16.800 <sup>a</sup>	161.000 <sup>b</sup>	71.700 <sup>b</sup>	19.200 <sup>c</sup>	102.000 <sup>b</sup>
30.400 <sup>a</sup>	193.000 <sup>b</sup>	58.000 <sup>b</sup>	17.500 <sup>c</sup>	54.700 <sup>b</sup>
84.100 <sup>a</sup>	164.000 <sup>b</sup>	123.600 <sup>b</sup>	36.700 <sup>c</sup>	119.600 <sup>b</sup>

<u>Importations des années</u>	<u>1852</u>	<u>1853</u>	<u>1854</u>	<u>1855</u>	<u>1856</u>	<u>1857</u>	<u>1858</u>
A. Importation plus forte que celle de 1855	100%	100%	100%	100%	100%	100%	100%
B. <u>Importation des denrées de la guerre civile et du guerre mondiale plus forte que les importations de 1855</u>							
C. <u>Augmentation due à la croissance démographique</u>							
D. <u>Augmentation due au caractère explosif des denrées achetées dans nos marchés</u>							
E. <u>Augmentation due au caractère explosif des denrées achetées dans nos marchés</u>							
F. <u>Augmentation due au caractère explosif des denrées achetées dans nos marchés</u>							
G. <u>Augmentation due à la croissance démographique</u>							
H. <u>Augmentation due à la croissance démographique</u>							

CARTE figurative et approximative des quantités de **COTON BRUT** importées en Europe  
en 1858 en 1864 et en 1865.

Dressée par M<sup>r</sup>. MINARD, Inspecteur Général des Ponts et Chaussées en retraite.  
Paris, le 14 Mai 1866.

Les tonnages de coton transportés sont représentés par les largeurs des zones colorées à raison d'un millimètre pour huit, ils sont de plus exprimés par les nombres écrits en travers des zones et dont l'unité est mille tonnes.

*Observation : Les importations sont un peu plus fortes que celles de la Carte parce que j'ai enlevé celles d'une dernière tonne et que les Douanes donnaient en bloc les trois petites expéditions de toute provenance, je n'ai pas à les rapporter.*

De l'importation du Coton en 1865. — La question  
commerciale du coton entre dans des phases nouvelles depuis que la guerre civile  
aux Etats-Unis d'Amérique a cessé.

Les portes de l'École ont percées de trous de fusil en 1916 et ont été déplacées à 1918, vers 1918, à l'angle de l'École et de la Chambre, dans une construction supplémentaire de l'église qui avait succédé au clocher, préalablement, et en 1916, par le côté sud-ouest à Mouenelle et à Trézivin. Il a donc été déplacé à nouveau. L'activité pastorale pour la population de cette place très étendue, dans l'importance de 1915, est venue d'en recouvrir un dessous de 10

Le malice des importateurs devient, un fait remarquable à lire. Du moins

Il est probable que l'empereur, dans son voyage à l'ouest, ait fait une halte à Béziers ou à Narbonne, et qu'il ait été de ce fait l'empereur d'Occident. La question est de savoir si, dans ce cas, il a été aussi empereur d'Asie, puisqu'il n'a pas pu être empereur d'Asie et d'Occident à la fois.

Cette très grande voie desservira le Canal de l'Estuaire de Saint-Louis, mais-t-elle servira après l'exploitation du Canal ? Indique-t-elle d'autres voies de production connues ou conjecturées en cette partie du pays à l'ouest.

variables pour le niveau de l'Eau centrale traversant la Mer Noire et la Mer d'Azov ? C'est ce qu'on va peut dire.

Il attendait nous avions à la lutte opératoire des trois Pige grande productrice, mais l'Elan Estrie qui cherchait à monopoliser le marché, nous étions le pion.

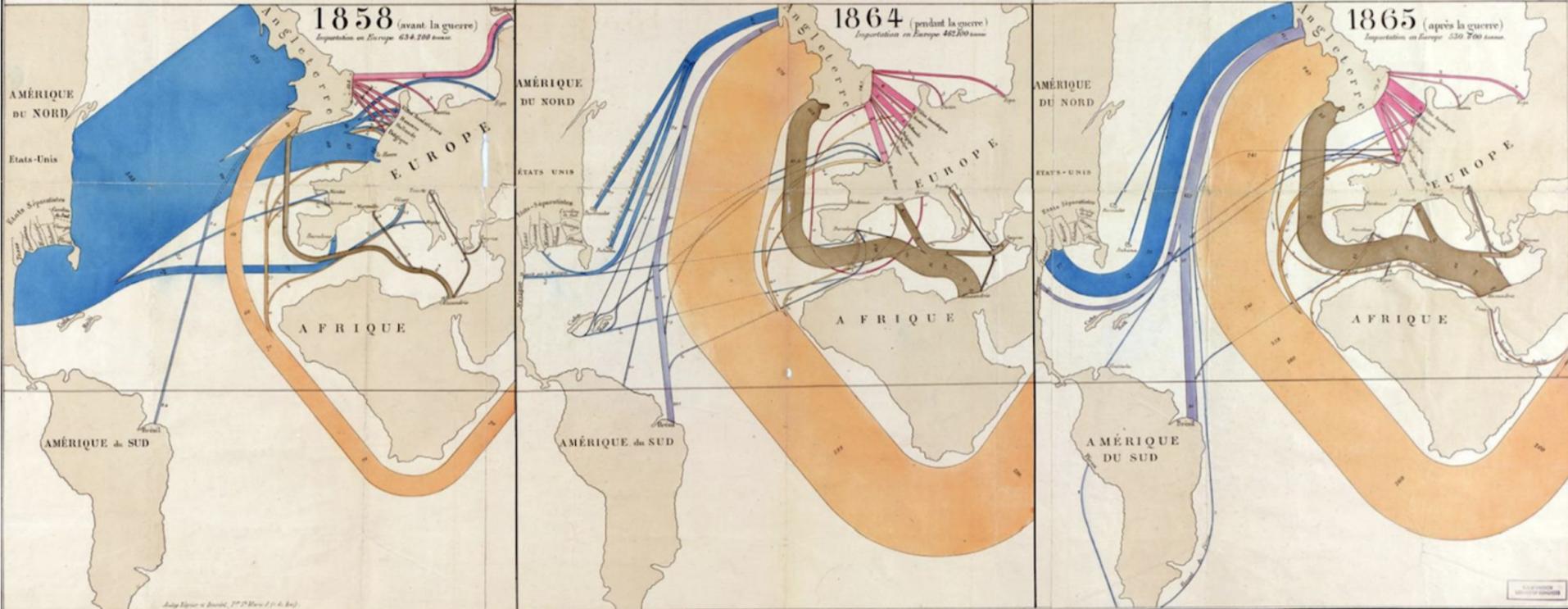
vers. 1<sup>re</sup> Et l'Etat finit par chahuter à reconnaître le marché, mais dans un sens négatif et ce entrepreneurs ont nécessairement estimé par l'évaluation, et l'indemnité des personnes affublées qu'ils ne pouvoient pas être plus compliqués; 2<sup>e</sup> L'Église qui abusait de sa puissance et accapte de tout pour celle du coton; 3<sup>e</sup> L'Etat qui donnait une

mauvaise impression sous plusieurs points de vue, sauf que, elle de temps à autre, peut faire le mal à la cause qu'elle a faite en causant des

Ensuite, les canaux floraux producteurs, pourront aussi déboucher dans un consommateur,

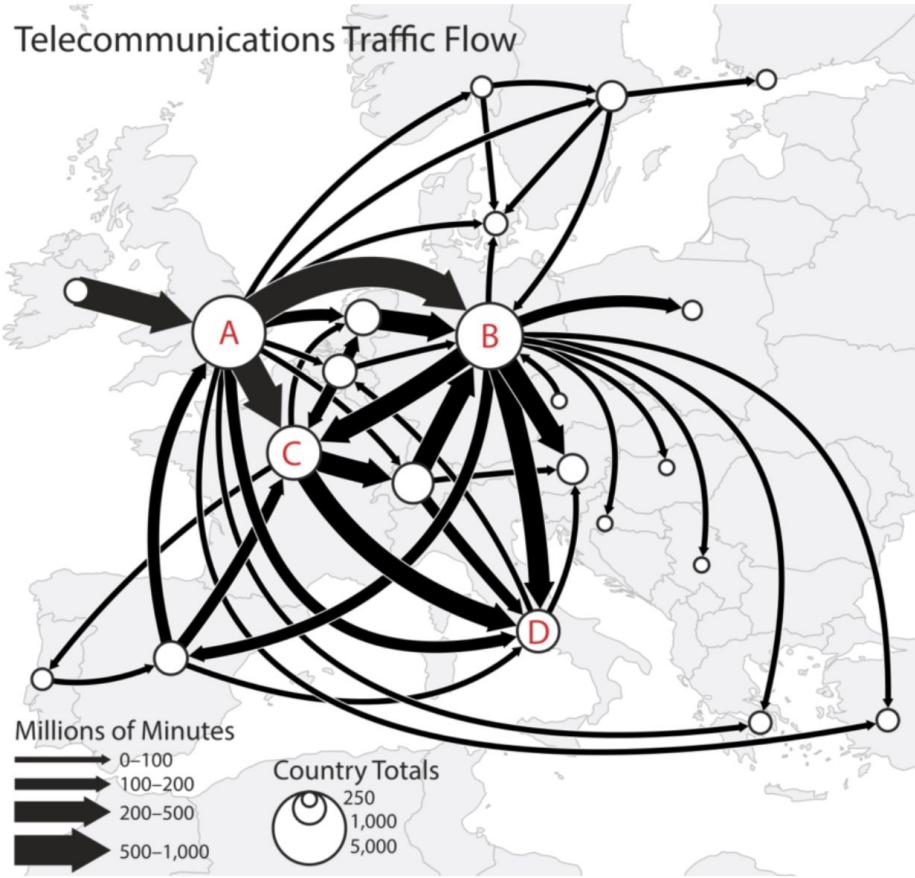
Ensuite, au gré des jours passés, nous nous sommes rencontrés, nous nous sommes échangés, il n'est pas probable que ce pays n'ait pas la même fierté d'avoir été d'une seule source la matrice pour une épopée de quatre millions de ses habitants. Sans doute il interrogeront entre eux, mais je suis sûr qu'ils ne feront rien de mal.

Il nous paraît donc nécessaire de faire une analyse de la situation actuelle et de proposer des mesures pour la résoudre.

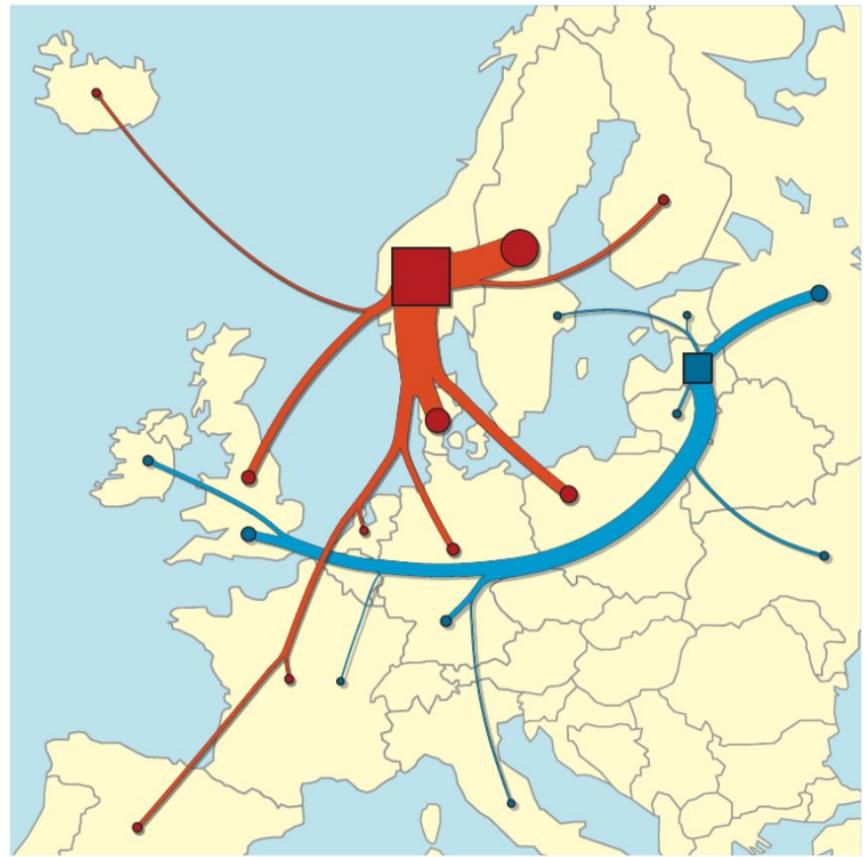


# Joseph Minard (1781–1870)

Telecommunications Traffic Flow

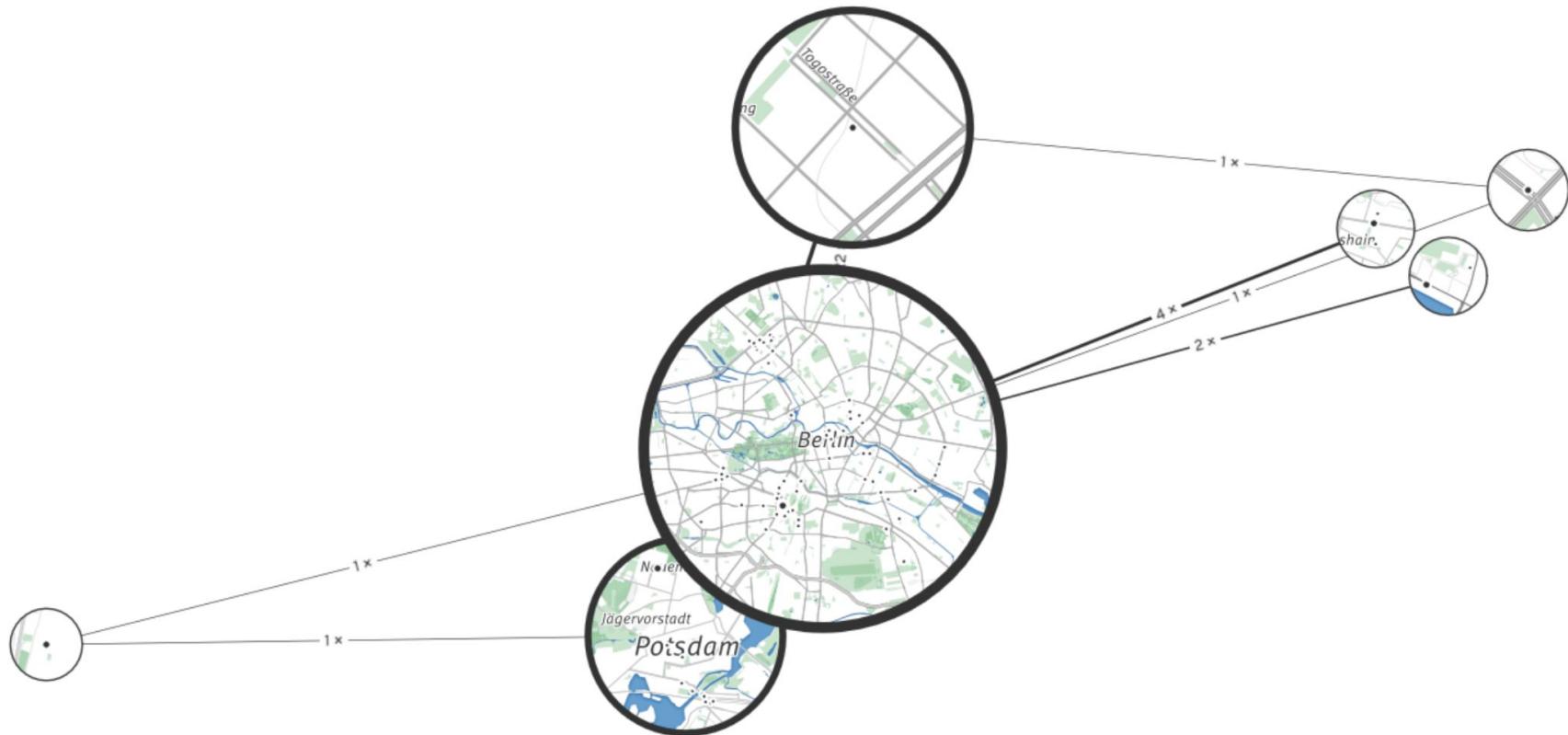


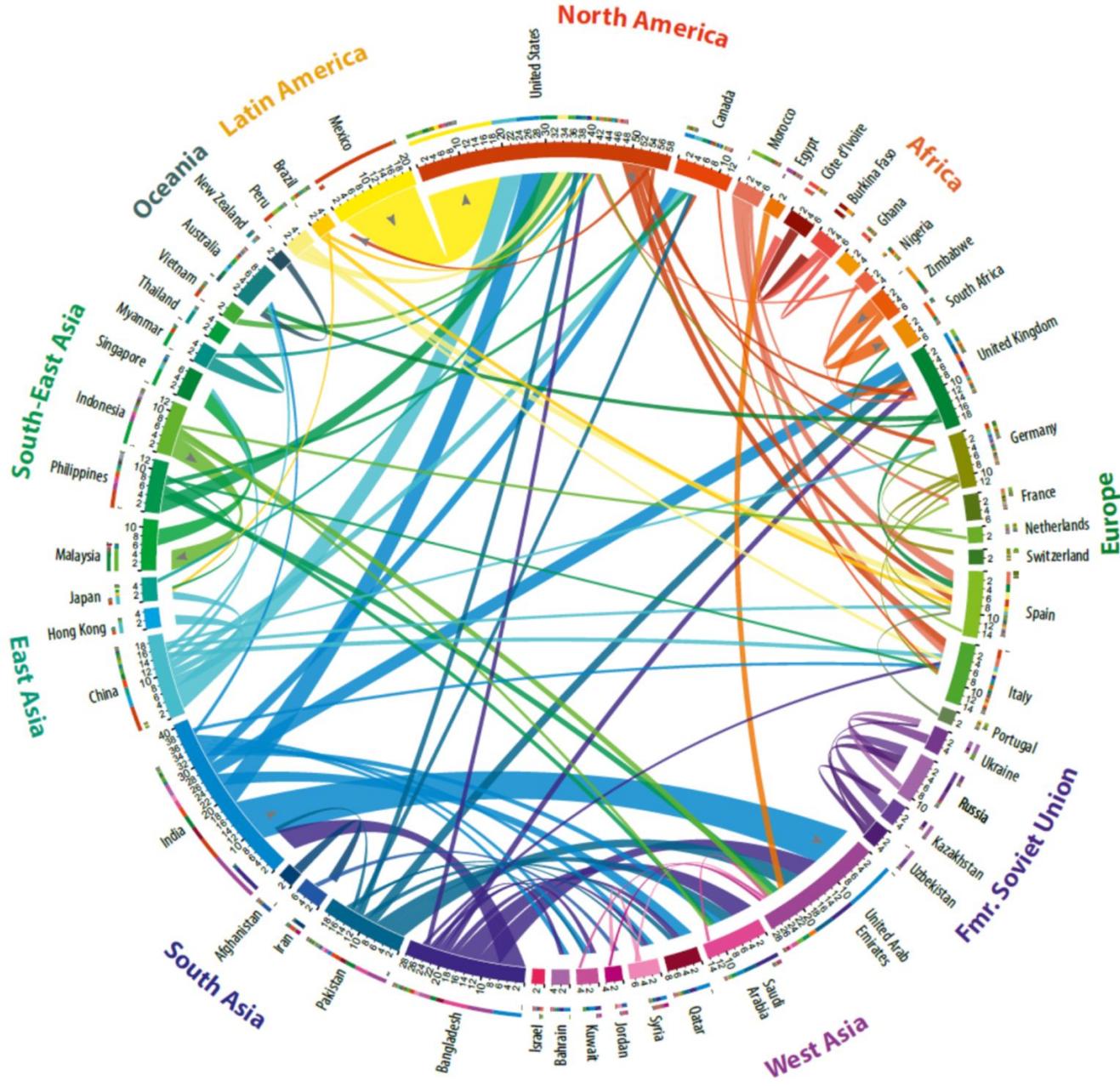
JENNY, BERNHARD, STEPHEN, DANIEL M., MUEHLENHAUS, IAN, et al.  
“Design principles for origin-destination flow maps”. *Cartography and Geographic Information Science* 45.1 (Jan. 2, 2018)

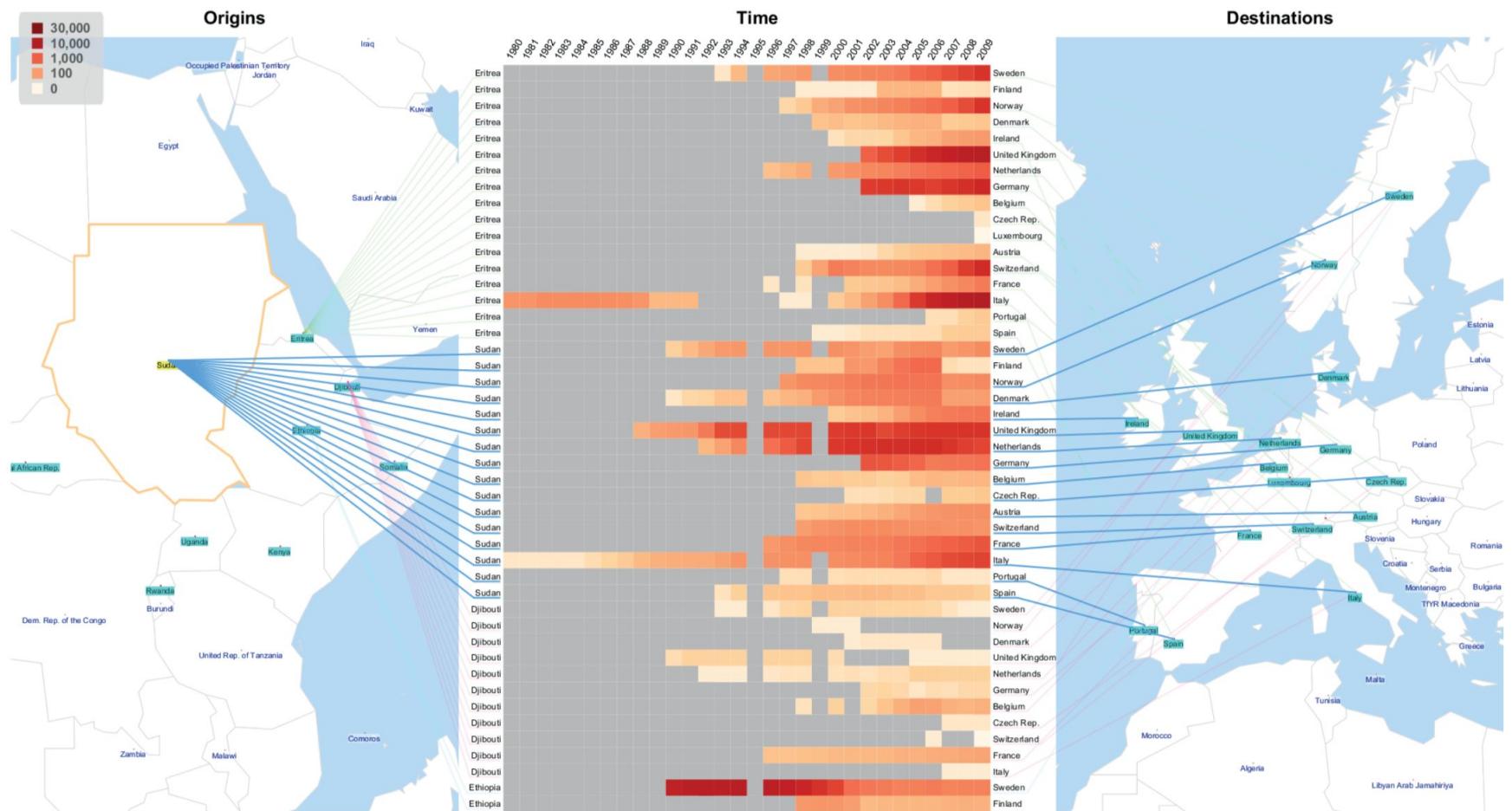


BUCHIN, K., SPECKMANN, B., and VERBEEK, K. “Flow Map Layout via Spiral Trees”. *IEEE Transactions on Visualization and Computer Graphics* 17.12 (Dec. 2011)

# Shifted Maps







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

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### Geography Representation

Map	Distorted Map	Abstract
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#### 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]

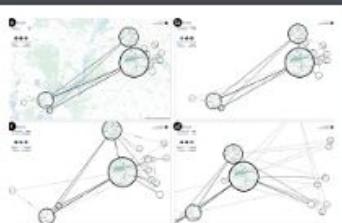
map abstract-abstract balanced  
required-interaction



#### 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



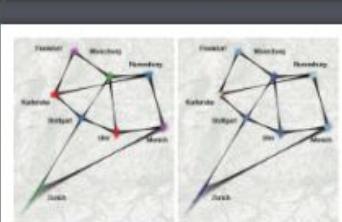
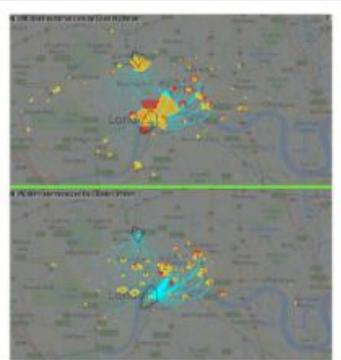
#### Shifted Maps: Revealing spatio-temporal topologies in movement data

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

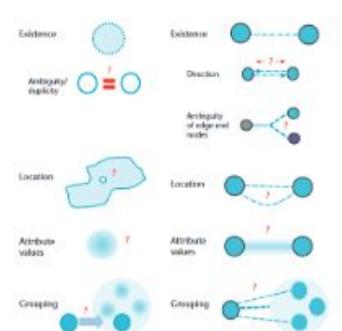


Figure 2. Overview and comparison of (a) node and (b) edge uncertainty. Node uncertainty encompasses the uncertainties that might affect individual nodes, whereas edge uncertainty is directly connected to and compounded by the various types of node uncertainty.

### Integration

Geography as Basis	Balanced	Network as Basis
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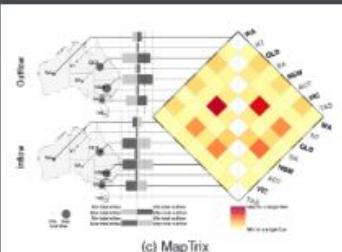
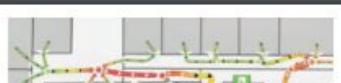
### Interaction

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

# 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.
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- 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/>