COMPARATIVE OVERVIEW OF NETWORK-ORIENTED VISUALIZATION METHODS

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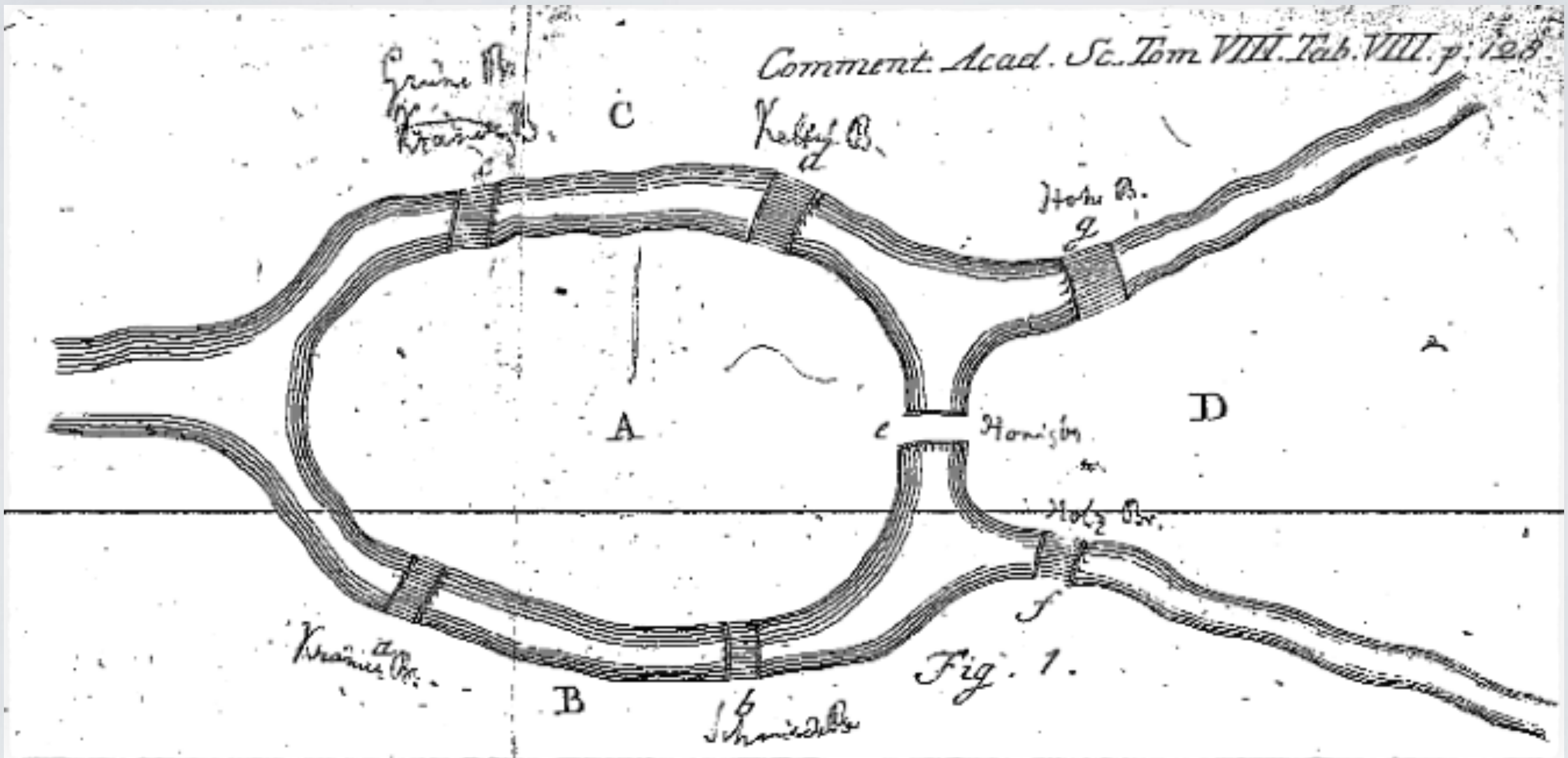
EARLY REPRESENTATION PRINCIPLES

Bridges of Königsberg (Euler, 1735)

EARLY REPRESENTATION PRINCIPLES



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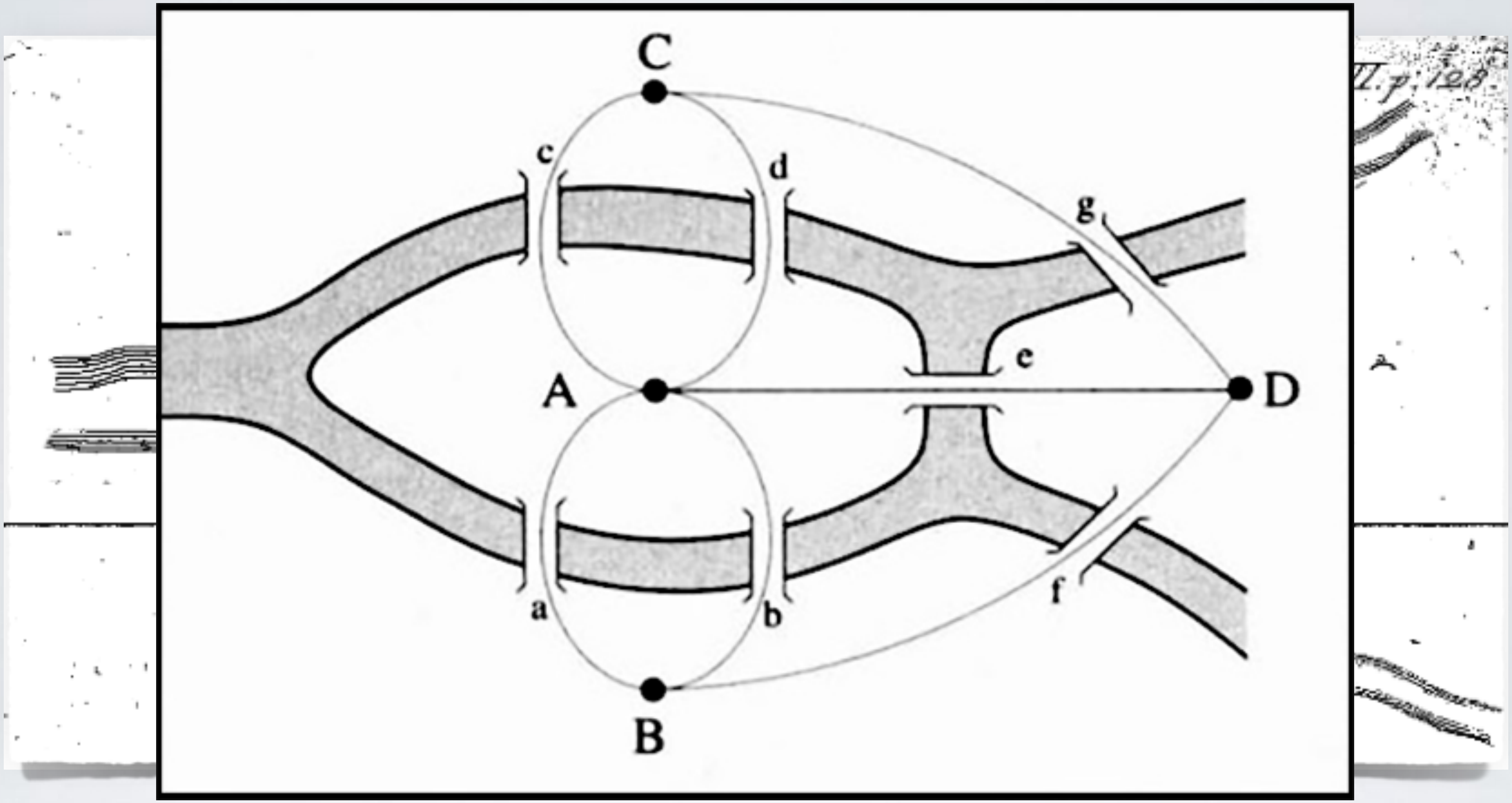


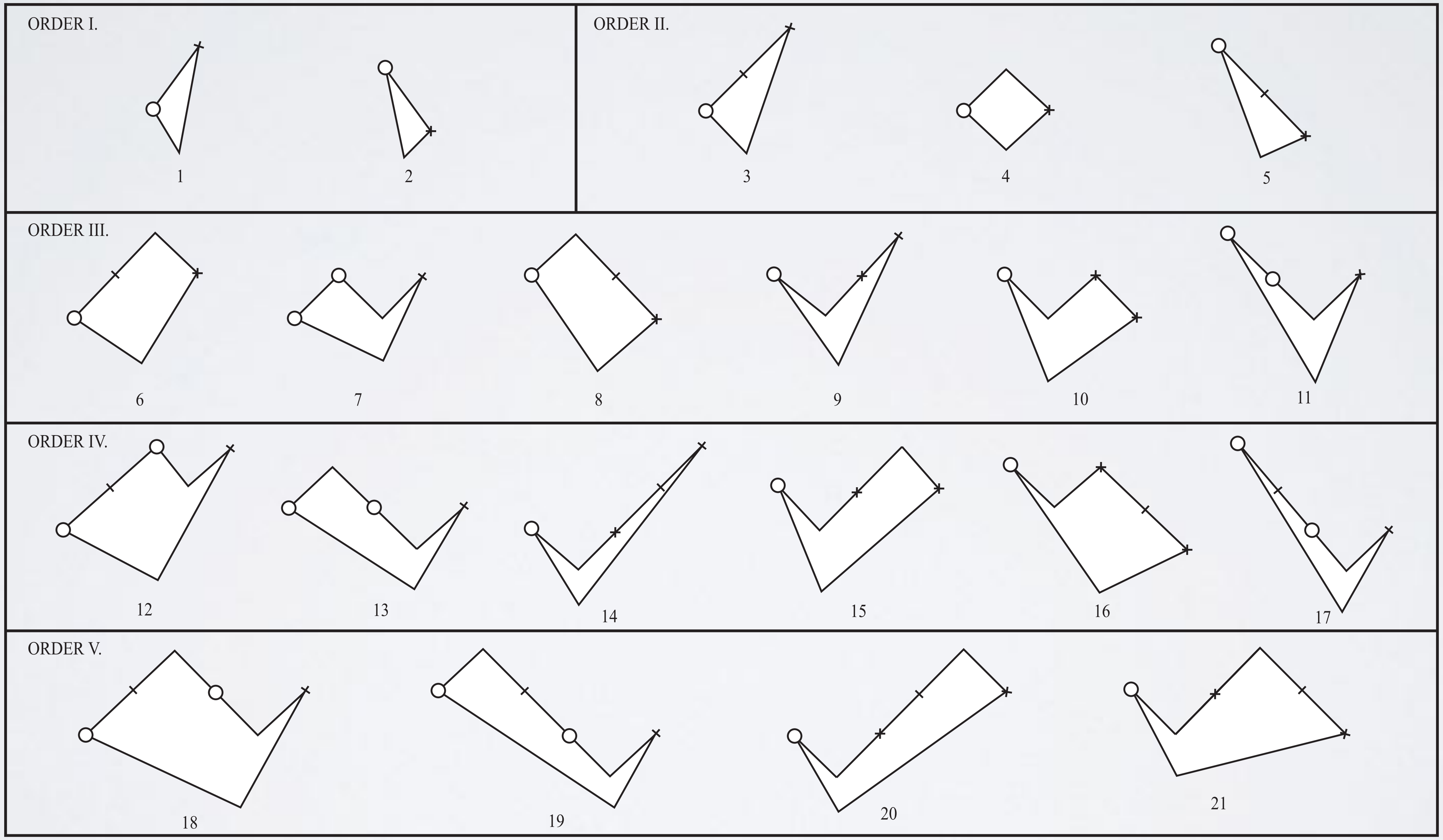
Bridges of Königsberg (Euler, 1735)

EARLY REPRESENTATION PRINCIPLES

Pfeffer, Freeman, 2015

Macfarlane, 1883

Analysis of Relationships of Consanguinity and Affinity



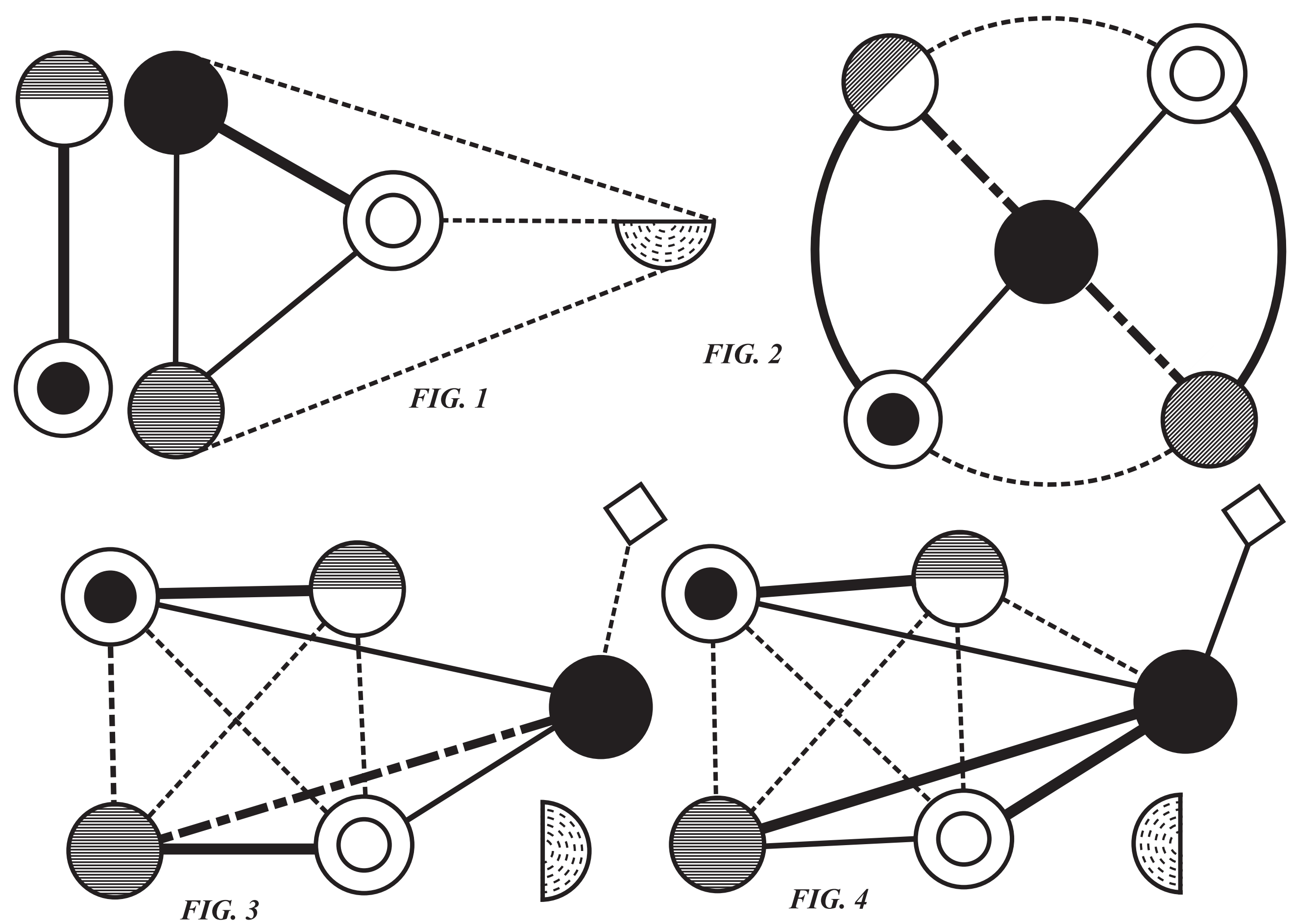
British marriage prohibition. Males (+), females (o). Earlier generations are placed higher on the page. The lowest point is the prohibited offspring.

EARLY REPRESENTATION PRINCIPLES

Pfeffer, Freeman, 2015

Bernfeld, 1922

Vom Gemeinschaftsleben der Jugend



Elly; Afil; Hely; Nandl; Ricky; Ad; Freundinnen außerhalb des Kreise.

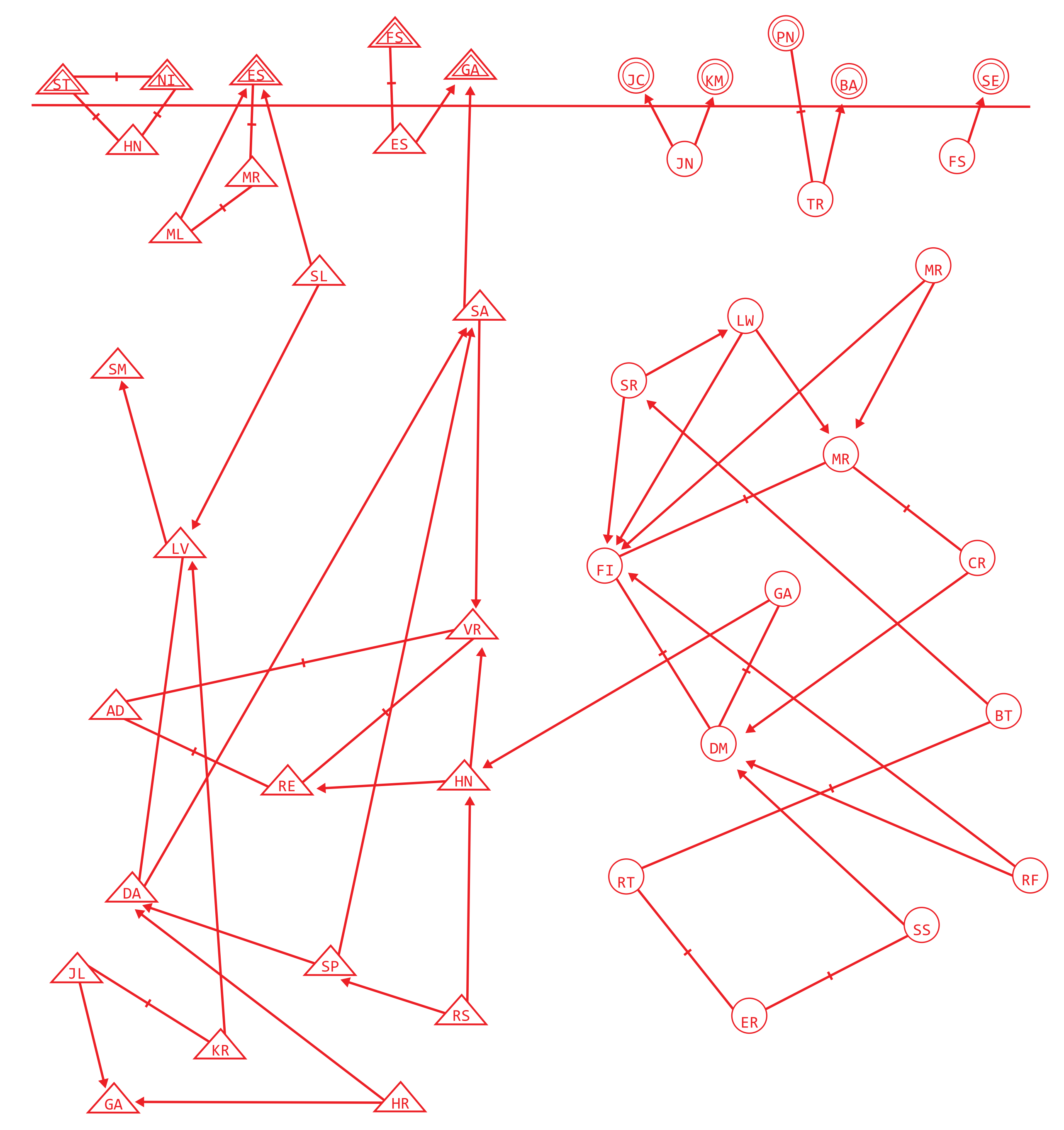
Die Intensitäten sind durch Verbindungsstriche symbolisiert, von der stärksten: über: und: zur schwächsten:

A circle of girl friends. Four figures show different relations. Line thickness represents intensity.

EARLY REPRESENTATION PRINCIPLES

Pfeffer, Freeman, 2015 & Beauguitte, 2013 about Moreno, 1934

"Who shall survive ? A New Approach to the Problem of Human Interrelations"



Class structure, 5th grade. Girls (circles) and boys (triangles). Links show two best friends. Top line defines group border.

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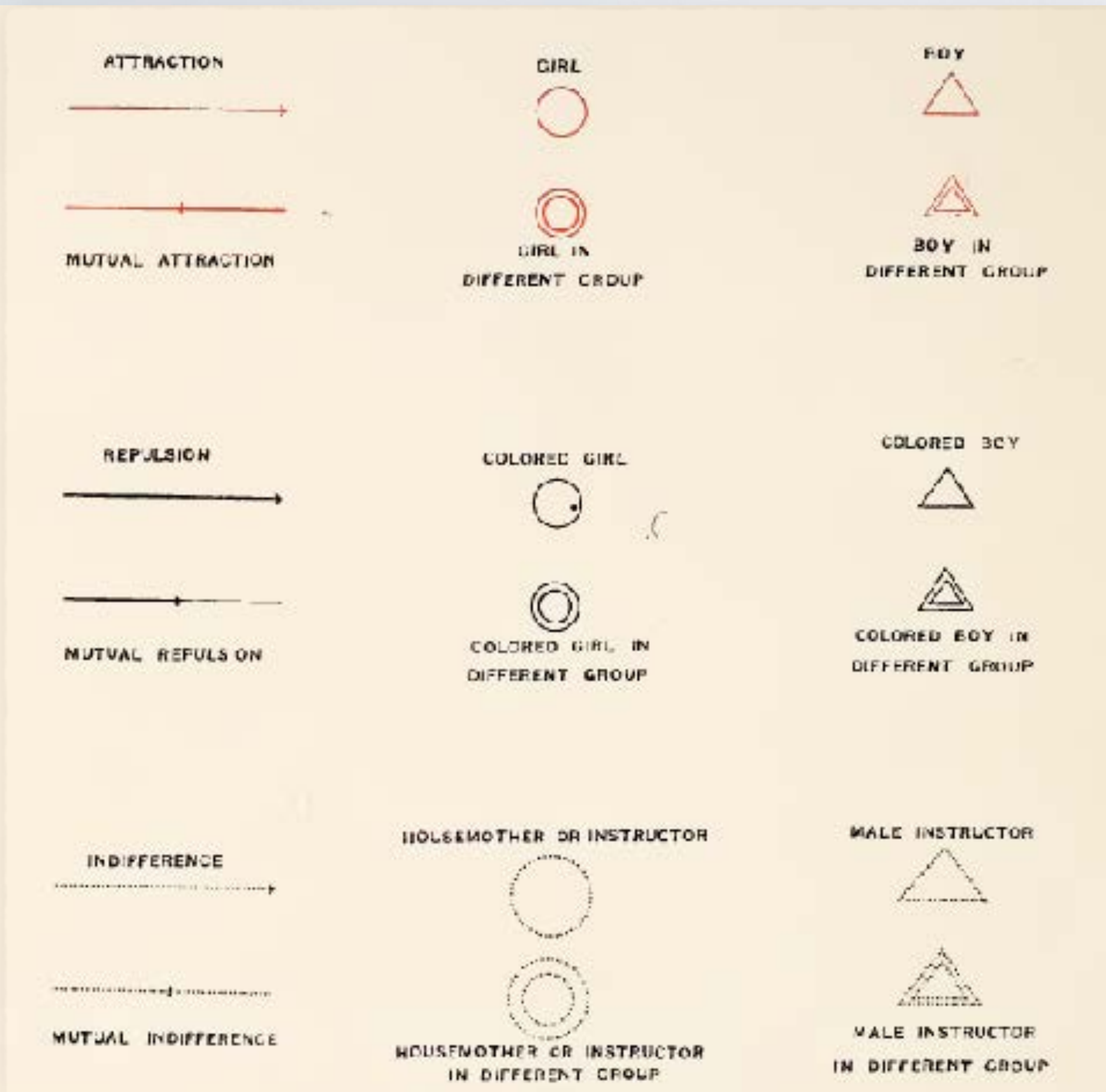


STRUCTURE OF A WORK GROUP—STEAM LAUNDRY

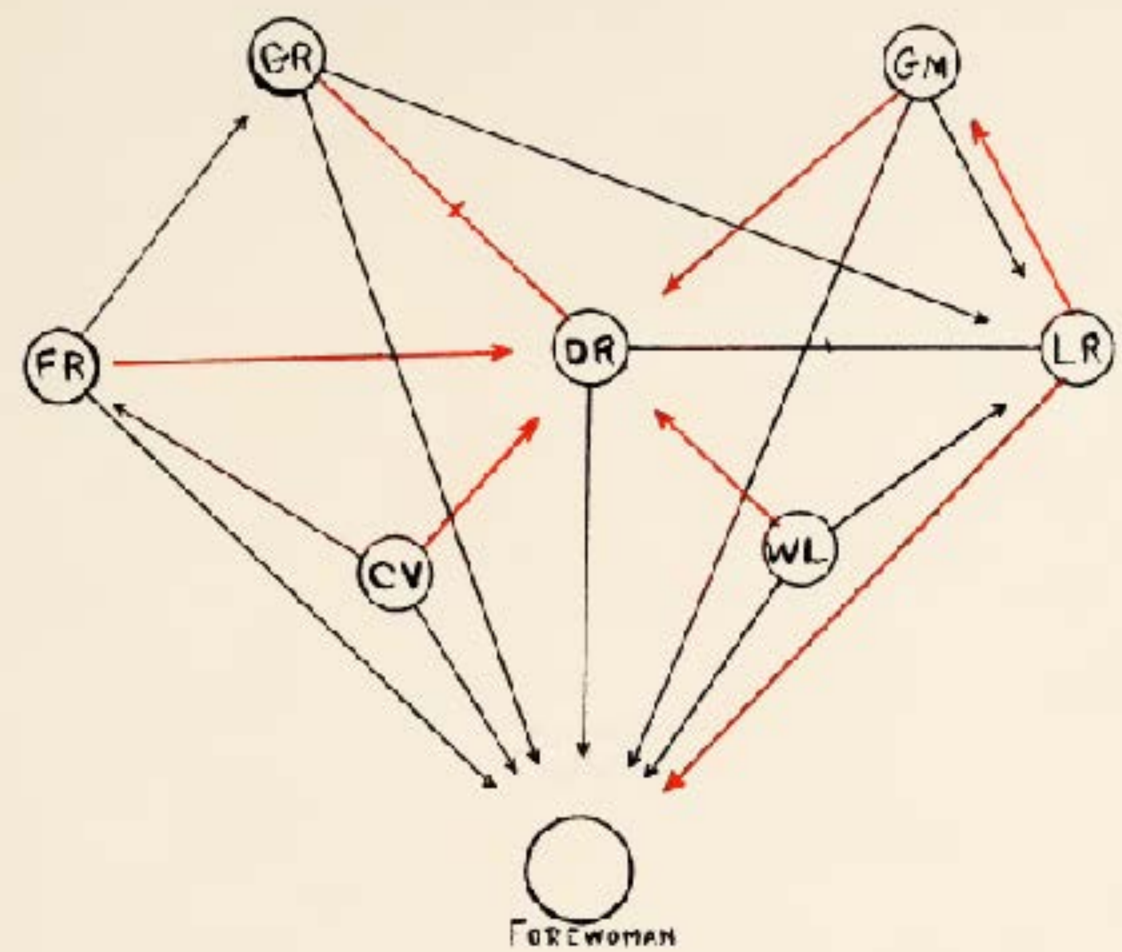


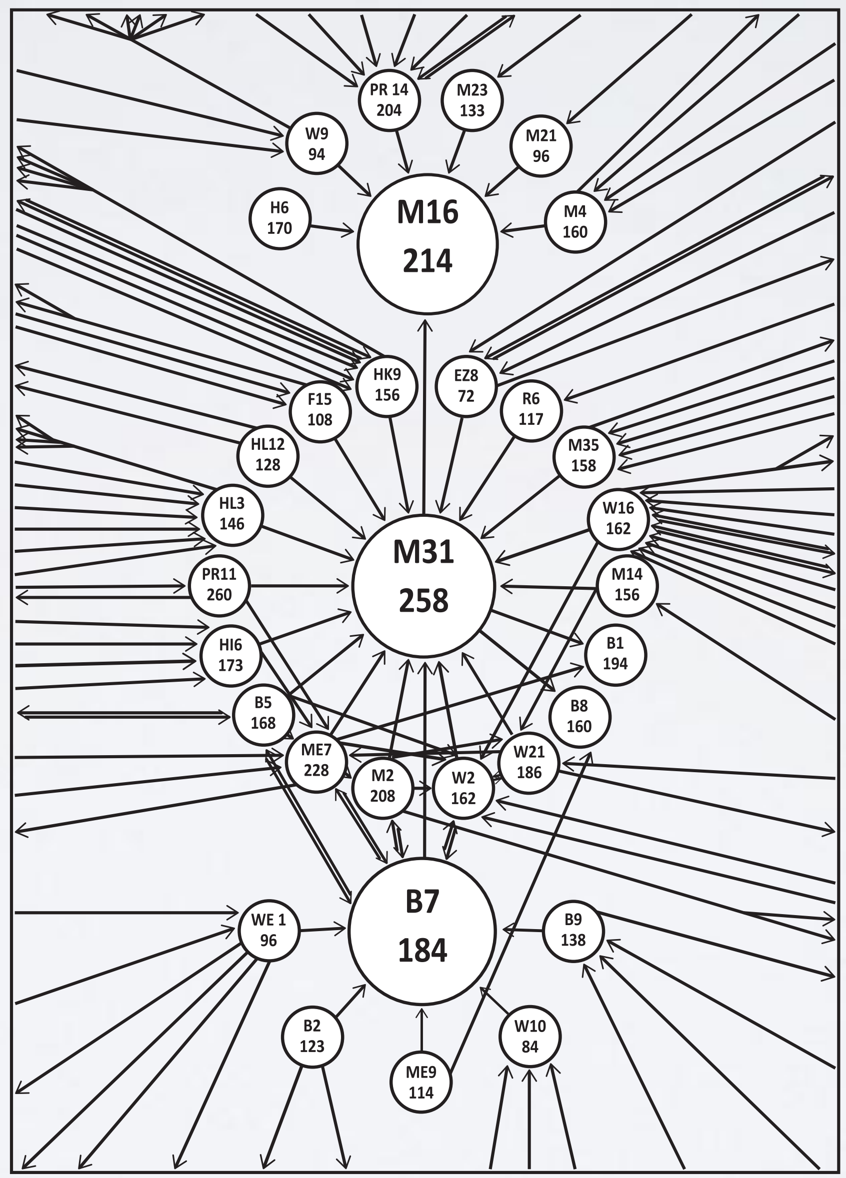
Fig. 2. Stella DR has gained a position of greater influence. In Fig. 1 she is the object of one attraction, Hilda GR; now she is the center of five attractions: Hilda GR, Myrtle WL, Lilliam FR, Rosalie CV, Esther GM, and forms with Hilda a pair. She is rejected by Philamina LR whom she rejects in return. In Fig. 1 the forewoman is rejected by four workers, now she is rejected by all but Philamina LR. The influence of Stella DR is apparent in the concentrated opposition against the forewoman. (See Chapter on Race.)

EARLY REPRESENTATION PRINCIPLES

Pfeffer, Freeman, 2015

Lundberg & Steele, 1938

Social Attraction-Patterns in a Village



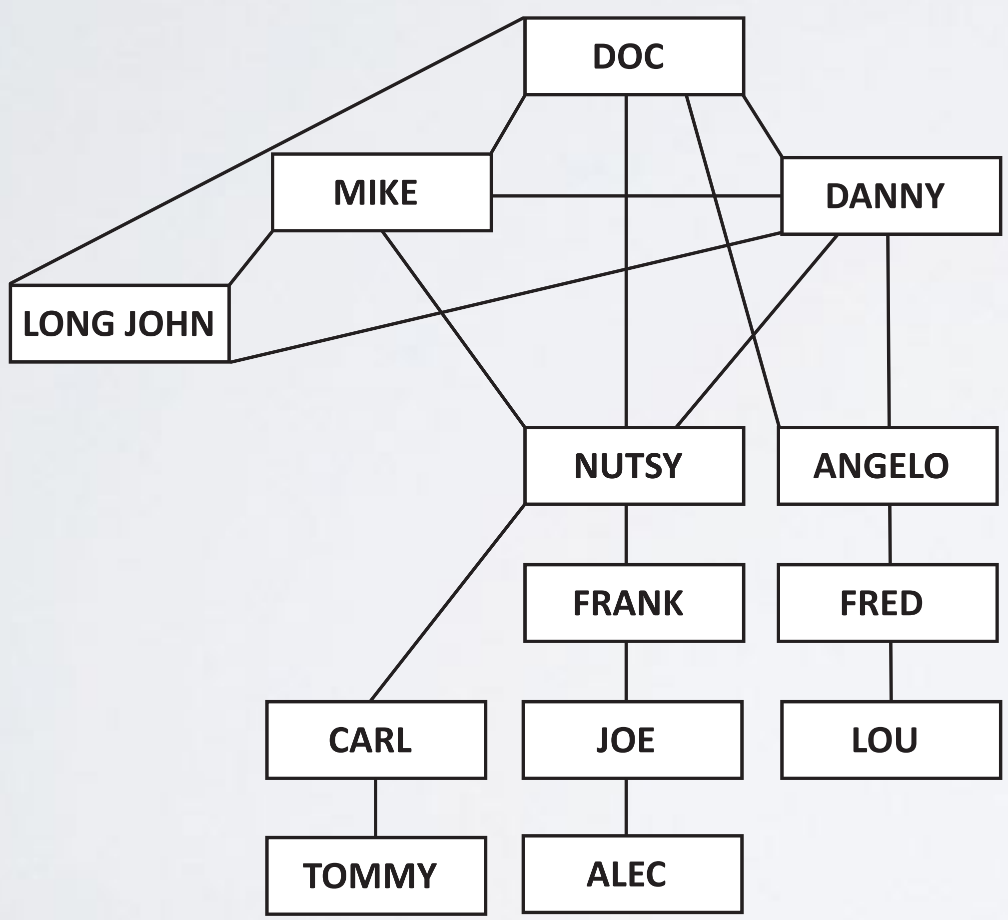
Most important friendships in the village. Number is socio-economic status. M31 = "Lady Bountiful".

EARLY REPRESENTATION PRINCIPLES

Pfeffer, Freeman, 2015

Whyte, 1943

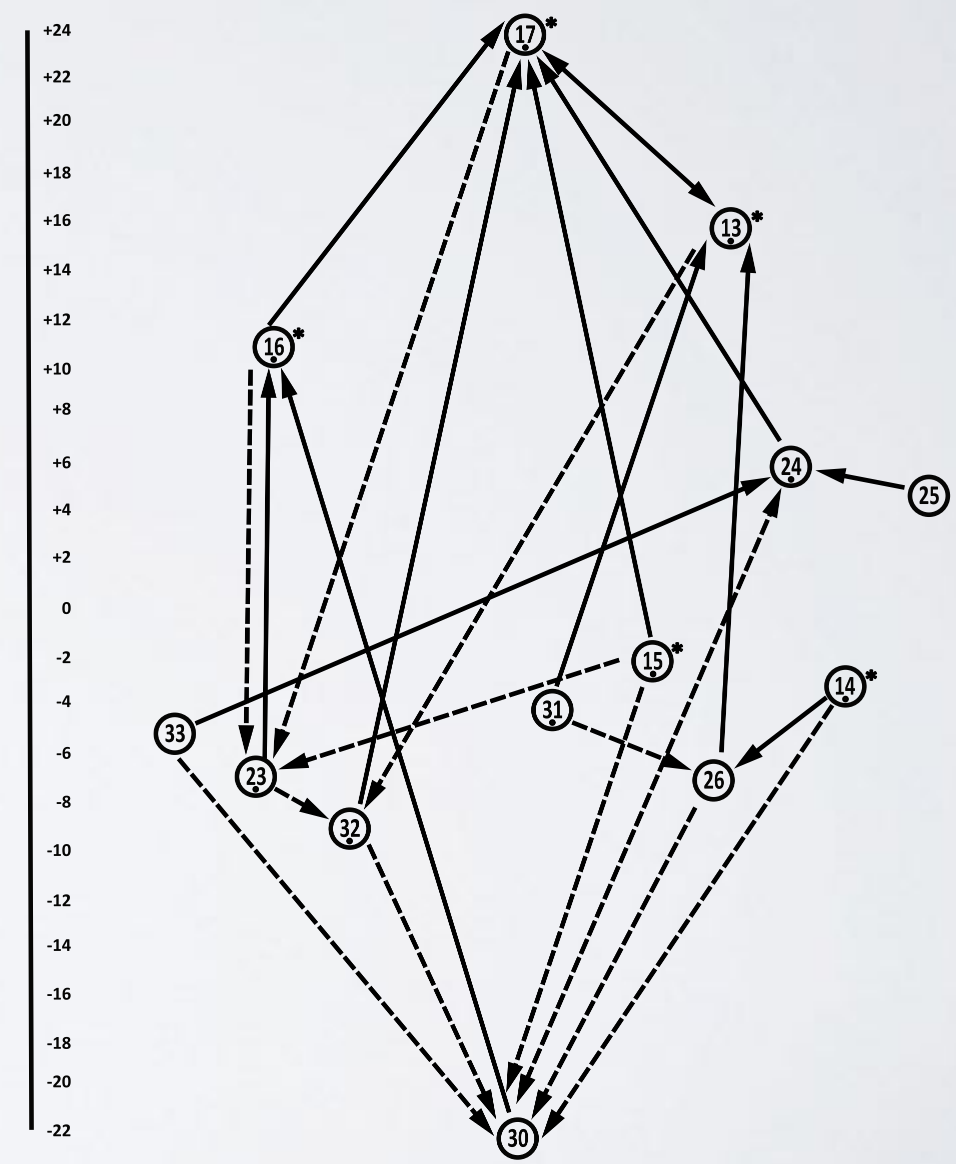
Street Corner Society



Corner boys and lines of influence.
Positions of boxes indicate relative status.

Sampson, 1968

A Novitiate in a Period of Change



Influence. Position of novices on y-axis shows sum of received positve (solid) and negative (dashed) choices.

EARLY REPRESENTATION PRINCIPLES

bipartite graphs

Pfeffer, Freeman, 2015

Davis et al., 1941

Deep South: A Social Anthropological Study of Caste and Class

Names of Participants of Group I	Code Numbers and Dates of Social Events Reported in *Old City Herald*													
	(1) 6/27	(2) 3/2	(3) 4/12	(4) 9/26	(5) 2/25	(6) 5/19	(7) 3/15	(8) 9/16	(9) 4/8	(10) 6/10	(11) 2/23	(12) 4/7	(13) 11/21	(14) 8/3
1. Mrs. Evelyn Jefferson	×	×	×	×	×	×	....	×	×	....	....	....	....	....
2. Ms. Laura Mandeville	×	×	×	....	×	×	×	×	....	....	....	....	....	....
3. Ms. Theresa Anderson	....	×	×	×	×	×	×	×	×	....	....	....	....	....
4. Ms. Brenda Rogers	×	....	×	×	×	×	×	×	....	....	....	....	....	....
5. Ms. Charlotte McDowd	....	....	×	×	×	....	×	....	....	....	....	....	....	....
6. Ms. Frances Anderson	....	....	×	....	×	×	....	×	....	....	....	....	....	....
7. Ms. Eleanor Nye	....	....	....	....	×	×	×	×	....	....	....	....	....	....
8. Ms. Pearl Oglethorpe	....	....	....	....	....	×	....	×	×	....	....	....	....	....
9. Ms. Ruth DeSand	....	....	....	....	×	....	×	×	×	....	....	....	....	....
10. Ms. Verne Sanderson	....	....	....	....	....	....	×	×	×	....	....	×	....	....
11. Ms. Myra Liddell	....	....	....	....	....	....	....	×	×	×	....	×	....	....
12. Ms. Katherine Rogers	....	....	....	....	....	....	....	×	×	×	....	×	×	×
13. Mrs. Sylvia Avondale	....	....	....	....	....	....	×	×	×	×	....	×	×	×
14. Mrs. Nora Fayette	....	....	....	....	....	×	×	....	×	×	×	×	×	×
15. Mrs. Helen Lloyd	....	....	....	....	....	....	×	×	....	×	×	×	....	....
16. Mrs. Dorothy Murchiso	....	....	....	....	....	....	....	×	×	....	....	....	....	....
17. Mrs. Olivia Carleton	....	....	....	....	....	....	....	....	×	....	×	....	....	....
18. Mrs. Flora Price	....	....	....	....	....	....	....	....	×	....	×	....	....	....

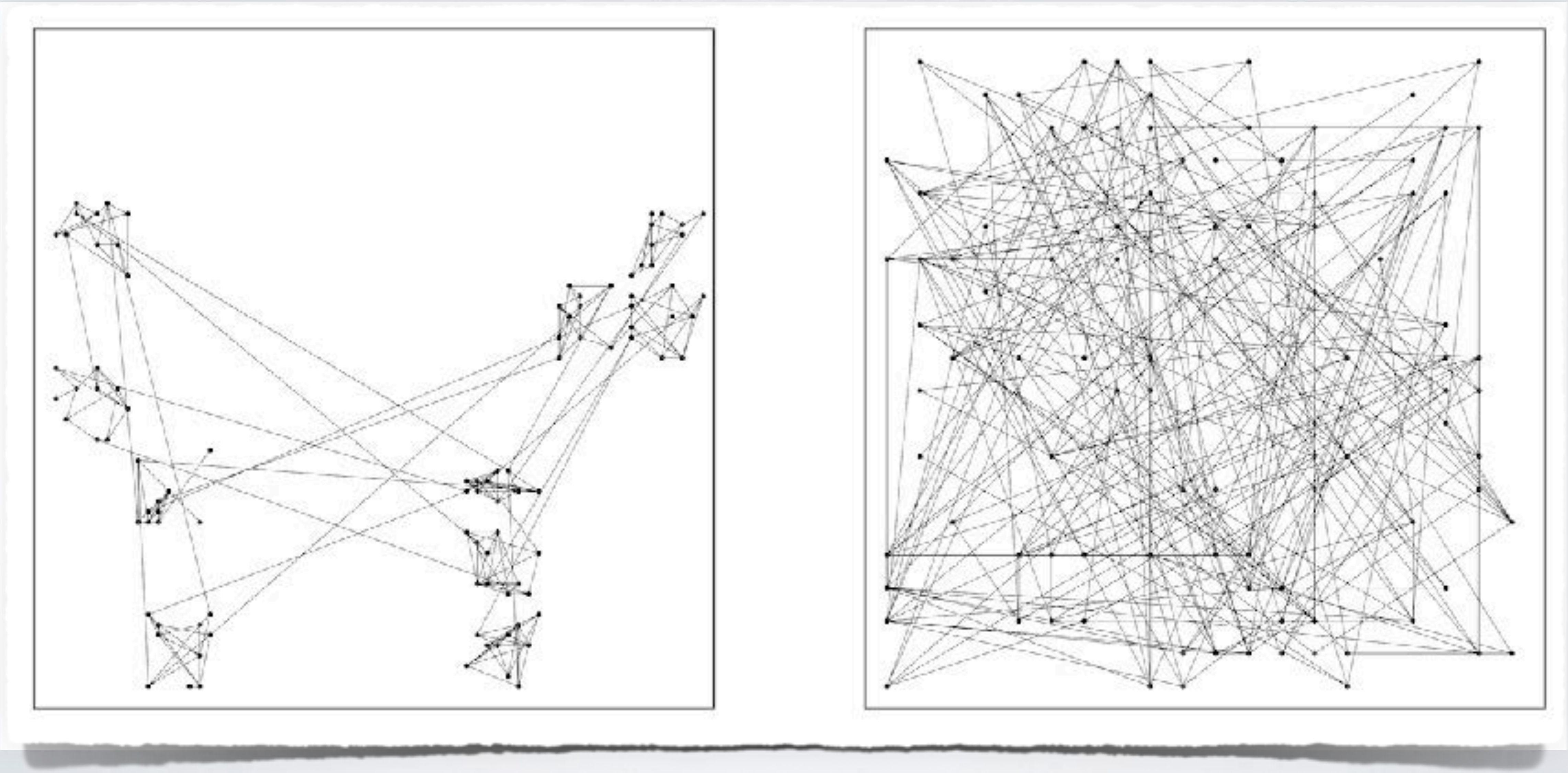
A group of women in Old City, 1936 – Group I. Women participating at social events.
Rows and columns were rearranged to show groups.

ALGORITHMIC VISUALIZATION

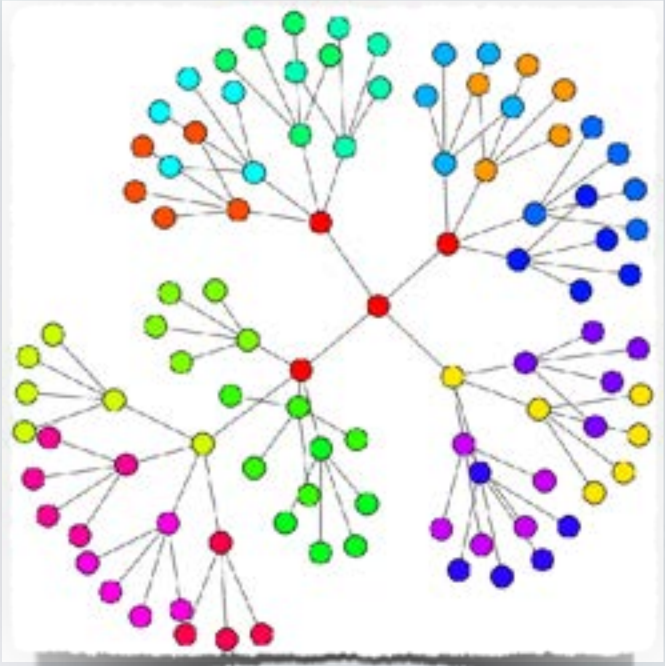
Zegura, Calvert,
Bhattacharjee, 1996

"How to model an internetwork"

VISUALIZE STRUCTURAL DIFFERENCES BETWEEN TWO GRAPHS

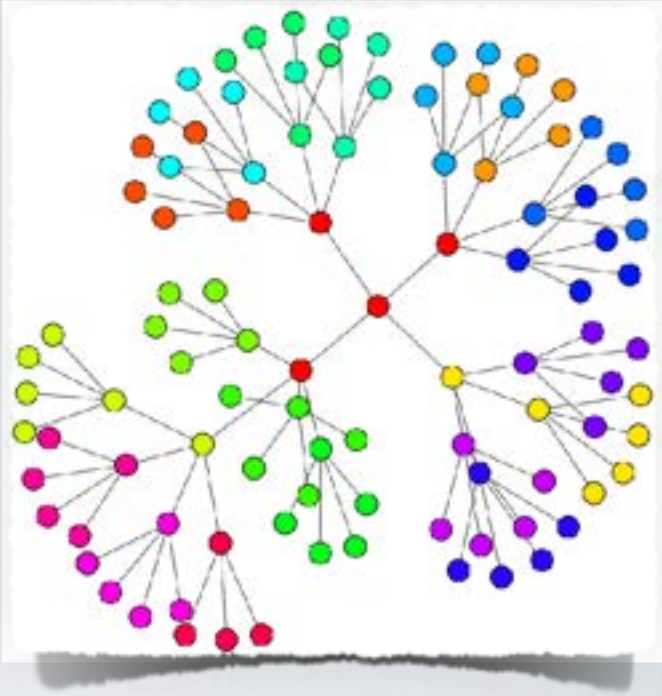


EARLY ALGORITHMS



- **trees:** Wetherell & Shannon, 1979
  acyclic graphs: Sugiyama, 1981

EARLY ALGORITHMS



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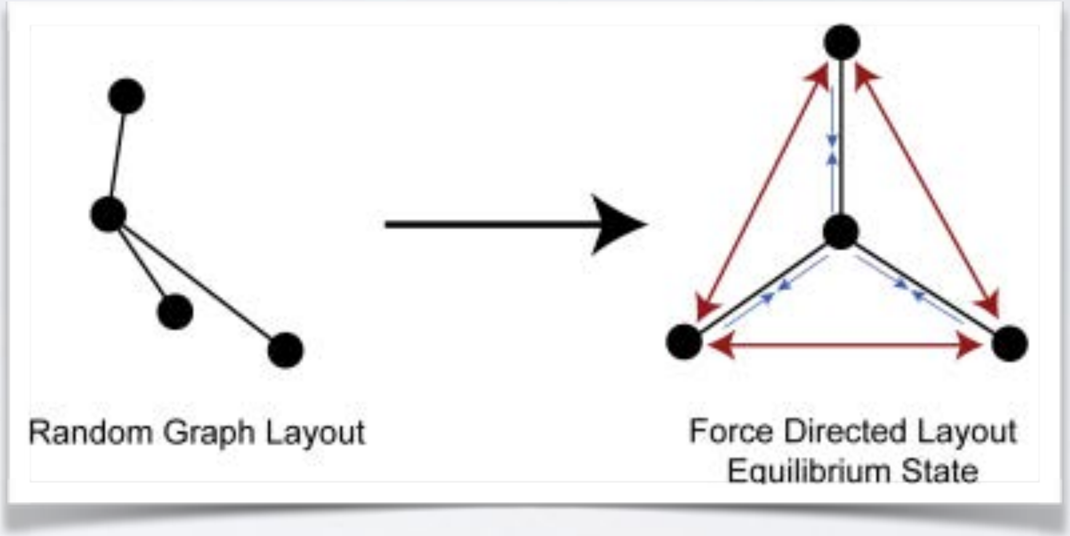
- **general graphs:**
  "*Force-directed layouts*"
  - Kamada-Kawai, 1989
    Fruchterman-Reingold, 1991



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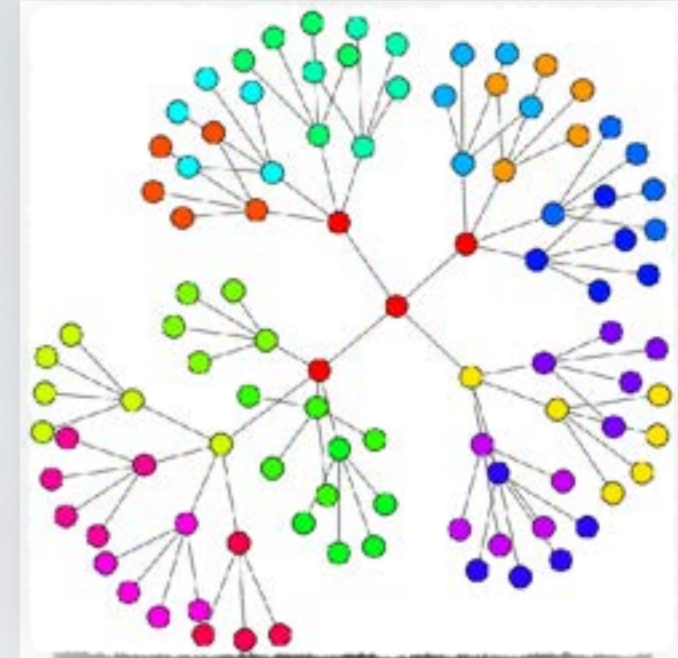

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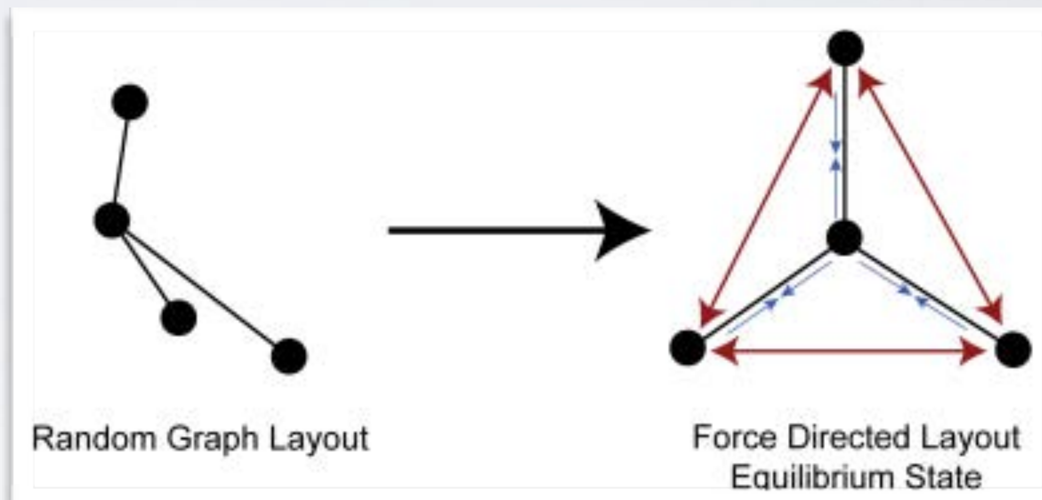
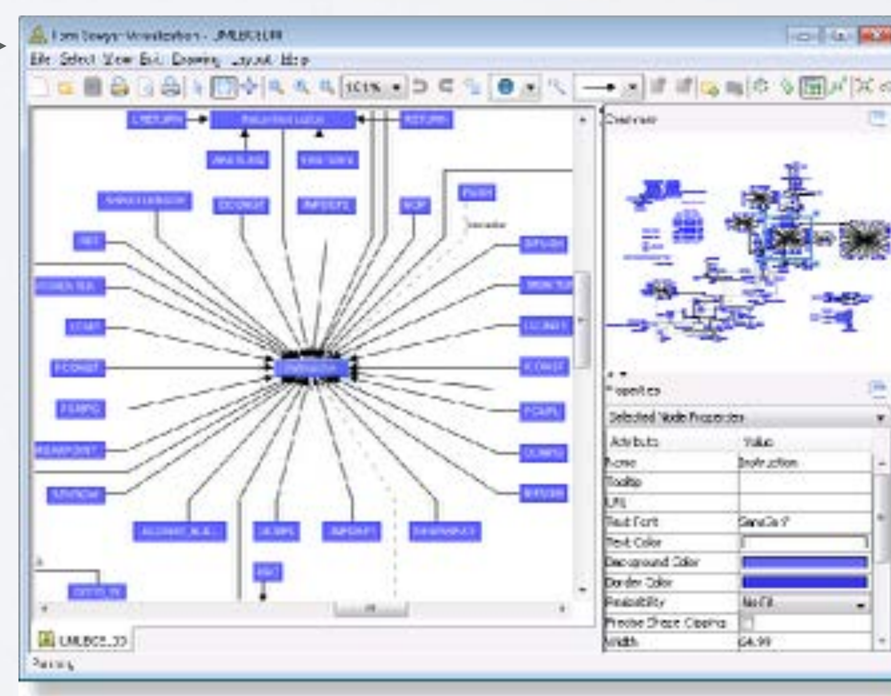
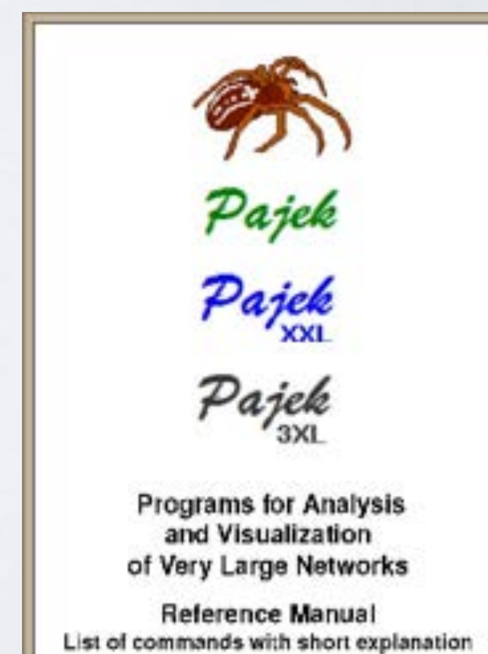


- **software:**
  Tom Sawyer Software (1991)
  GraphViz (1993), Pajek (1996),
  Gephi (2009)



Gephi
makes graphs handy



KAMADA-KAWAI
FRUCHTERMAN-RHEINGOLD

Overview: Network of Europe‘s top 12,000 political accounts

The visualization of Europe’s political Twittersphere is star-shaped. The **center** consists of **accounts directly related to EU politics**, such as European Parliament members and candidates and (mostly British) **international news media**.

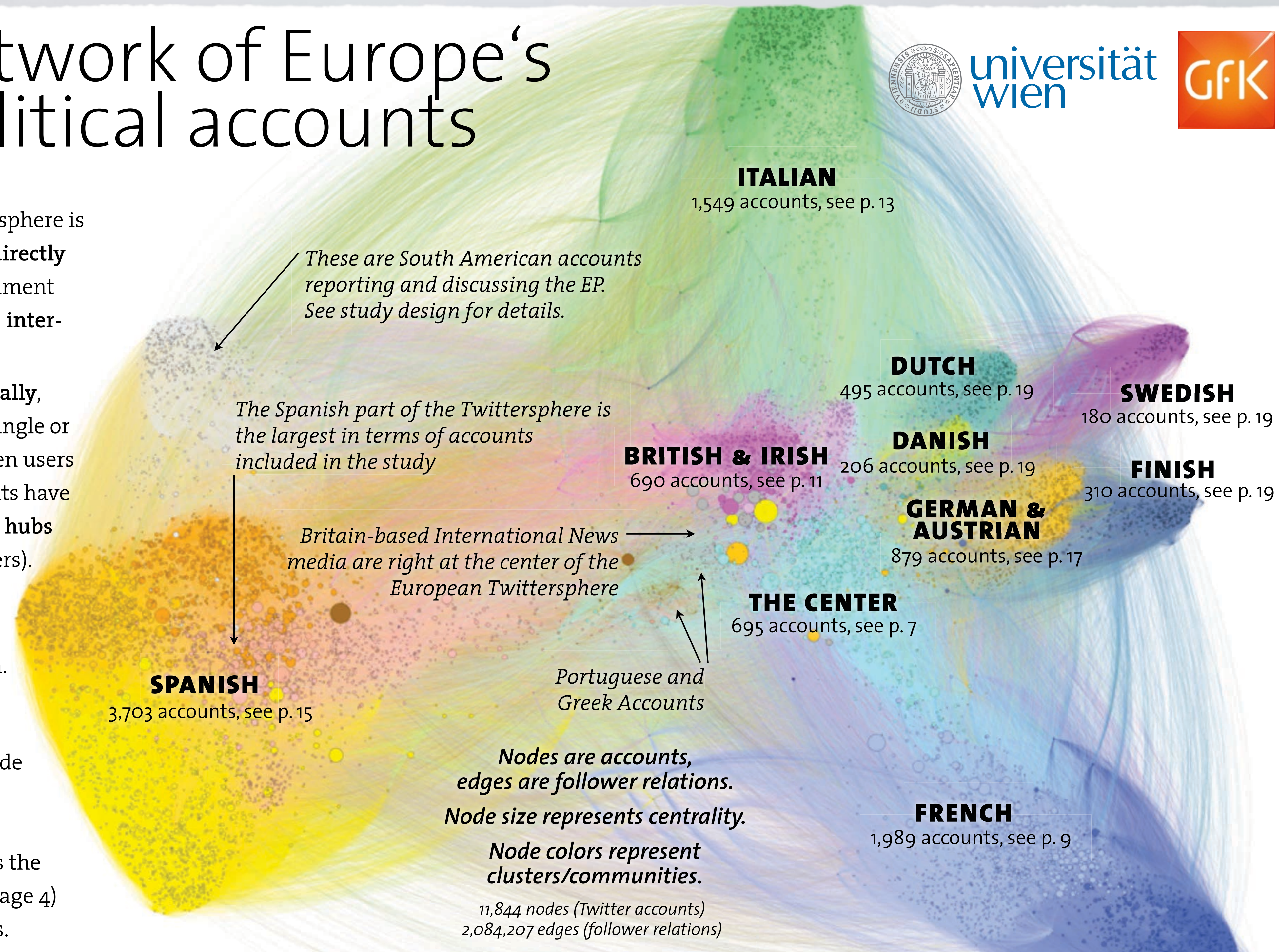
The **peripheral clusters** are **structured nationally**, representing the political Twitterspheres of single or multiple countries. Direct connections between users from certain countries exist and some accounts have particular roles as **transnational information hubs** (situated at the edges of, or in-between, clusters).

However, the accounts in the **central trans-European sphere** are the most important in terms of Europeanwide information diffusion.

Eastern Europe missing?

Only very few Eastern European accounts made it into the study, due to three reasons:

1. Twitter is **hardly used** in Eastern Europe
2. Users did not have enough followers to pass the **threshold of 250** incoming connections (see page 4)
3. Users **hardly tweeted** about the EP elections.



Bertelsmann**Stiftung**

spotlight europe

2014/02 — Mai 2014

Im Netz der Populisten

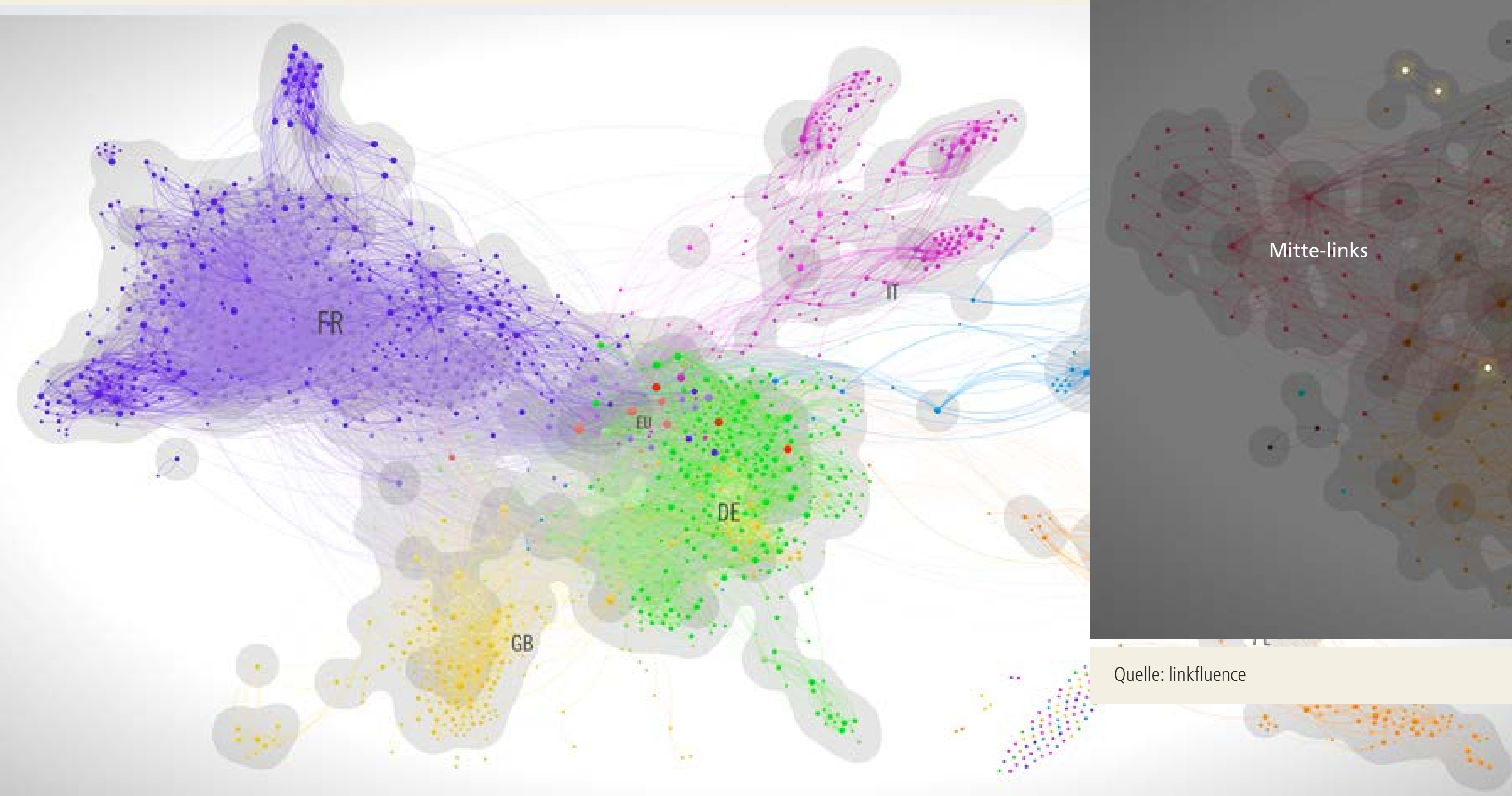
73 Prozent der Bevölkerung der Europäischen Union nutzten 2013 das Internet. Tendenz steigend. Kurz vor der Europawahl wollten wir daher wissen: Wie präsent und aktiv sind die antieuropäischen Populisten im Internet? Resultat: Die Anti-Europäer sind isoliert und zersplittert. Es gibt aber eine lebendige pro-europäische Netzöffentlichkeit. Nur zivilgesellschaftliche Initiativen brauchen noch mehr Unterstützung.

988 Internetseiten mit antieuropäischen Inhalten

In Deutschland, Frankreich, Großbritannien, Italien, den Niederlanden und Polen

1.638 europapolitische Internetseiten

In Deutschland und Frankreich mit pro- und antieuropäischen Inhalten;
in Großbritannien, den Niederlanden, Italien und Polen mit antieuropäischen Inhalte



Quelle: linkfluence

Deutschland

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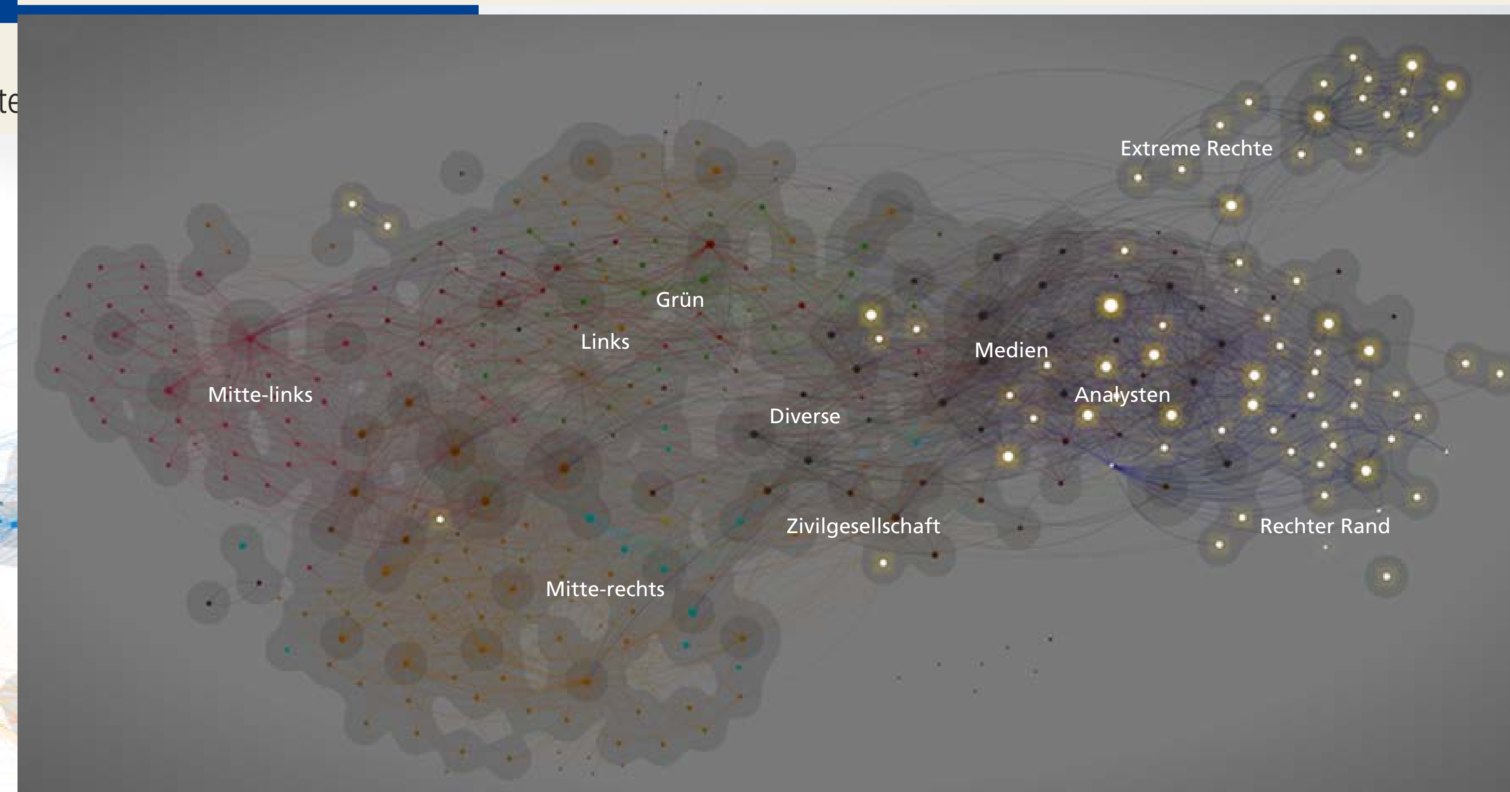

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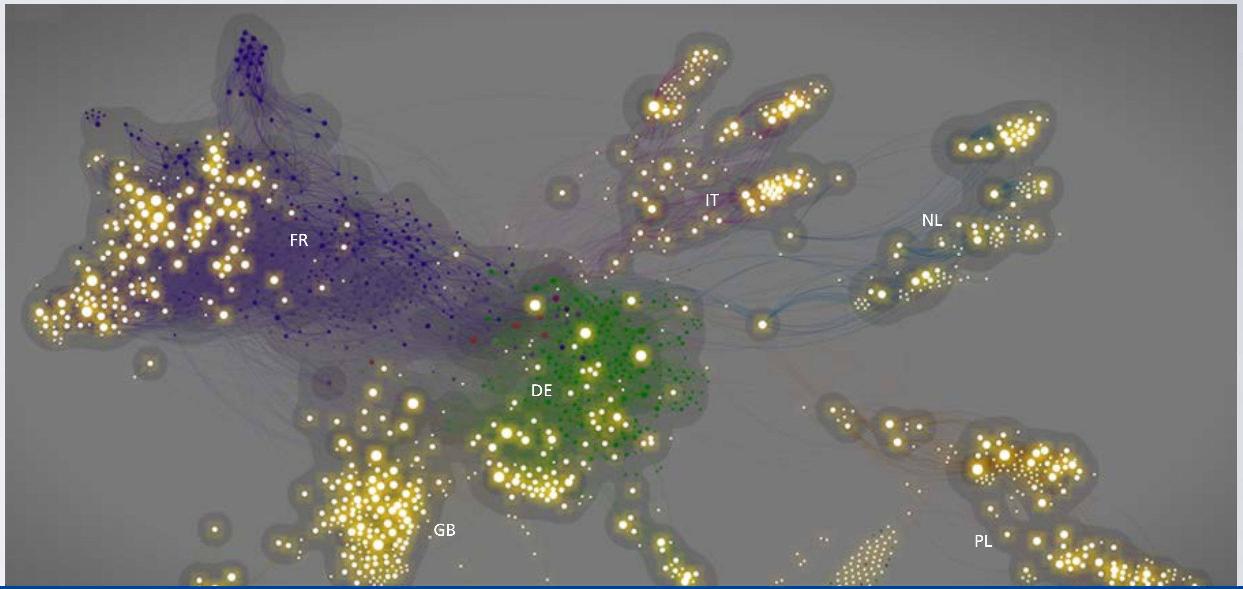

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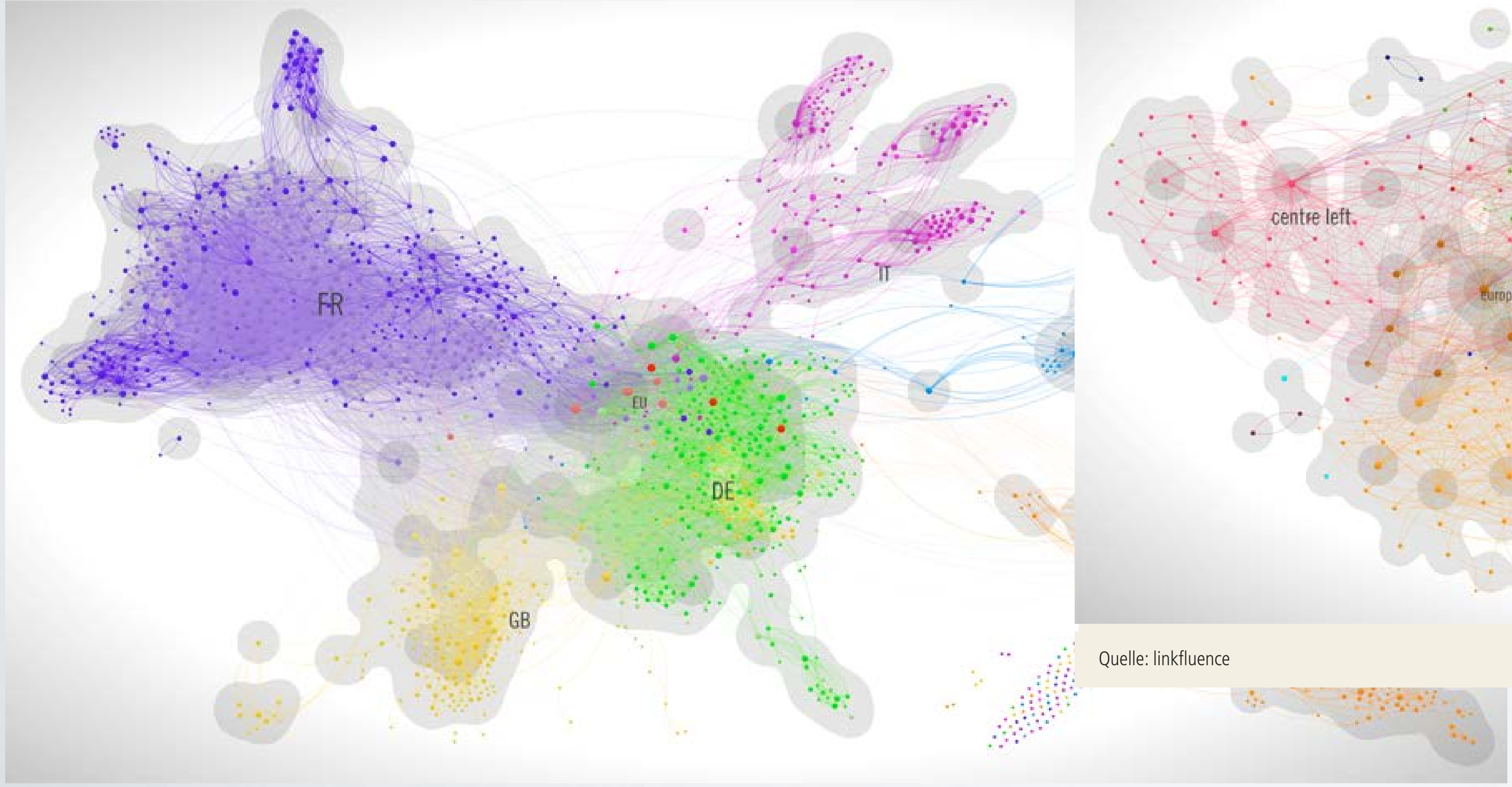
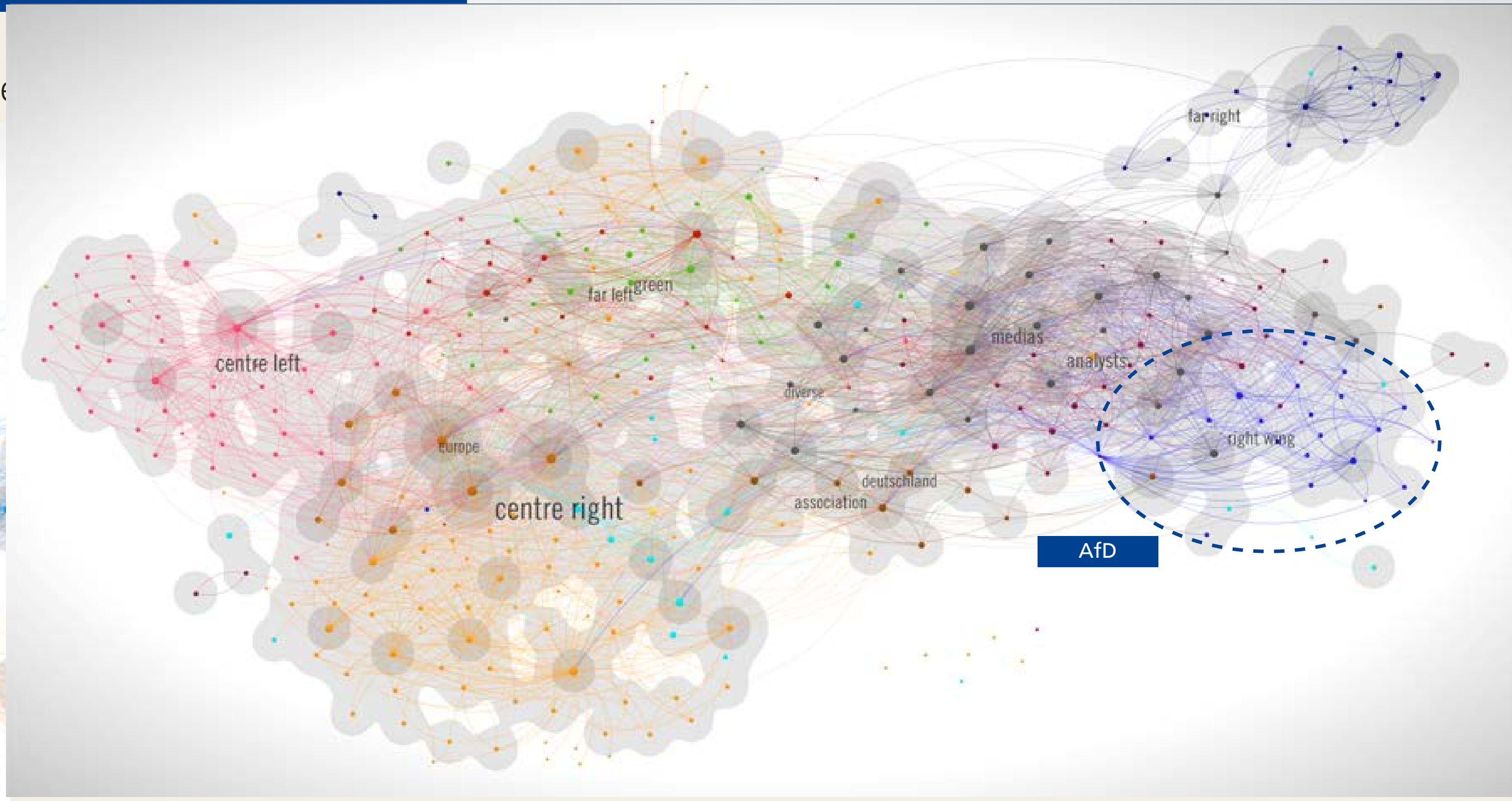


Quelle: linkfluence

Deutschland

349 Internetseiten mit pro- und antieuropäischen Inhalten



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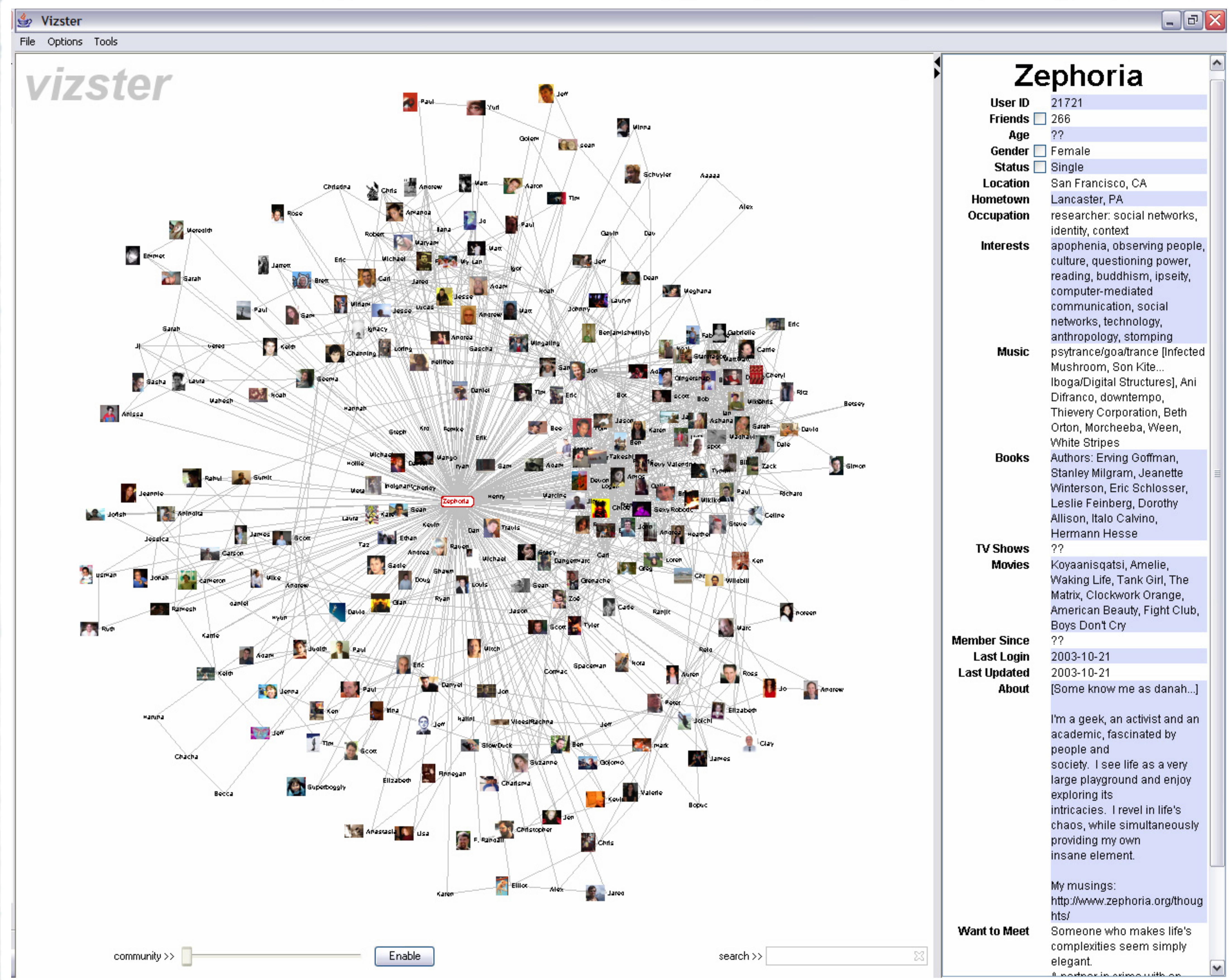
Heer, boyd, 2005

"Vizster: Visualizing Online Social Networks"



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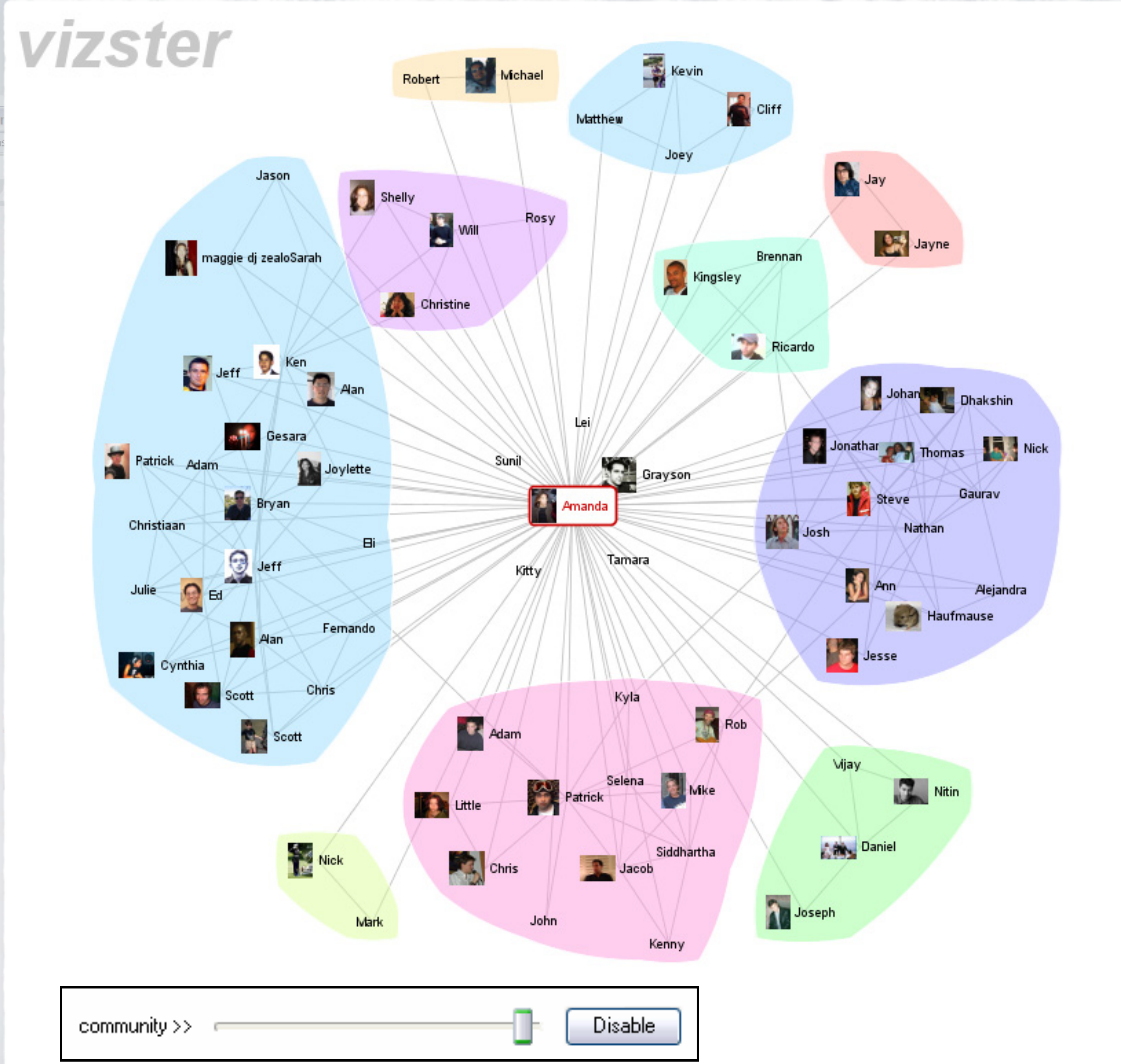


Figure 10: Community structure visualization using algorithmically determined optimum.

Heer, boyd, 2005

"Vizster: Visualizing Online Social Networks"

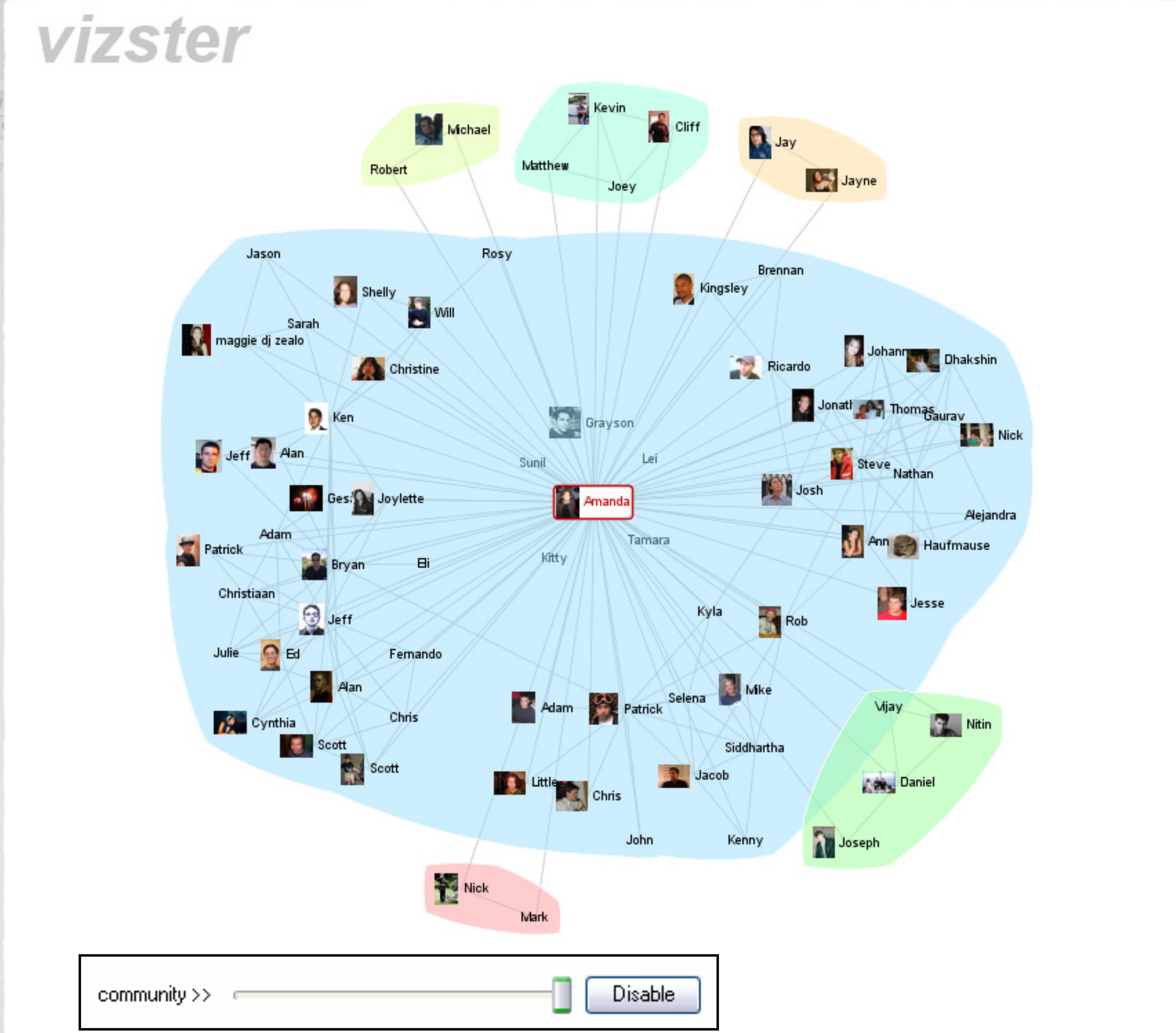
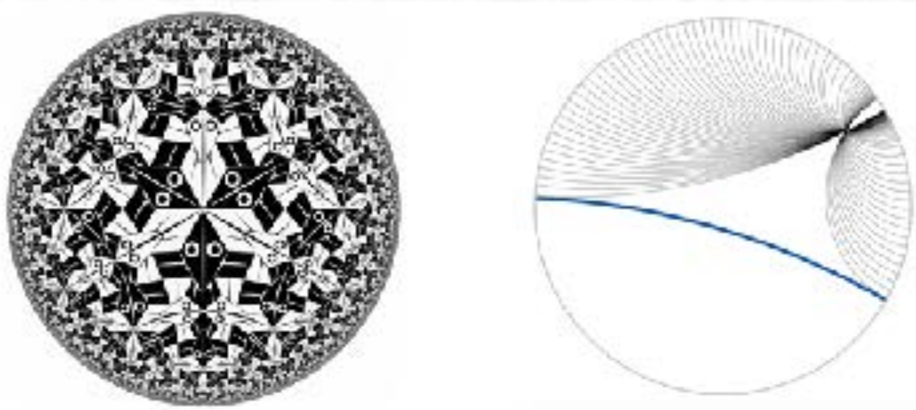


Figure 11: Community structure visualization after the community slider has been dragged to the right.

HYPERBOLIC EMBEDDINGS

Chamberlain, Clouth, Deisenroth, 2017

"Neural Embeddings of Graphs in Hyperbolic Space"

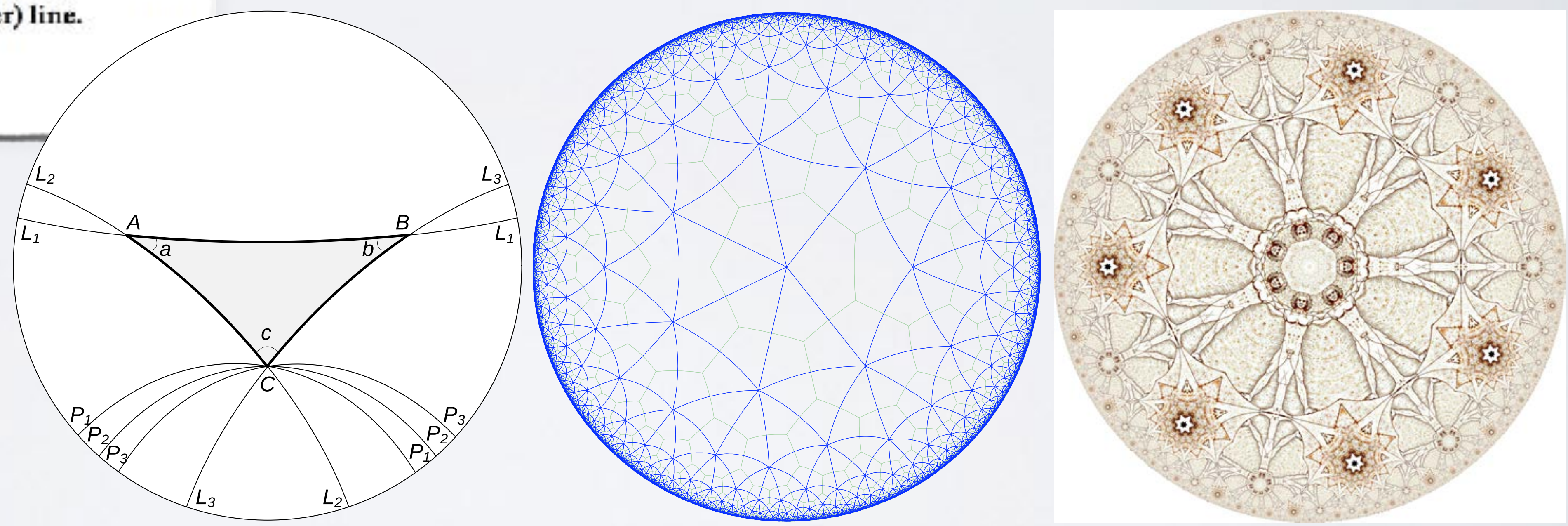


(a) "Circle Limit 1" by M.C. Escher illustrates the Poincaré disc model of hyperbolic space. Each tile is of constant area in hyperbolic space, but vanishes in Euclidean space at the boundary.

(b) A set of straight lines in the Poincare disk that all pass through a given point and are all parallel to the blue (thicker) line.

Krioukov, Papadopoulos, Kitsak, Vahdat, Boguñá, 2010

"Hyperbolic Geometry of Complex Networks"



(a) (b) (c)

FIG. 1: (Color online) Poincaré disk model. In **(a)**, $L_{1,2,3}$ and $P_{1,2,3}$ are examples of hyperbolic lines. Lines $L_{1,2,3}$ intersect to form triangle ABC. The sum of its angles $a + b + c < \pi$. As opposed to Euclidean geometry, there are infinitely many lines (examples are $P_{1,2,3}$) that are parallel to line L_1 and go through a point C that does not belong to L_1. In **(b)**, a $\{7, 3\}$-tessellation of the hyperbolic plane by equilateral triangles, and the dual $\{3, 7\}$-tessellation by regular heptagons are shown. All triangles and heptagons are of the same hyperbolic size but the size of their Euclidean representations exponentially decreases as a function of the distance from the center, while their number exponentially increases. In **(c)**, the exponentially increasing number of men illustrates the exponential expansion of hyperbolic space. The `Poincaré` tool [1] is used to construct a $\{7, 7\}$-tessellation of the hyperbolic plane, rendering a fragment of *The Vitruvian Man* by Leonardo da Vinci.

HYPERBOLIC EMBEDDINGS

Chamberlain, Clouth, Deisenroth, 2017

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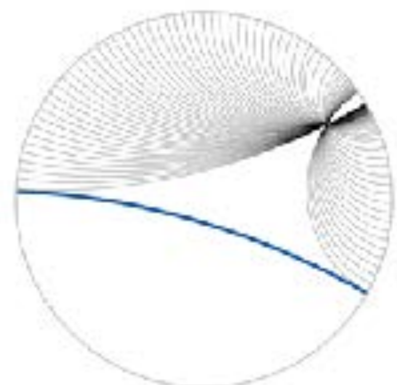

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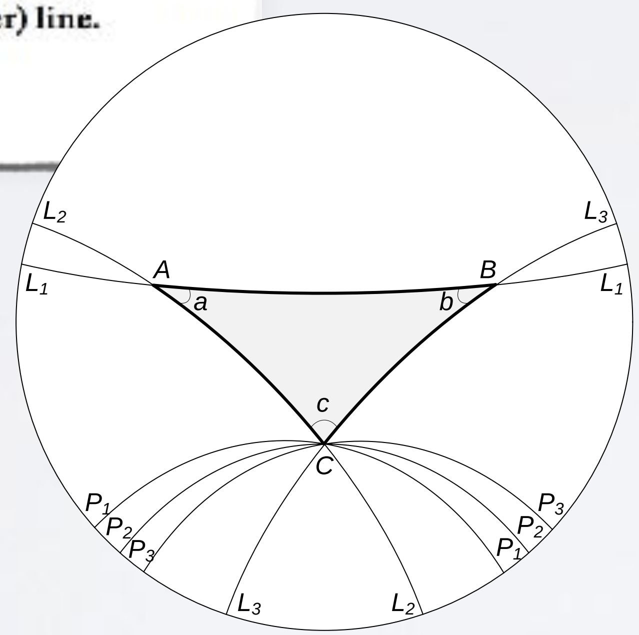
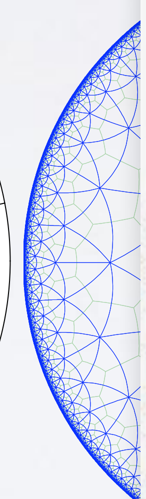
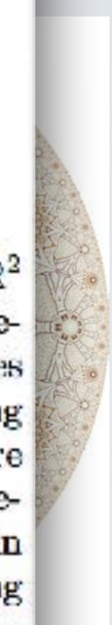


(a)





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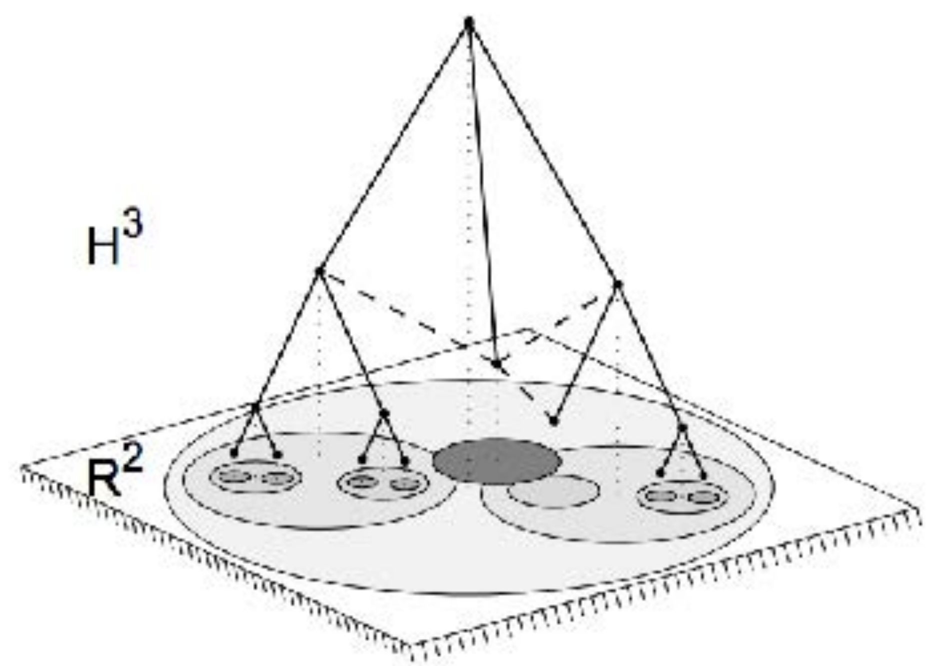
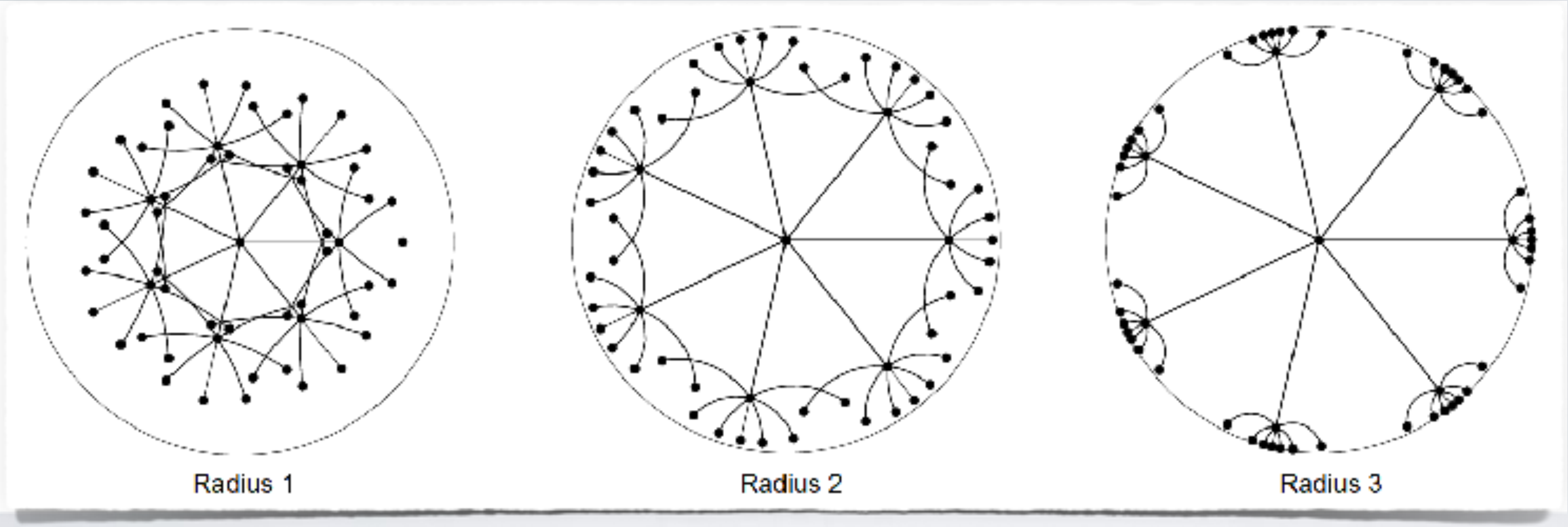


FIG. 2: Mapping between disks in the Euclidean plane $\mathbb{R}^2$ and points in the Poincaré half-space model of the three-dimensional hyperbolic space $\mathbb{H}^3$ [21]. The x, y-coordinates of disks in $\mathbb{R}^2$ are the x, y-coordinates of the corresponding points in $\mathbb{H}^3$. The z-coordinates of these points in $\mathbb{H}^3$ are the radii of the corresponding disks. This mapping represents the tree-like hierarchy among the disks. Two points in $\mathbb{H}^3$ are connected by a solid link if one of the corresponding disks is the minimum-size disk that fully contains the other disk. This hierarchy is not perfect; thus, the tree structure is approximate. The darkest disk in the middle partially overlaps with three other disks at different levels of the hierarchy. Two points in $\mathbb{H}^3$ are connected by a dashed link if the corresponding disks partially overlap. These links add cycles to the tree. The shown structure is thus not strictly a tree, but it is hyperbolic [27].

Krioukov, Papadopoulos, Kitsak, Vahdat, Boguñá, 2010

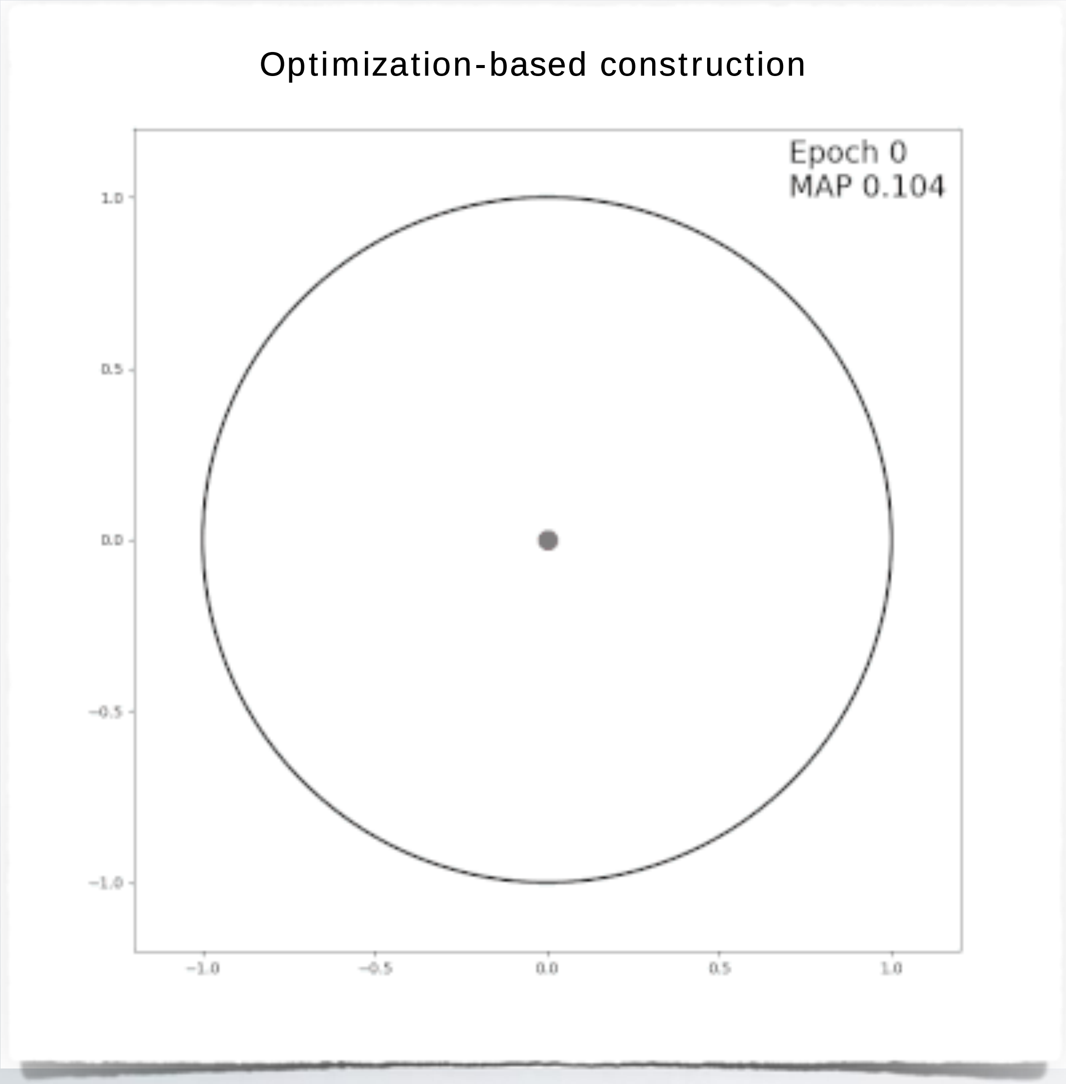
"Hyperbolic Geometry of Complex Networks"

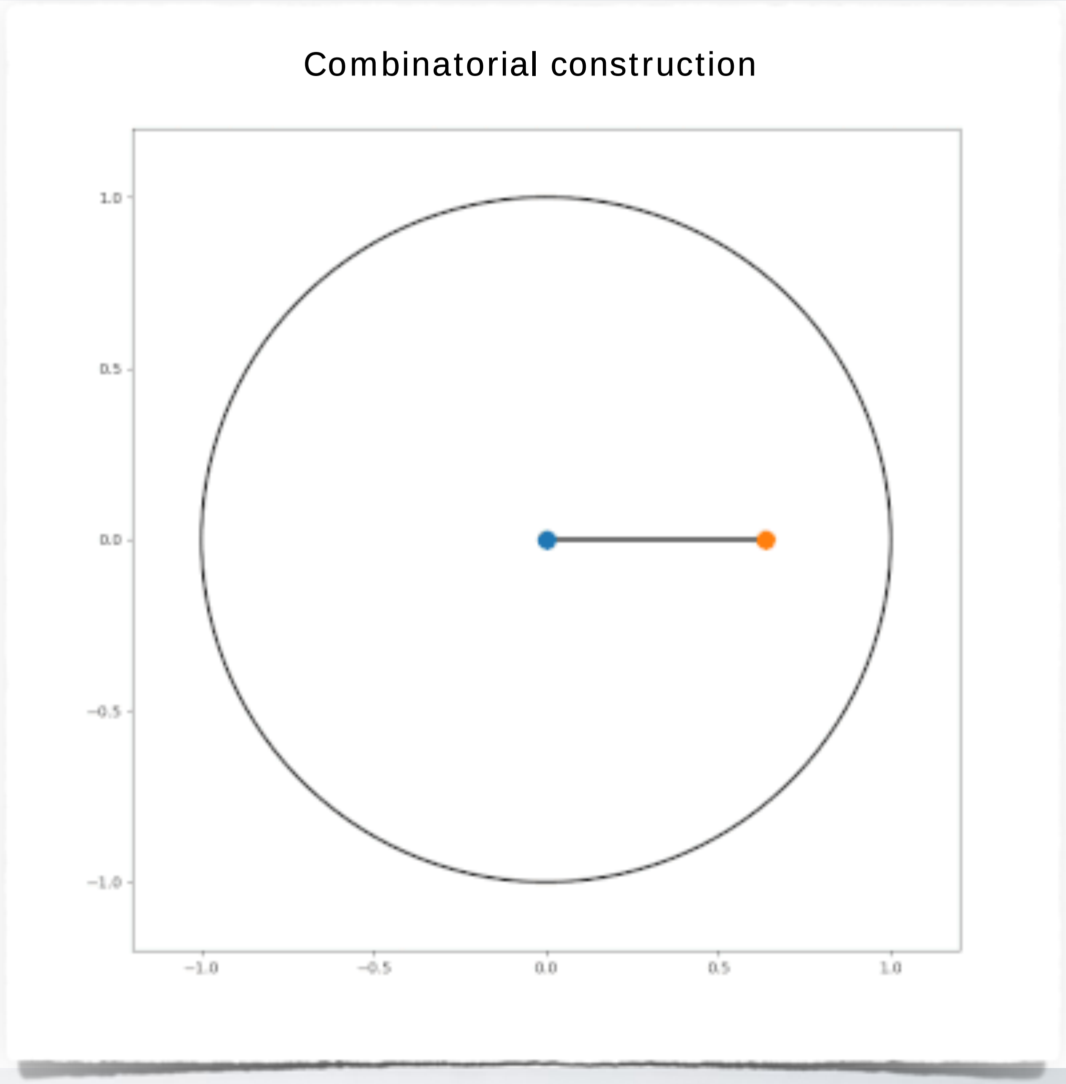
HYPERBOLIC EMBEDDINGS



De Sa, Gu, Ré, Sala, 2018

"Hyperbolic Embeddings with a Hopefully Right Amount of Hyperbole"





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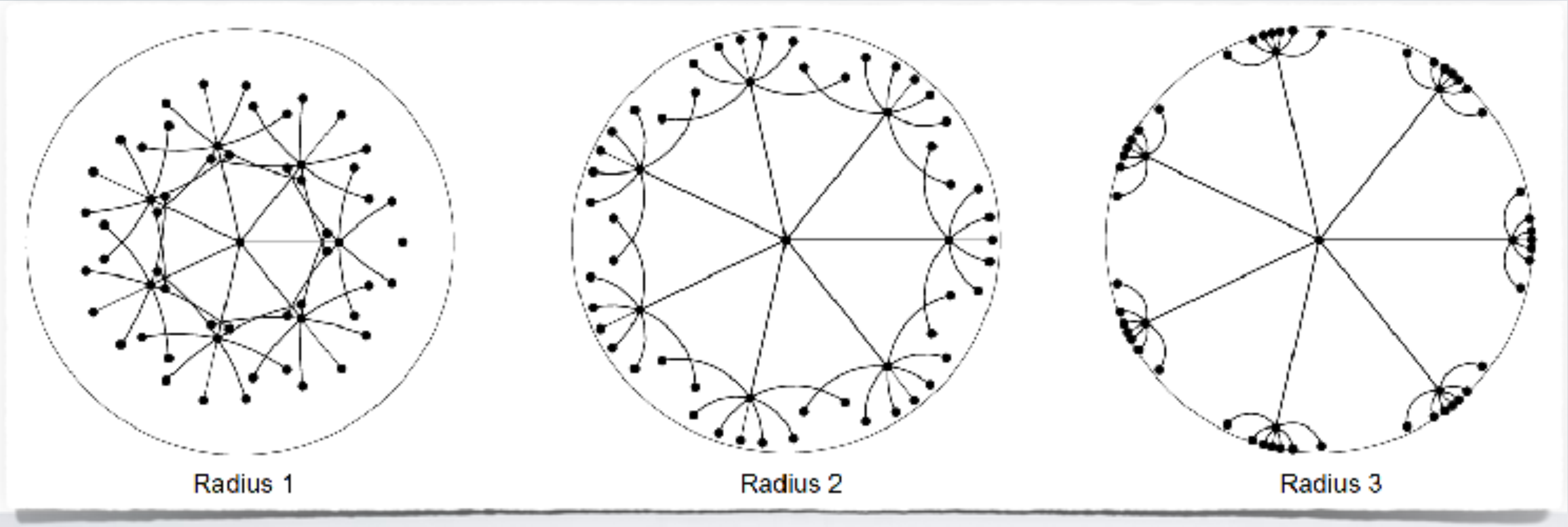

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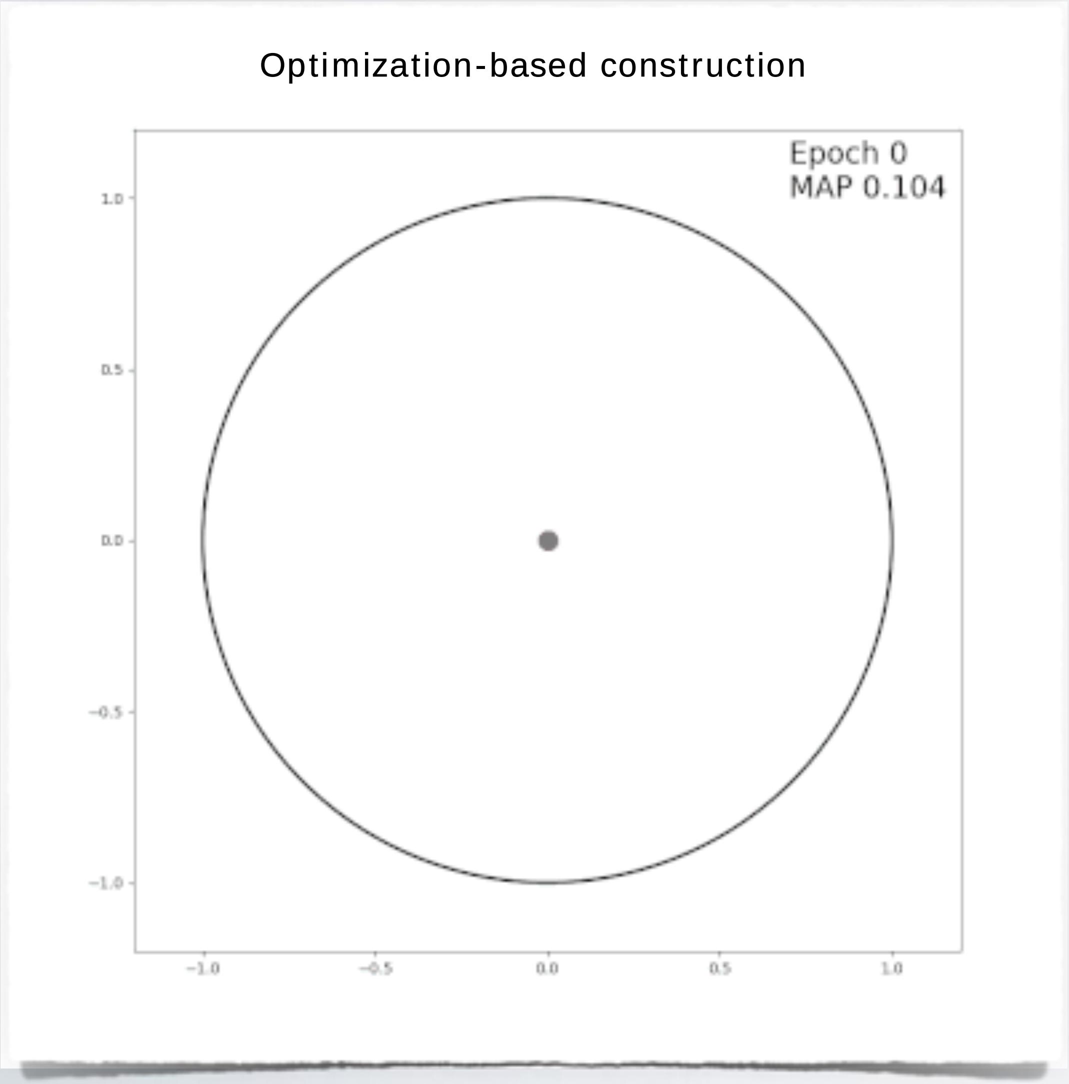
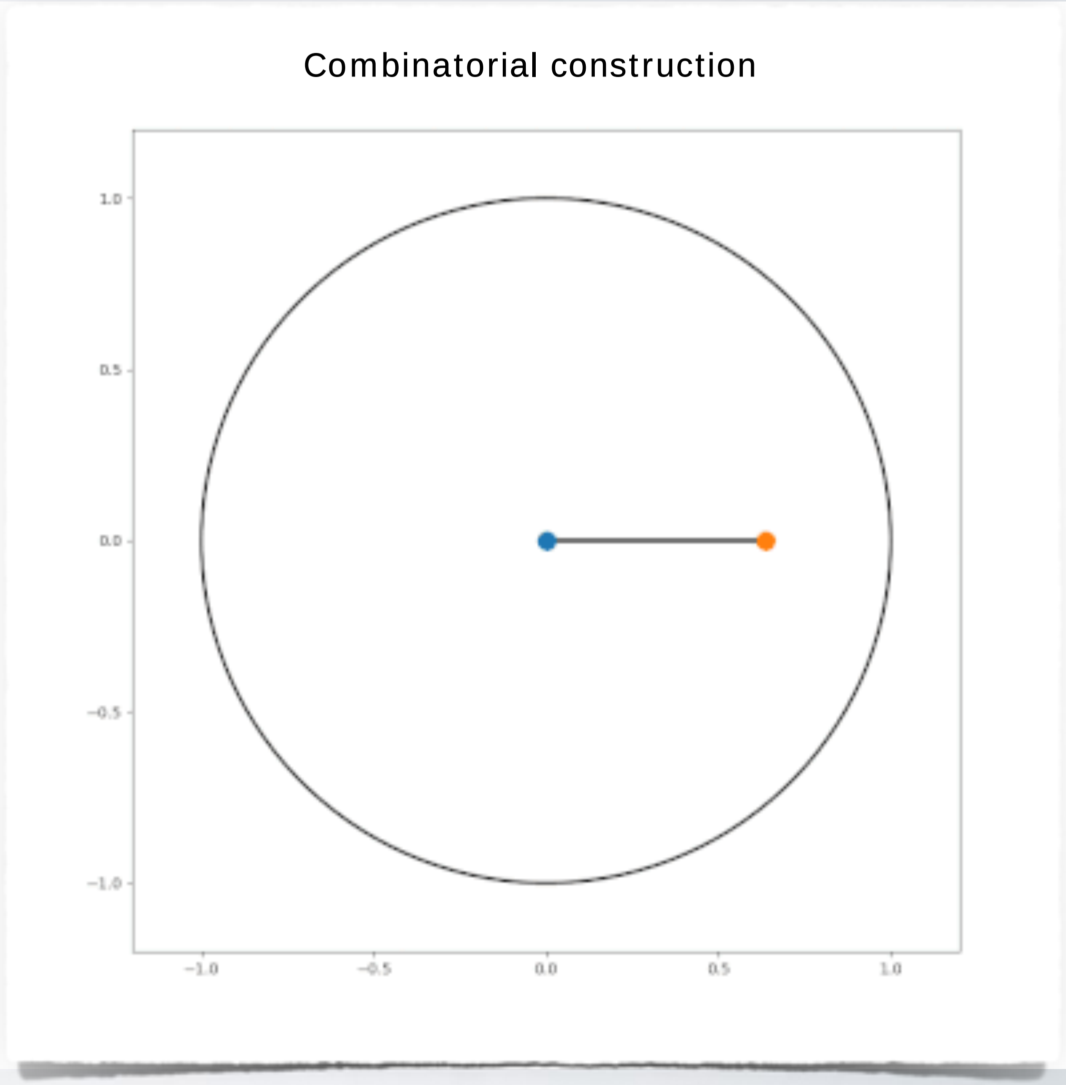
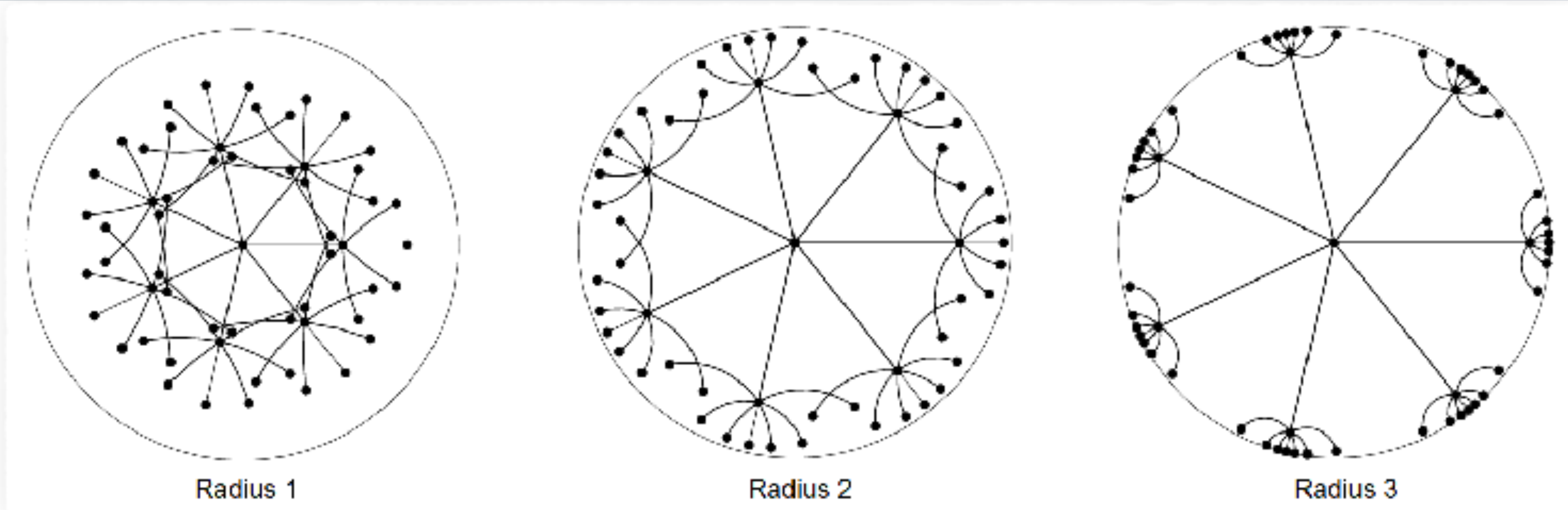


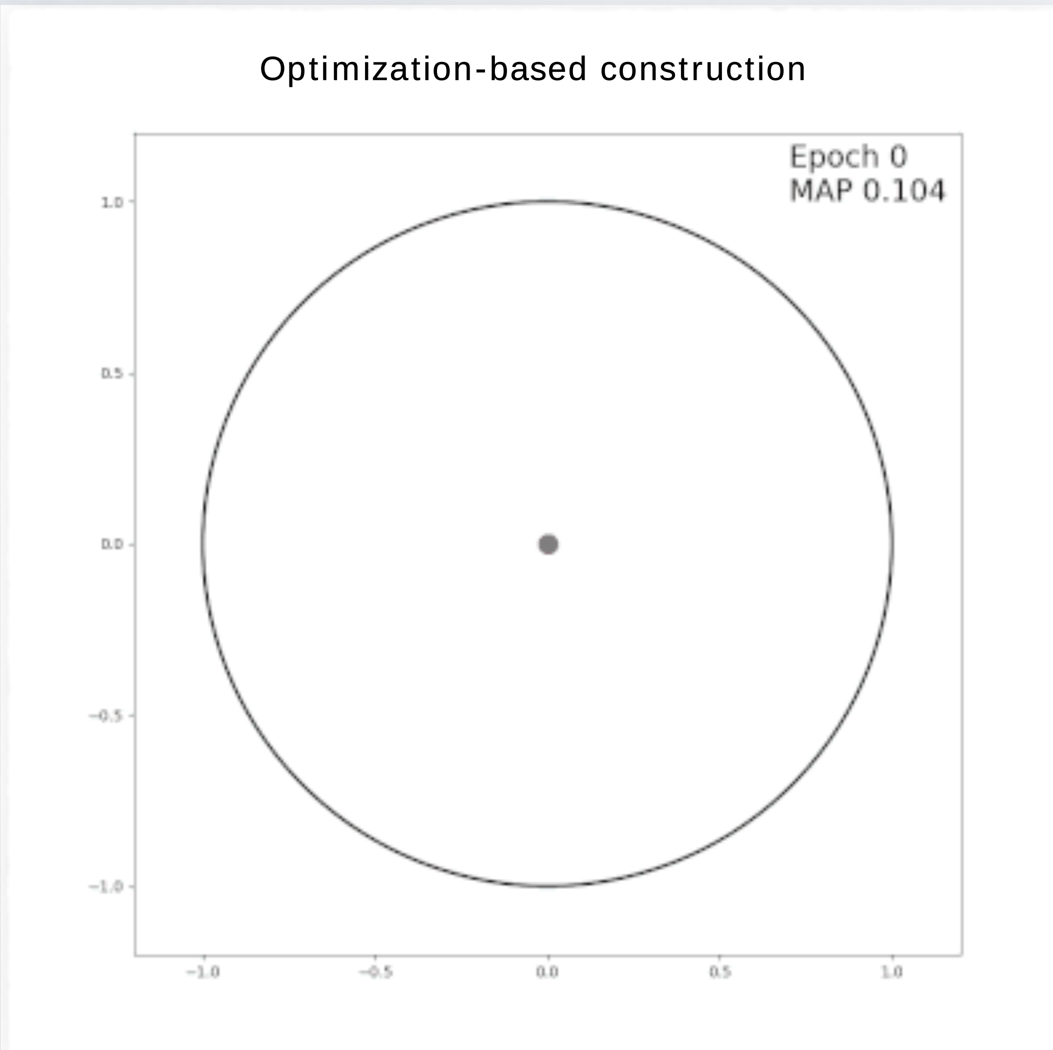


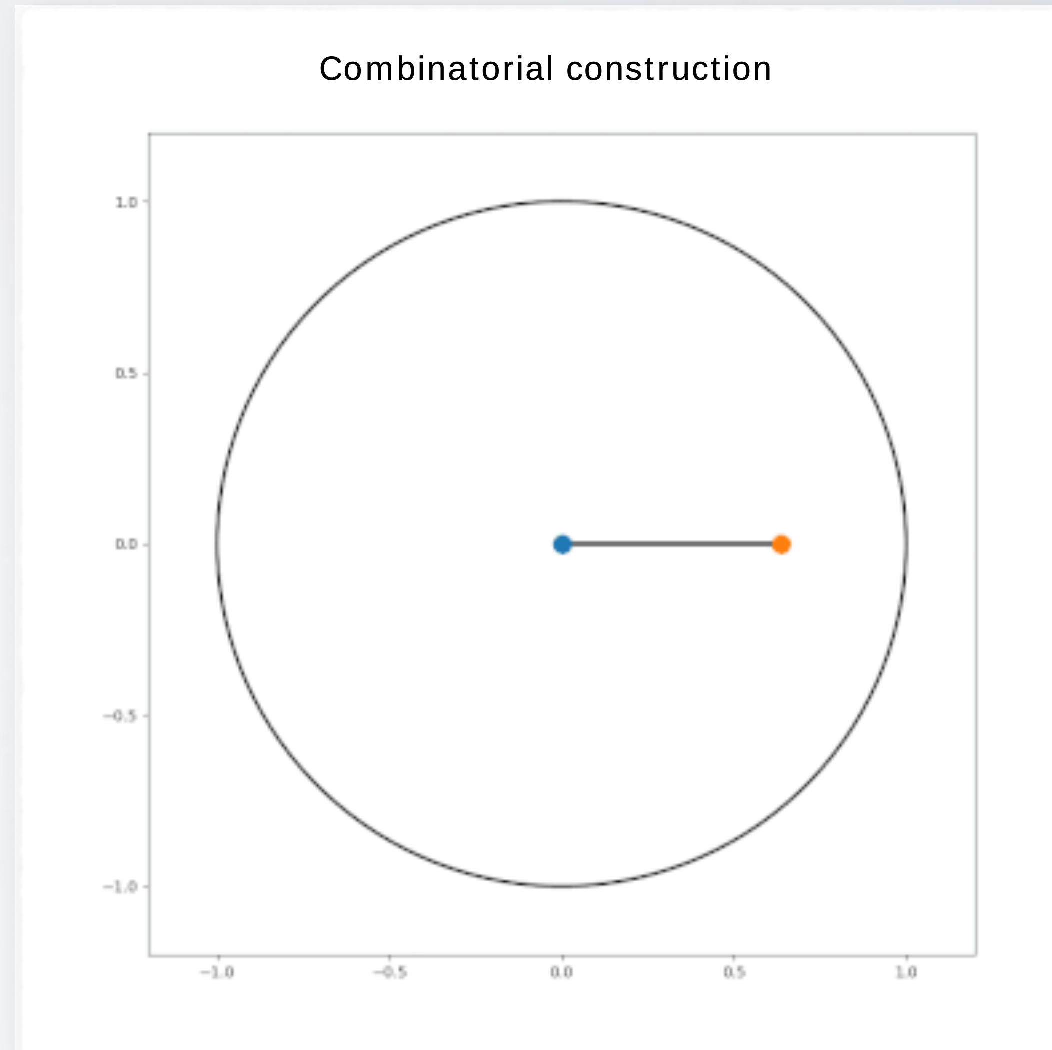
HYPERBOLIC EMBEDDINGS



De Sa, Gu, Ré, Sala, 2018

"Hyperbolic Embeddings with a Hopefully Right Amount of Hyperbole"

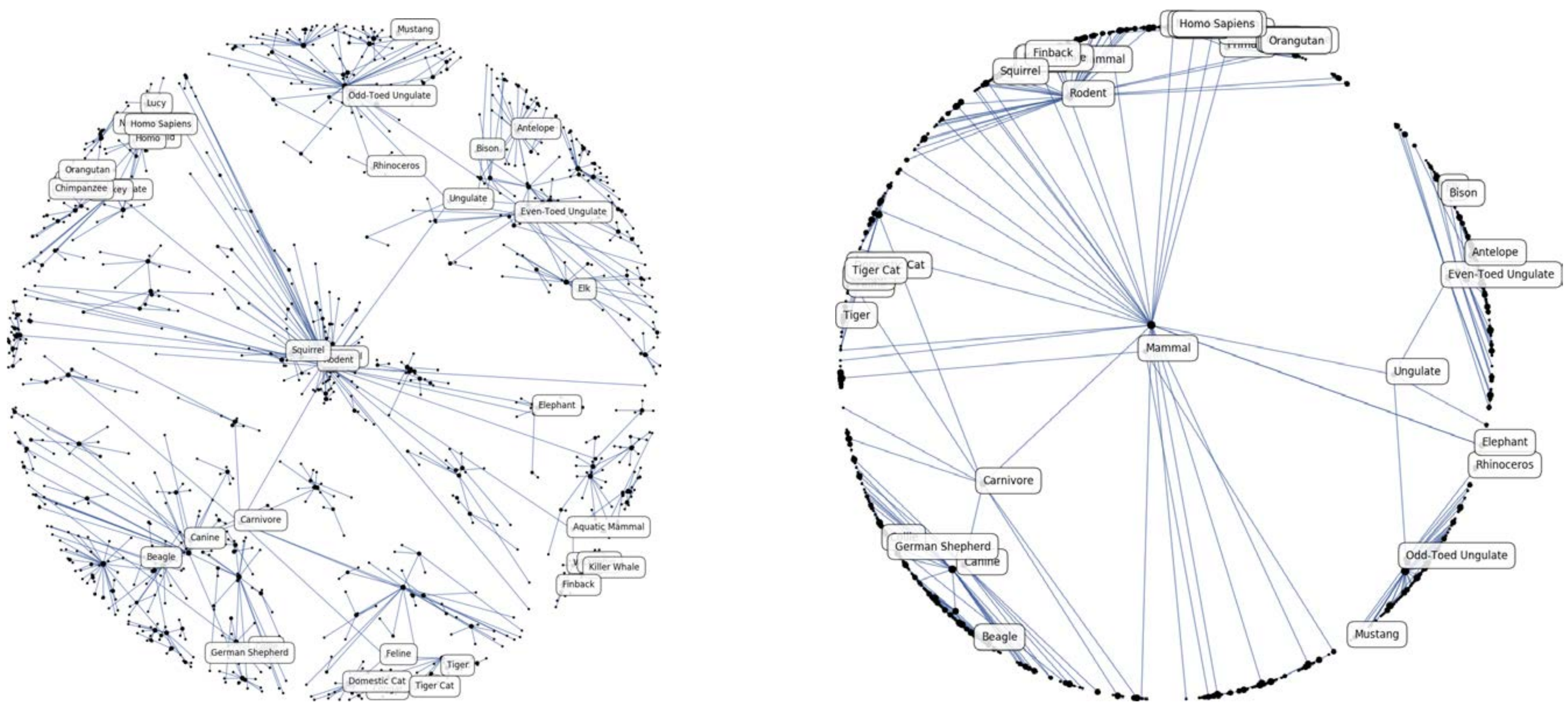




HYPERBOLIC EMBEDDINGS

Nickel, Kiela, 2017

"Poincaré Embeddings for Learning Hierarchical Representations"



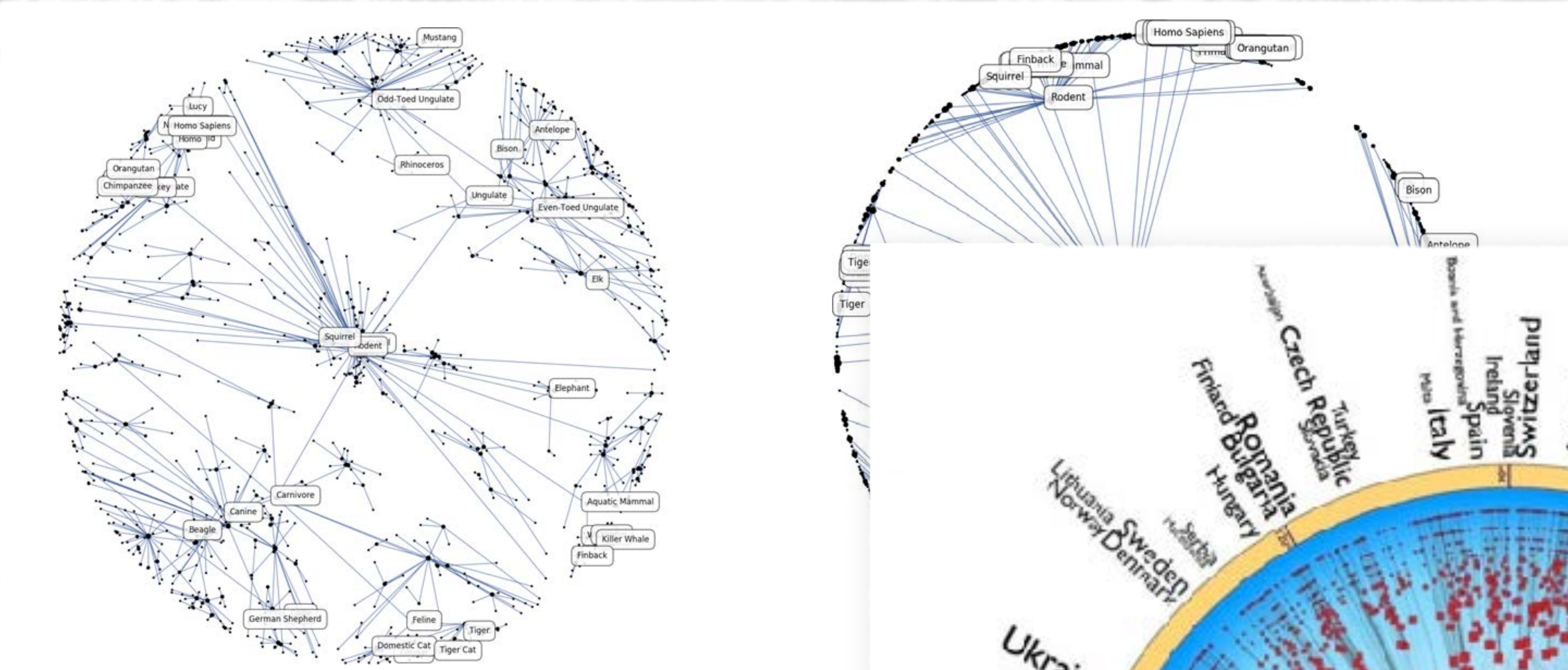
(a) Intermediate embedding after 20 epochs (b) Embedding after convergence

Figure 2: Two-dimensional Poincaré embeddings of transitive closure of the WORDNET mammals subtree. Ground-truth `is-a` relations of the original WORDNET tree are indicated via blue edges. A Poincaré embedding with $d = 5$ achieves mean rank 1.26 and MAP 0.927 on this subtree.

HYPERBOLIC EMBEDDINGS

Nickel, Kiela, 2017

"Poincaré Embeddings for Learning Hierarchical Representations"



(a) Intermediate embedding after 20 epochs

Figure 2: Two-dimensional Poincaré embeddings of tra
subtree. Ground-truth `is-a` relations of the original Wo
Poincaré embedding with $d = 5$ achieves mean rank 1.2

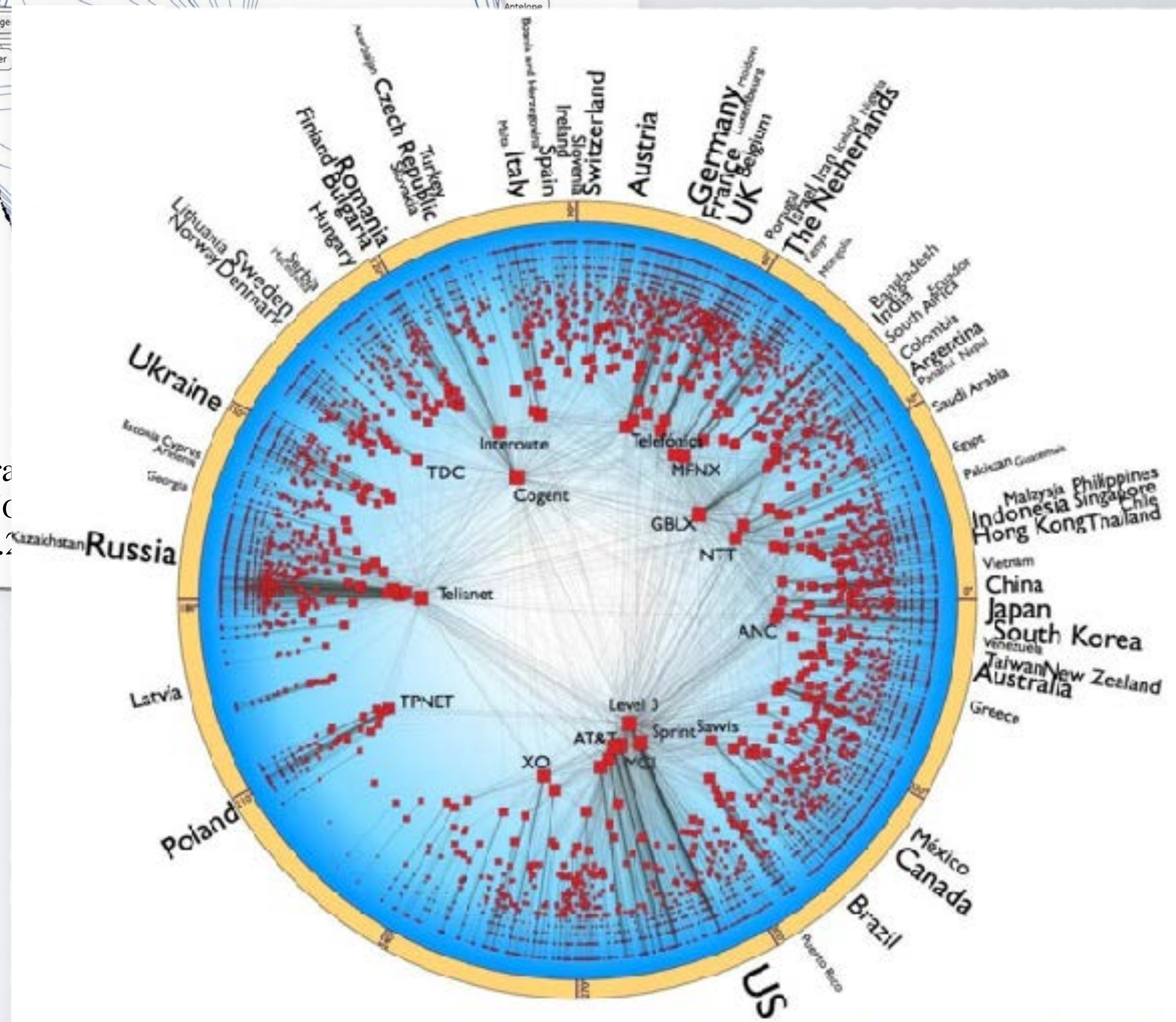
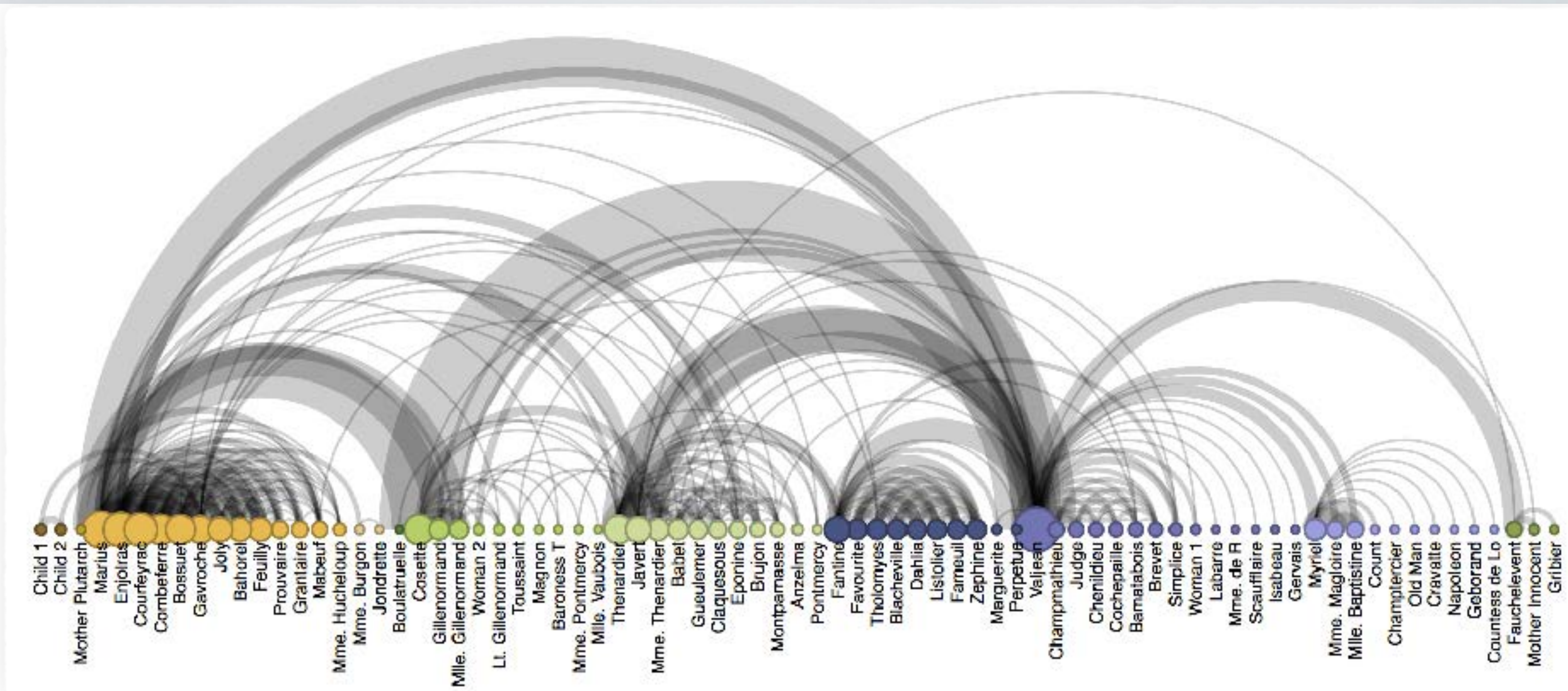


Image credit Boguna, Krioukov, Papadopolous

ARC DIAGRAMS

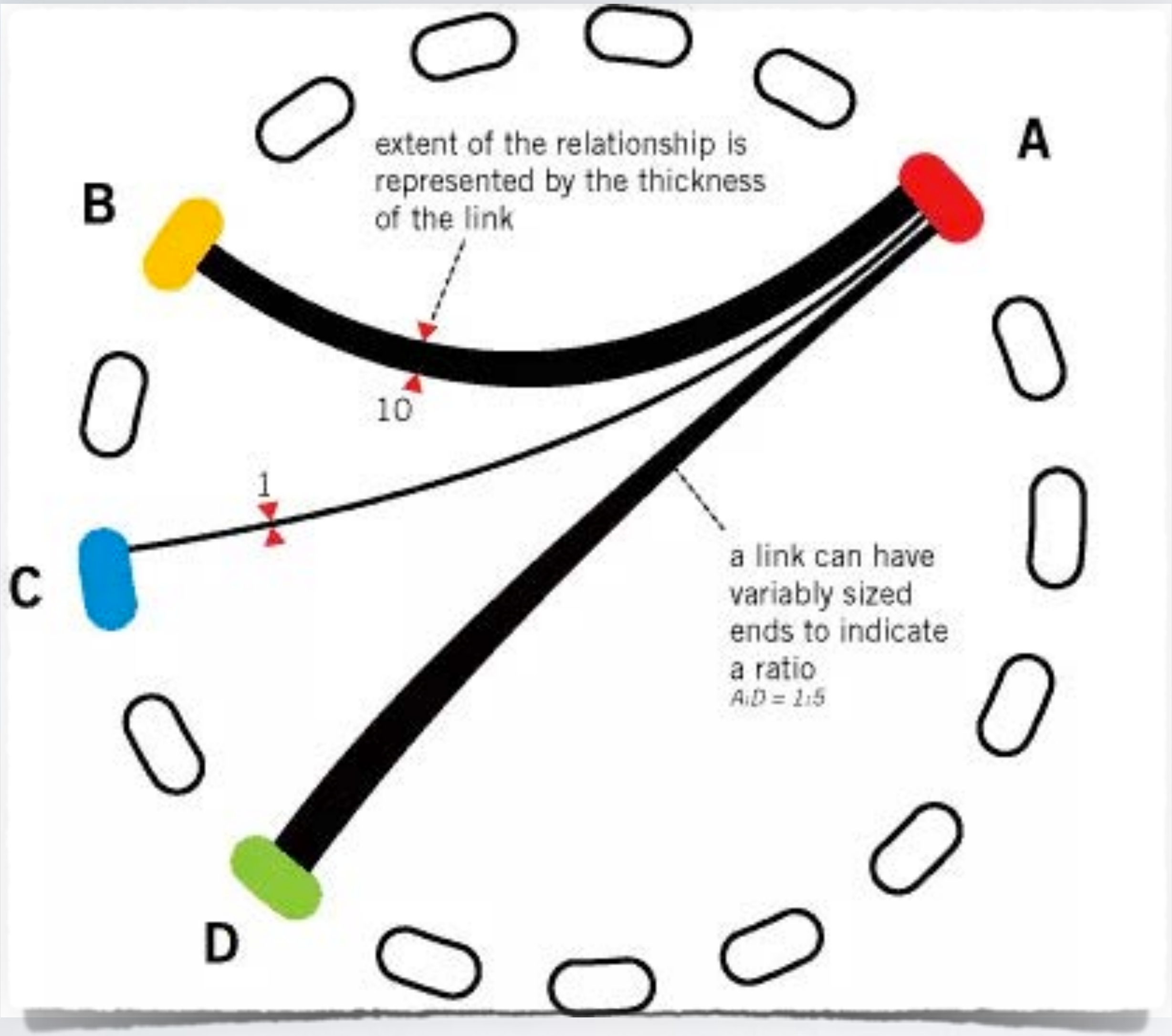


"Character co-occurrence in the chapters of Victor Hugo's classic novel *Les Misérables*.

Node colors depict cluster memberships computed by a community-detection algorithm"

Protovis

CIRCULAR LAYOUTS / CHORD DIAGRAMS

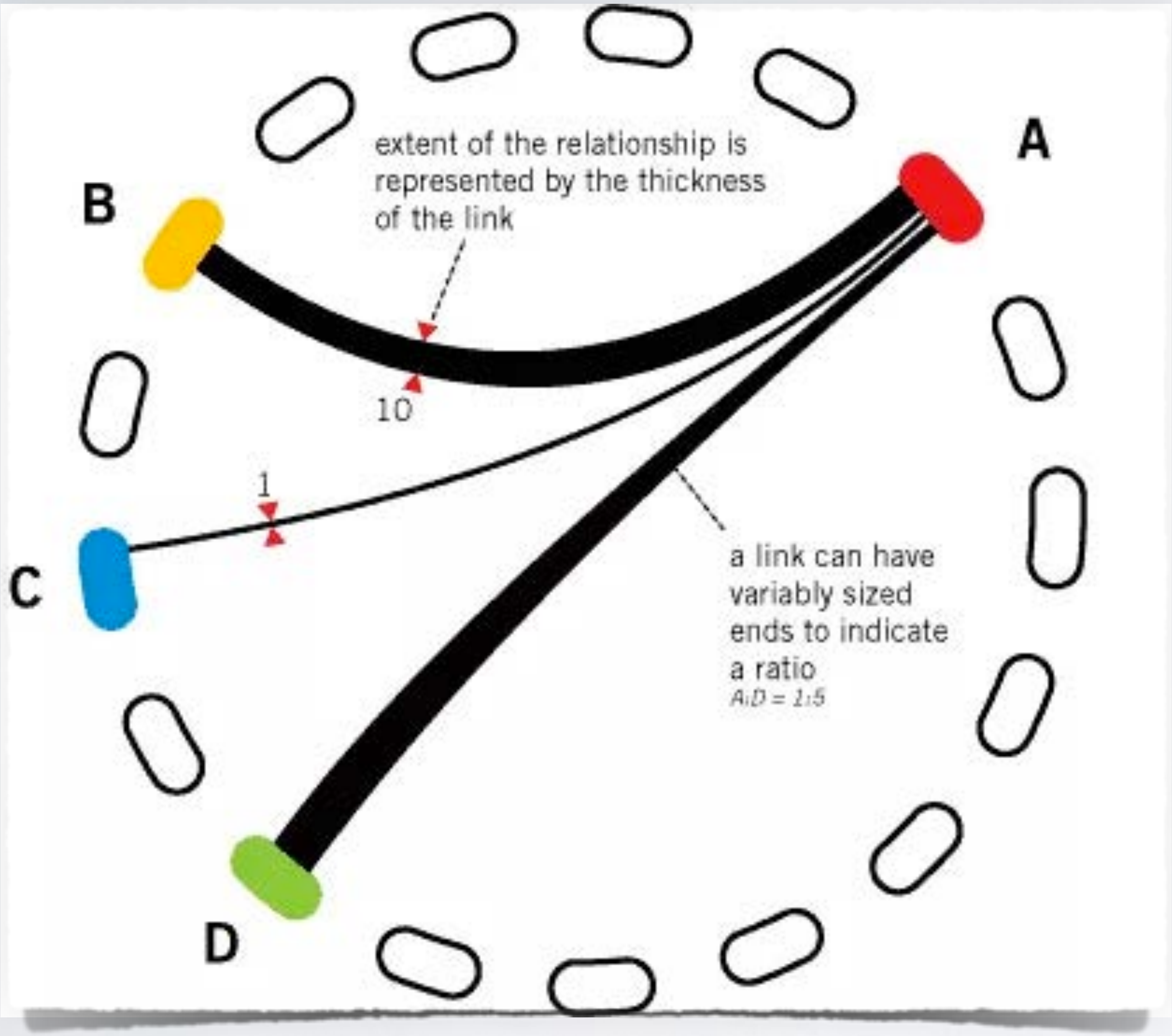


Krzywinski, 2009

"Visual Representation of Tabular Information – How to Fix the Uncommunicative Table"

e.g. chordDiagram() function of R package "circlize"

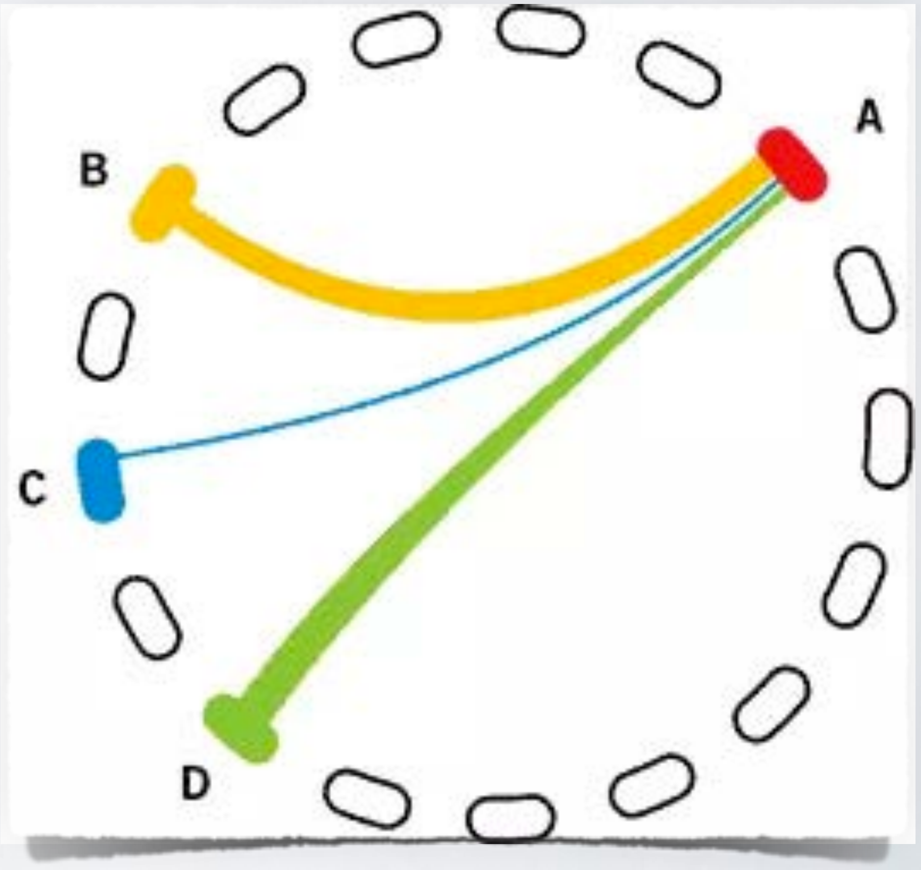
CIRCULAR LAYOUTS / CHORD DIAGRAMS



Krzywinski, 2009

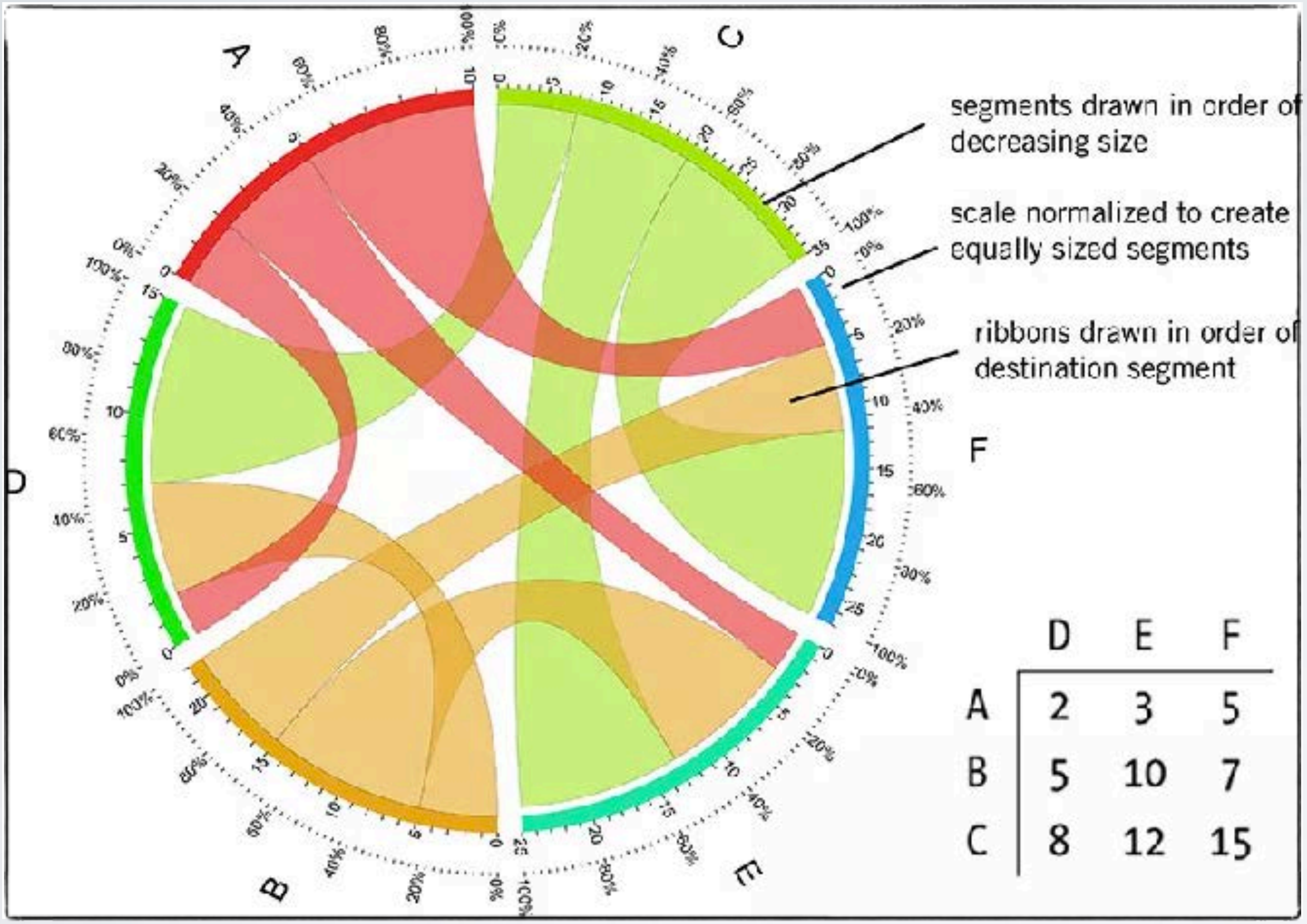
"Visual Representation of Tabular Information – How to Fix the Uncommunicative Table"

using colors to
indicate directionality

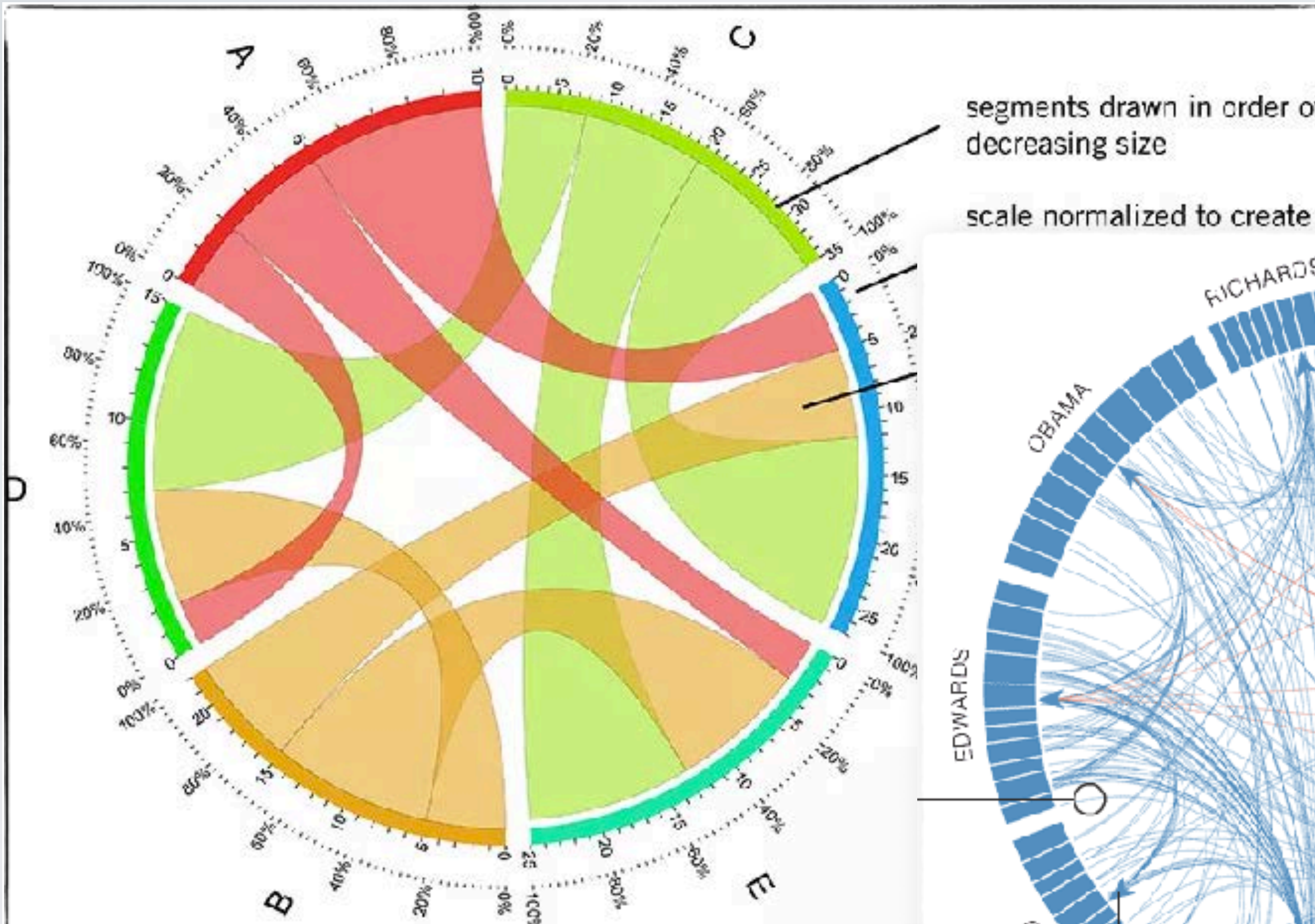


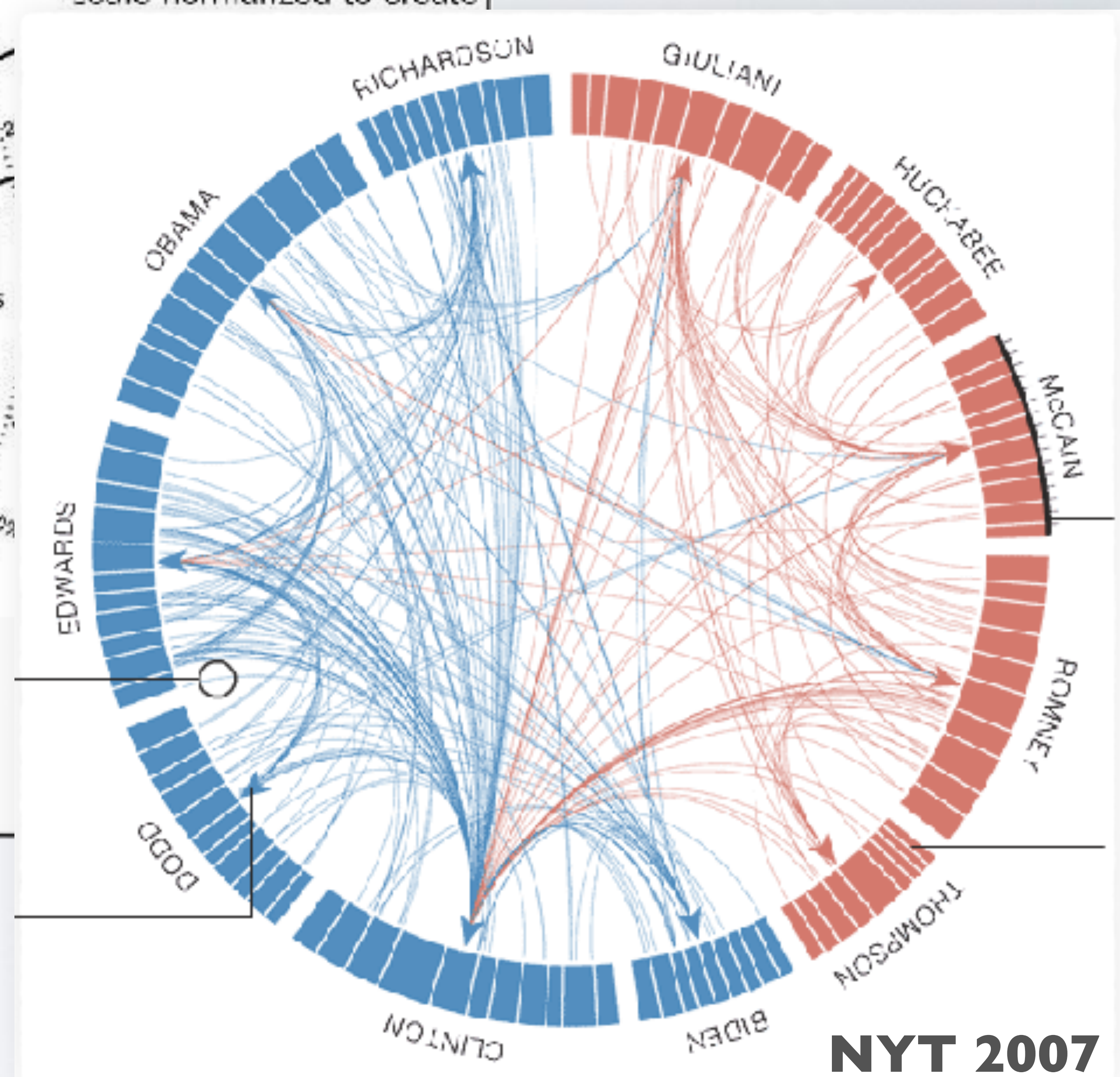

```
e.g. chordDiagram() function
  of R package "circlize"
```

CIRCULAR LAYOUTS / CHORD DIAGRAMS



CIRCULAR LAYOUTS / CHORD DIAGRAMS





HIERARCHICAL EDGE BUNDLES

Holten, 2006

"Hierarchical Edge Bundles: Visualization of Adjacency Relations in Hierarchical Data"

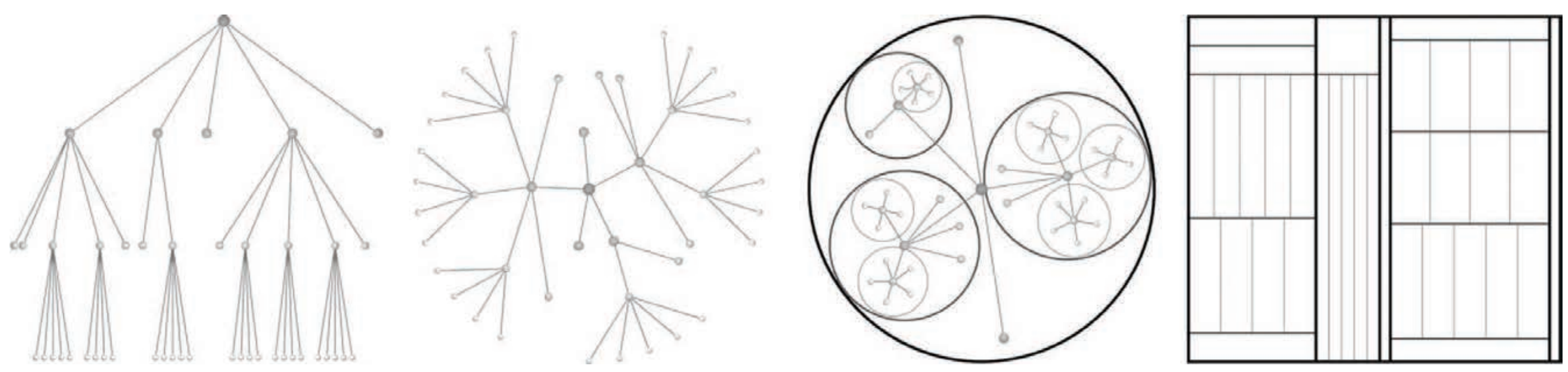


Fig. 1. Common tree visualization techniques. From left-to-right: rooted tree, radial tree, balloon tree, and treemap layout.

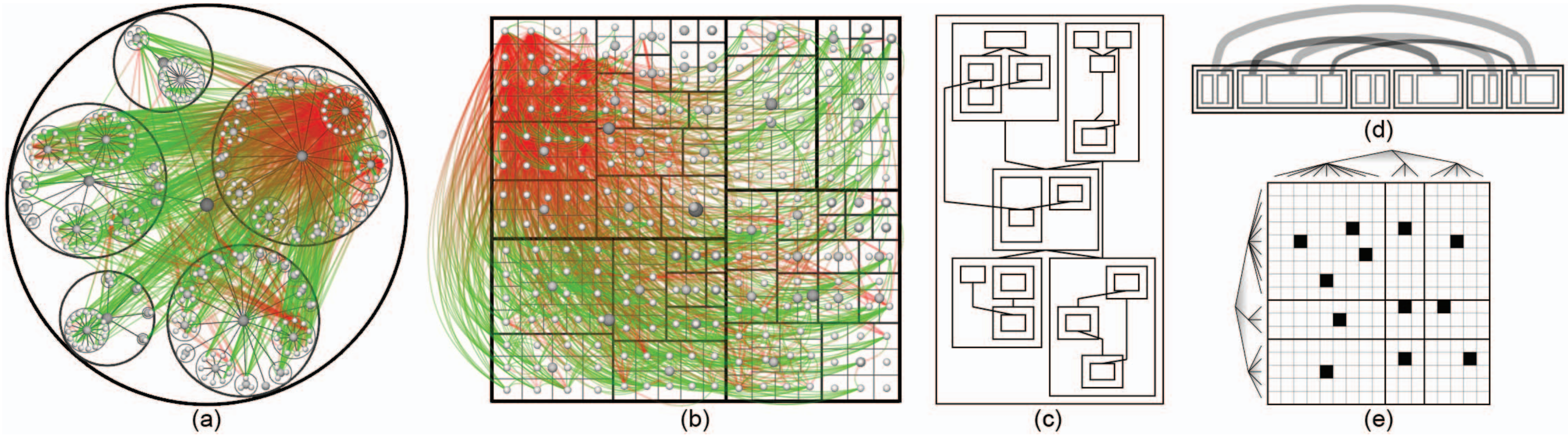


Fig. 2. Displaying adjacency relations using existing methods. A call graph visualized on top of the associated source code tree using (a) color-coded directed straight edges and (b) curved link edges (caller = green, callee = red); (c) standard compound digraph drawing; (d) ArcTrees for visualizing relations in hierarchical data; (e) a matrix view for showing relations between entities. (a) and (b) suffer from visual clutter, (c) and (d) furthermore suffer from the problem that they do not scale well for compound graphs containing a large hierarchy, and (e) is less intuitive than node-link- and enclosure-based representations.

HIERARCHICAL EDGE BUNDLES

Holten, 2006

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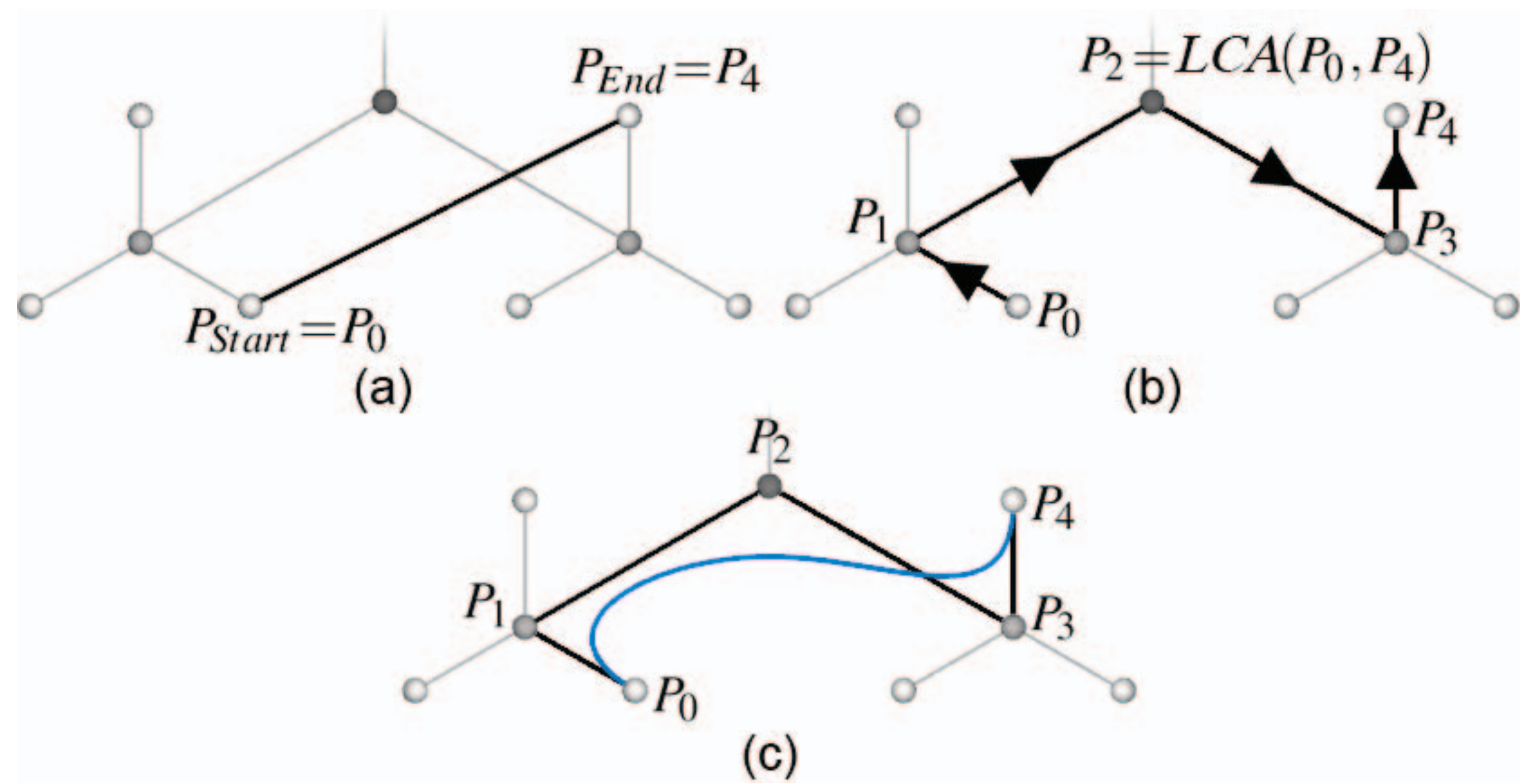

Fig. 3. Bundling adjacency edges by using the available hierarchy. (a) Straight line connection between P_0 and P_4; (b) path along the hierarchy between P_0 and P_4; (c) spline curve depicting the connection between P_0 and P_4 by using the path from (b) as the control polygon.

HIERARCHICAL EDGE BUNDLES

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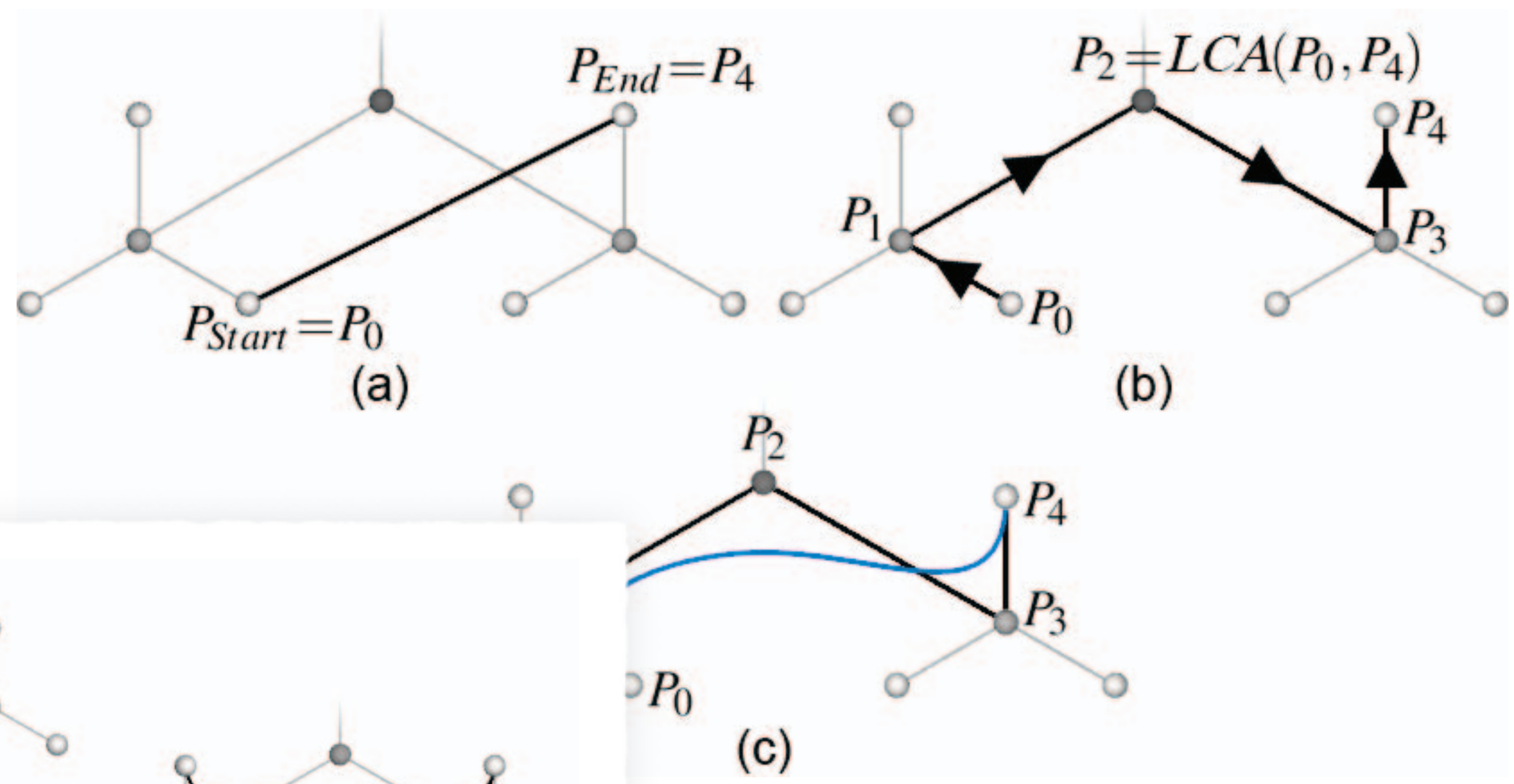

edges by using the available hierarchy. (a) een P_0 and P_4; (b) path along the hierarchy curve depicting the connection between om (b) as the control polygon.

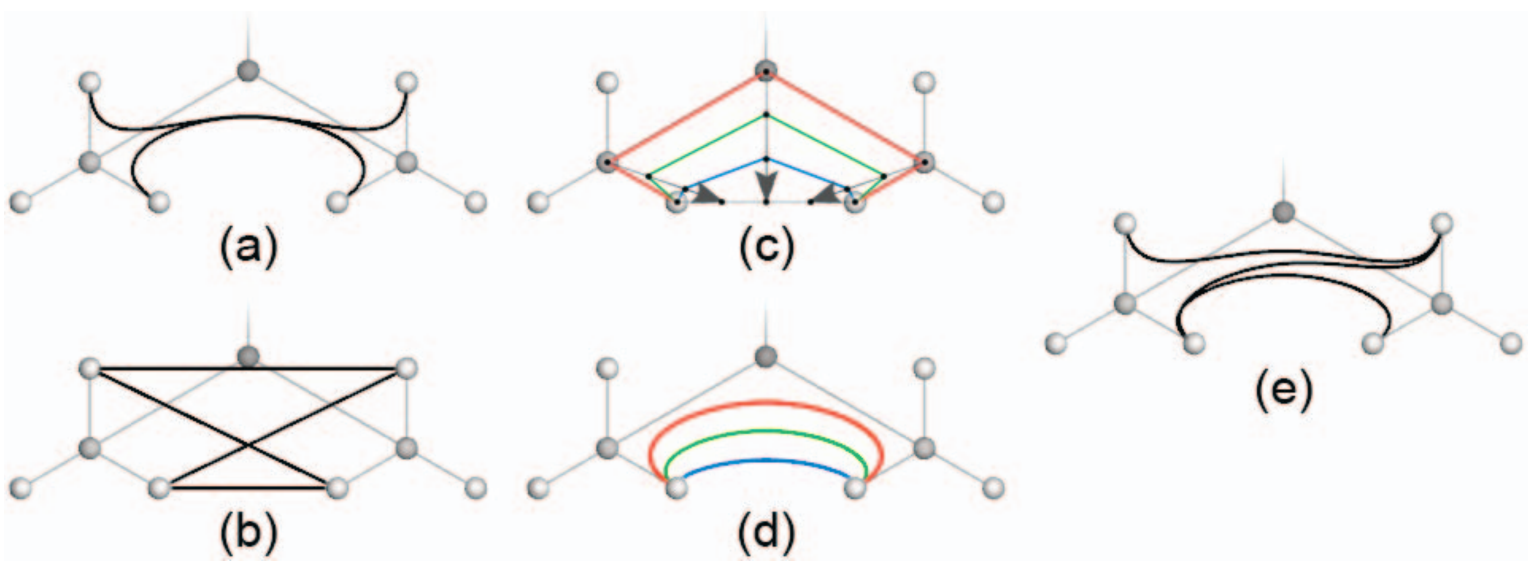

Fig. 4. Resolving bundling ambiguity. The bundle in (a) might contain each edge depicted in (b). (c) and (d) show how different values of β (red $= 1$, green $= \frac{2}{3}$, and blue $= \frac{1}{3}$) can be used to alter the shape of spline curves. As shown in (e), a fairly high bundling strength ($\beta = 0.8$) can be chosen to retain visual bundles while still resolving ambiguity.

HIERARCHICAL EDGE BUNDLES

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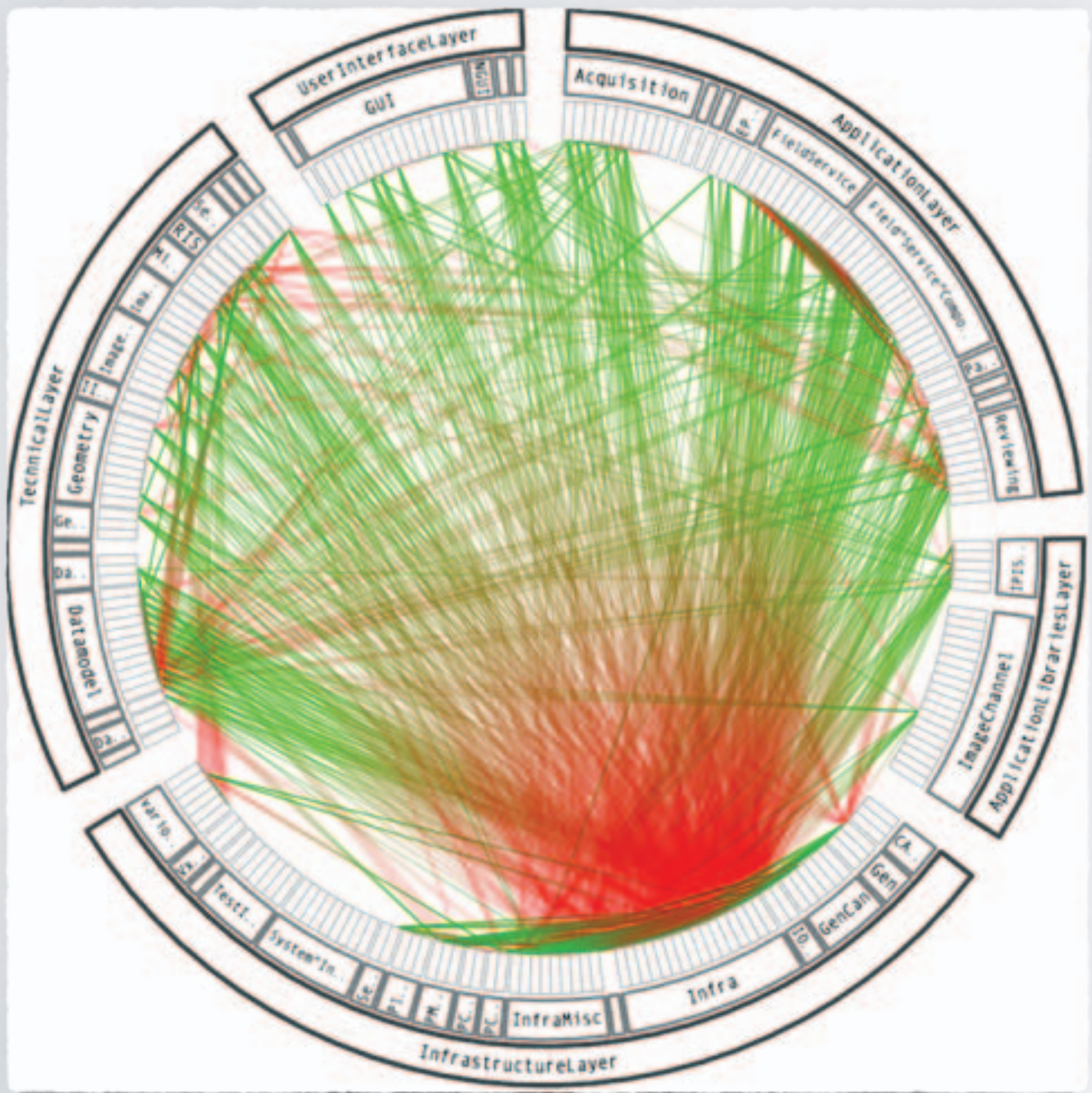
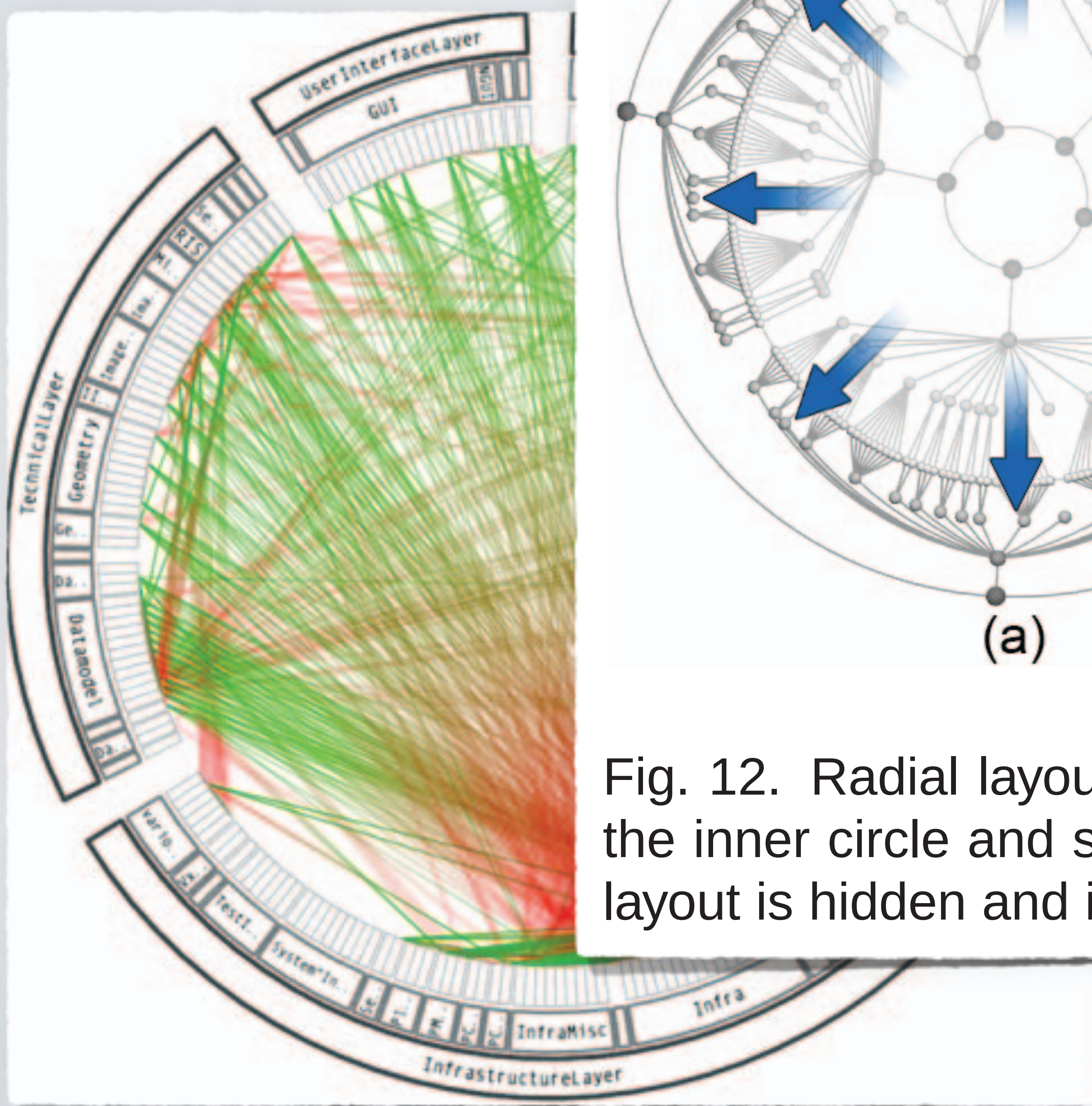


A software system and its associated call graph (caller = green, callee = red)

HIERARCHICAL EDGE BUNDLES

Holten, 2006

"Hierarchical Edge Bundles: Visualization of Adjacency Relations in Hierarchical Data"



A software system and its associated call graph (caller = green, callee = red)

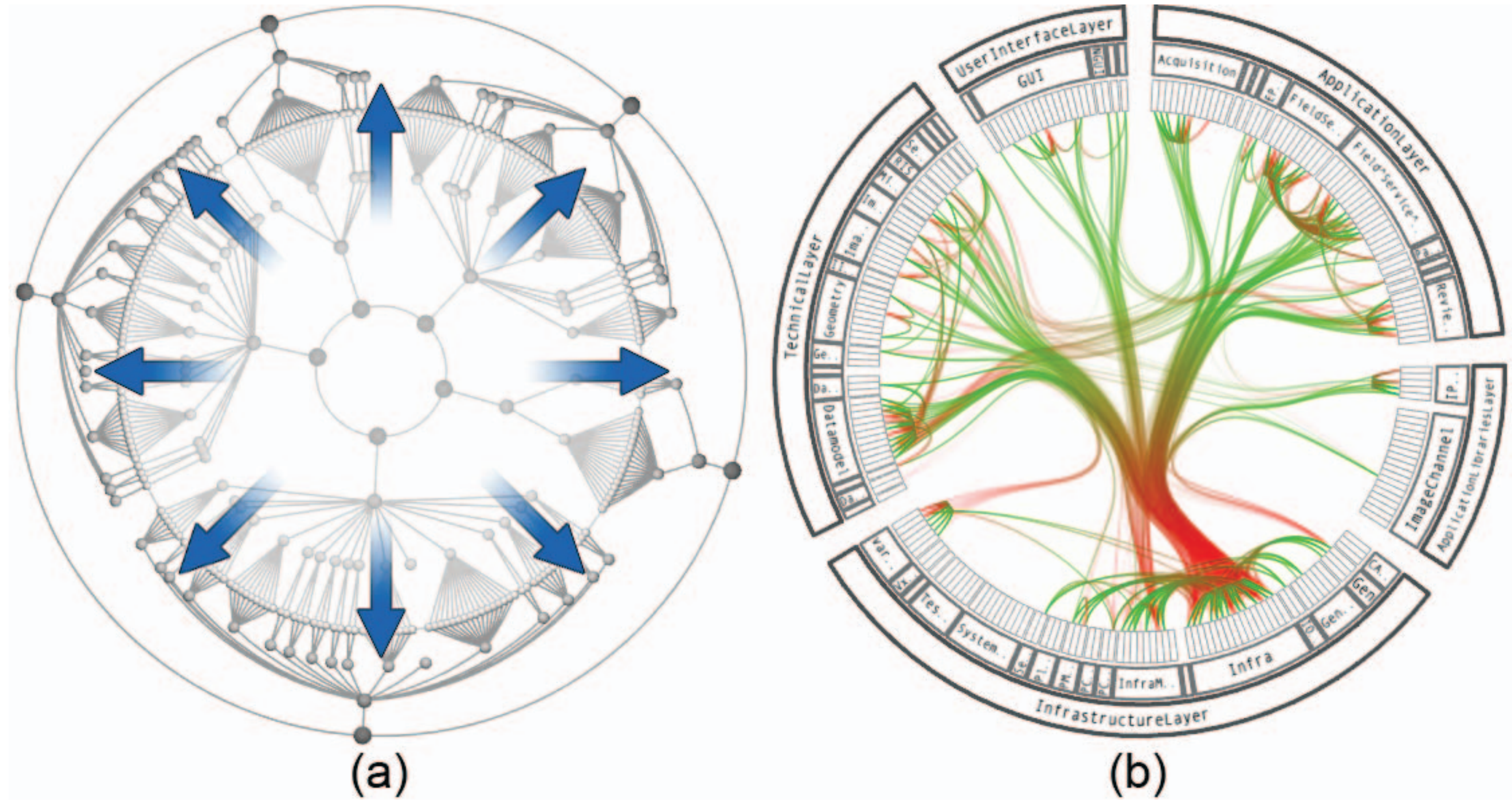


Fig. 12. Radial layout construction. (a) A radial tree layout is used for the inner circle and subsequently mirrored to the outside; (b) the inner layout is hidden and its structure is used to guide the adjacency edges.

HIERARCHICAL EDGE BUNDLES

Holten, 2006

"Hierarchical Edge Bundles: Visualization of Adjacency Relations in Hierarchical Data"

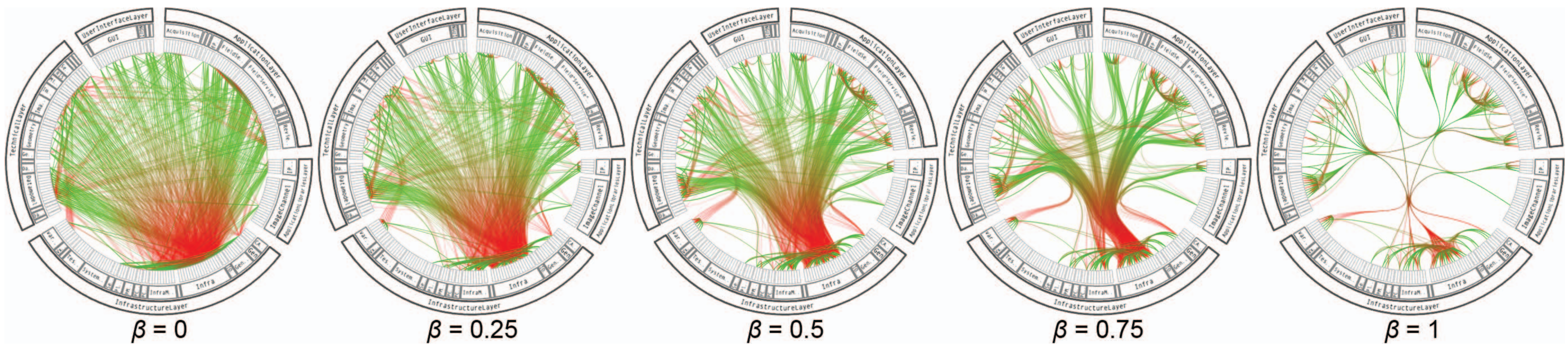
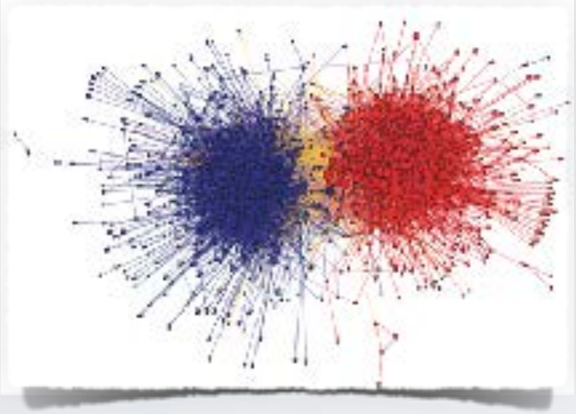


Fig. 14. Using the bundling strength β to provide a trade-off between low-level and high-level views of the adjacency relations. The value of β increases from left-to-right; low values mainly provide low-level, node-to-node connectivity information, whereas high values provide high-level information as well by implicit visualization of adjacency edges between parent nodes that are the result of explicit adjacency edges between their respective child nodes.

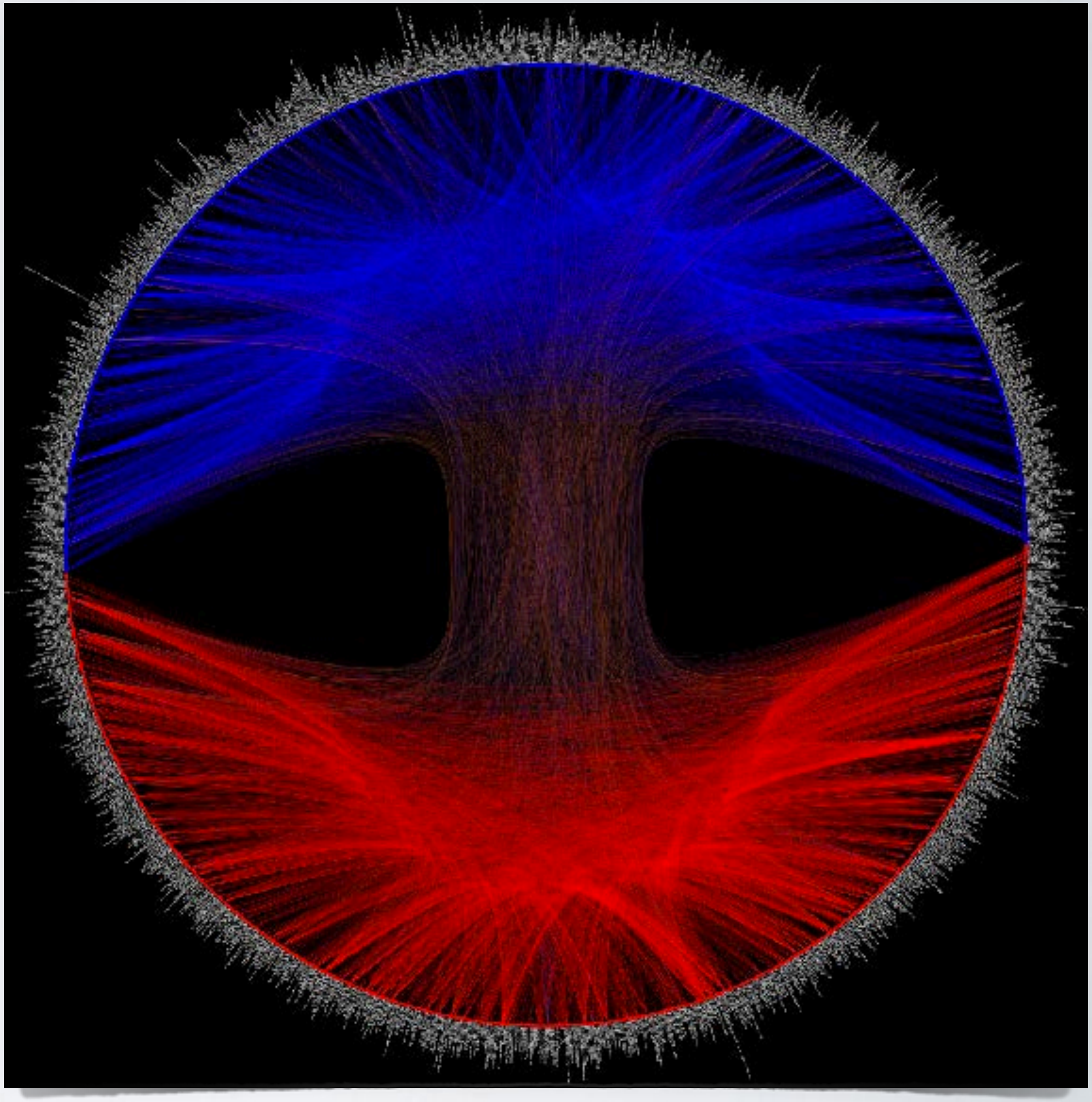
HIERARCHICAL EDGE BUNDLES

Compton, 2015

"graph-tool's visualization is pretty good", blog post



""Here's a plot of the political blogging network described by Adamic and Glance in "The political blogosphere and the 2004 US Election". The layout is determined using graph-tool's implementation of hierarchal edge bundles. The color scheme is the same as in the original paper, i.e. each node corresponds to a blog url and the colors reflect political orientation, red for conservative, and blue for liberal. Orange edges go from liberal blogs to conservative blogs, and purple ones from conservative to liberal (cf fig. 1 in Adamic and Glance). All 1,490 nodes and 19,090 edges are drawn.""



HIERARCHICAL EDGE BUNDLES

Compton, 2015

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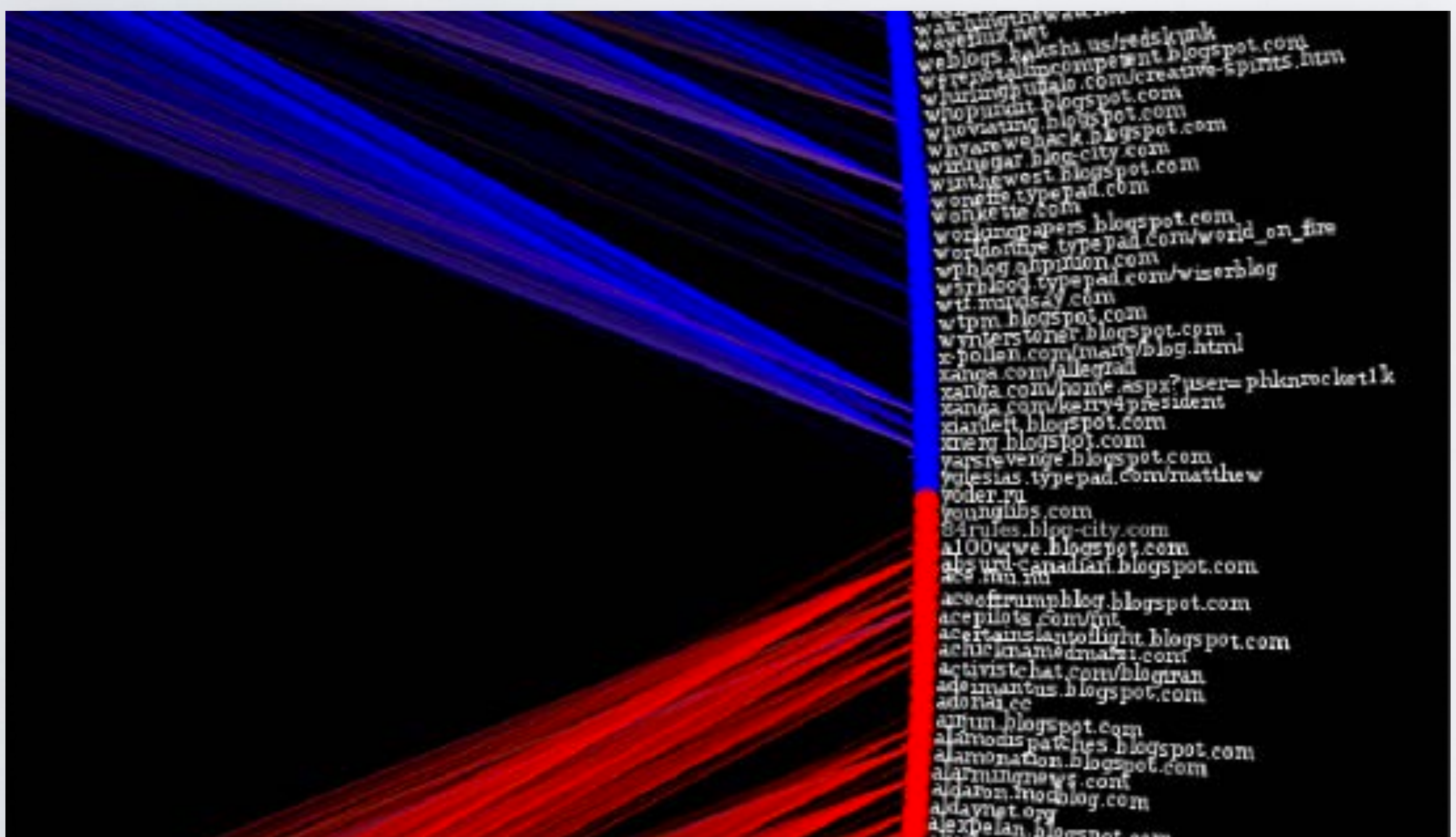

graphtool-demo-by-compton.py

```
import graph_tool.all as gt
import math

g = gt.collection.data["polblogs"] #  http://www2.scedu.unibo.it/roversi/SocioNet/Ada

#use 1->Republican, 2->Democrat
red_blue_map = {1:(1,0,0,1),0:(0,0,1,1)}
plot_color = g.new_vertex_property('vector<double>')
g.vertex_properties['plot_color'] = plot_color
for v in g.vertices():
    plot_color[v] = red_blue_map[g.vertex_properties['value'][v]]

#build tree
t = gt.Graph()

#add verticies with same idx as G
for v in g.vertices():
    tv = t.add_vertex()

#add hierachy points
reps = t.add_vertex()
dems = t.add_vertex()
root = t.add_vertex()
t.add_edge(root,reps)
t.add_edge(root,dems)

#assign clusters based on political affiliation
for tv in t.vertices():
    if t.vertex_index[tv] < g.num_vertices():
        if g.vertex_properties['value'][tv] == 1:
            t.add_edge(reps,tv)
        else:
            t.add_edge(dems,tv)

tpos = pos = gt.radial_tree_layout(t, t.vertex(t.num_vertices() - 1), weighted=True)
cts = gt.get_hierarchy_control_points(g, t, tpos)
pos = g.own_property(tpos)


#labels
text_rot = g.new_vertex_property('double')
g.vertex_properties['text_rot'] = text_rot
for v in g.vertices():
    if pos[v][0] >0:
        text_rot[v] = math.atan(pos[v][1]/pos[v][0])
    else:
        text_rot[v] = math.pi + math.atan(pos[v][1]/pos[v][0])

gt.graph_draw(g, pos=pos,
              vertex_size=10,
              vertex_color=g.vertex_properties['plot_color'],
              vertex_fill_color=g.vertex_properties['plot_color'],
              edge_control_points=cts,
              vertex_text=g.vertex_properties['label'],
              vertex_text_rotation=g.vertex_properties['text_rot'],
              vertex_text_position=1,
              vertex_font_size=9,
              edge_color=g.edge_properties['edge_color'],
              vertex_anchor=0,
              bg_color=[0,0,0,1],
              output_size=[4024,4024],
              output='polblogs.png')
```

MATRIX-BASED VISUALIZATION

Liiv, 2010

"Seriation and Matrix Reordering Methods: An Historical Overview"

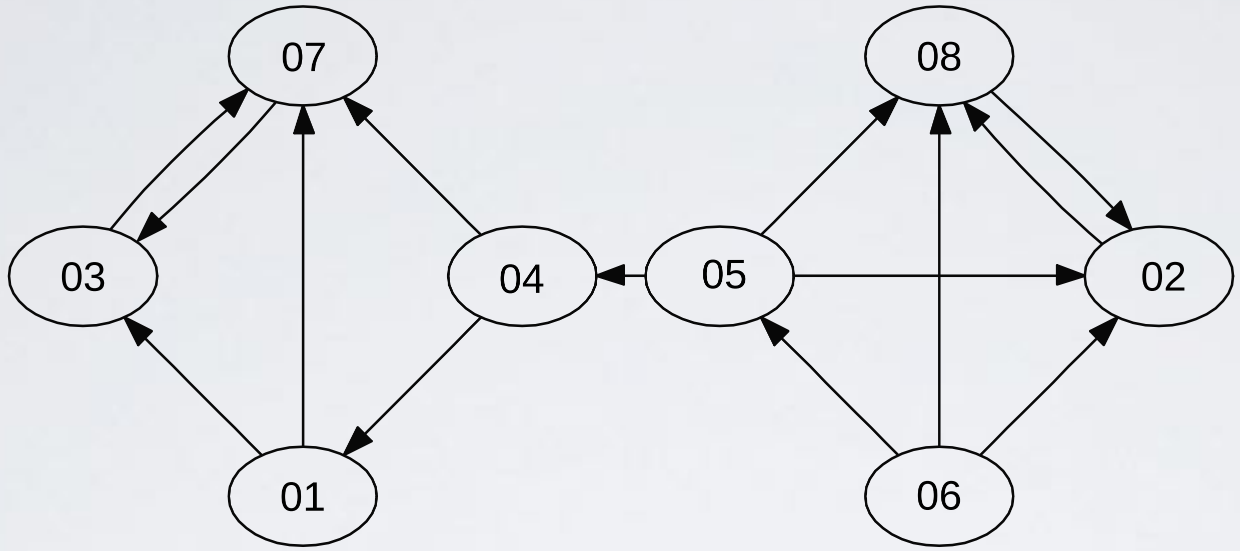

Fig. 2 An example graph.

Henry, Fekete, McGuffin, 2007

"NodeTrix: A Hybrid Visualization of Social Networks"

There is a sort of duality between the two forms: nodes correspond to points in node-link diagrams, but to line segments (rows and columns) in matrices, and, conversely, edges correspond to line segments in node-link diagrams, but to points (intersections of rows and columns) in matrices.

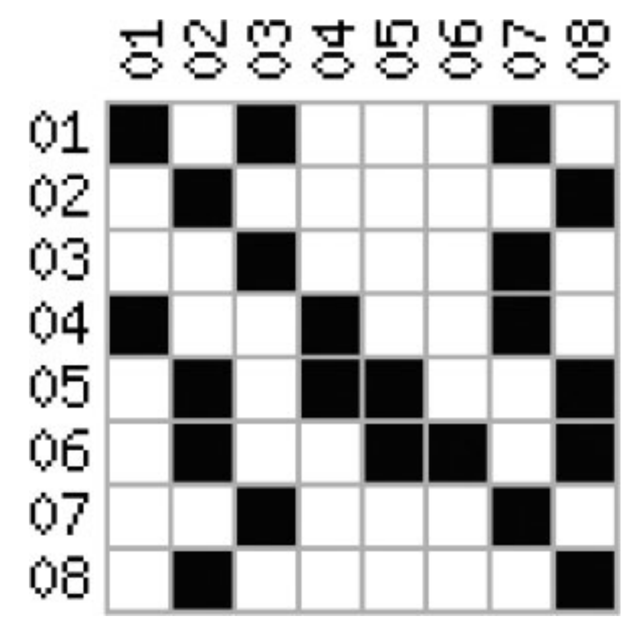

Fig. 3 A graphical 'Bertin' plot for the example dataset.

MATRIX-BASED VISUALIZATION

Liiv, 2010

"Seriation and Matrix Reordering Methods: An Historical Overview"

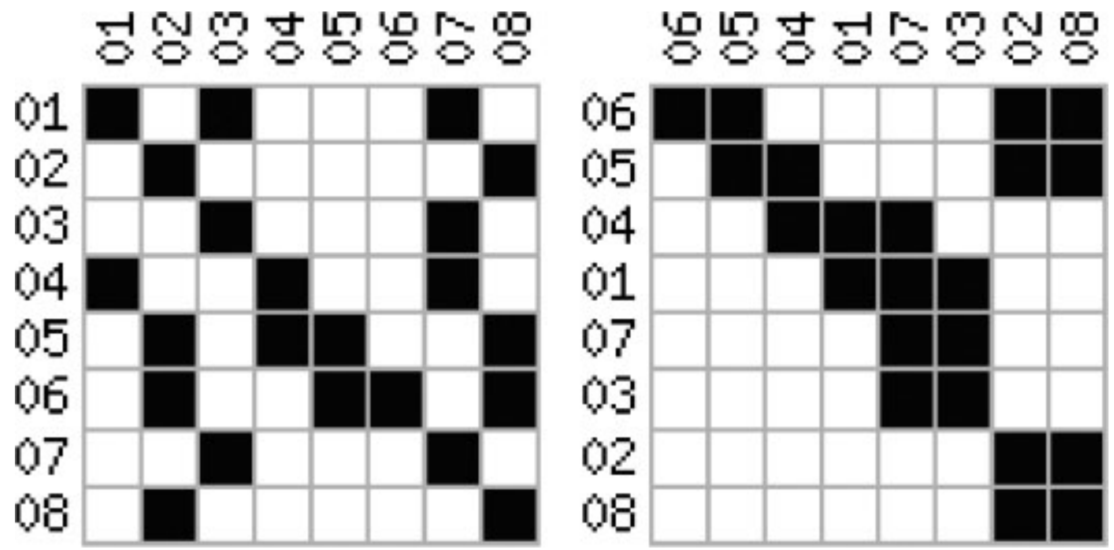

Fig. 4 An example of the seriation procedure.

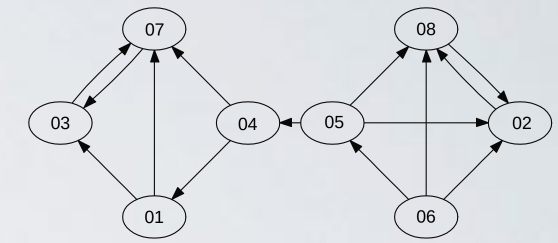

Fig. 2 An example graph.

MATRIX-BASED VISUALIZATION

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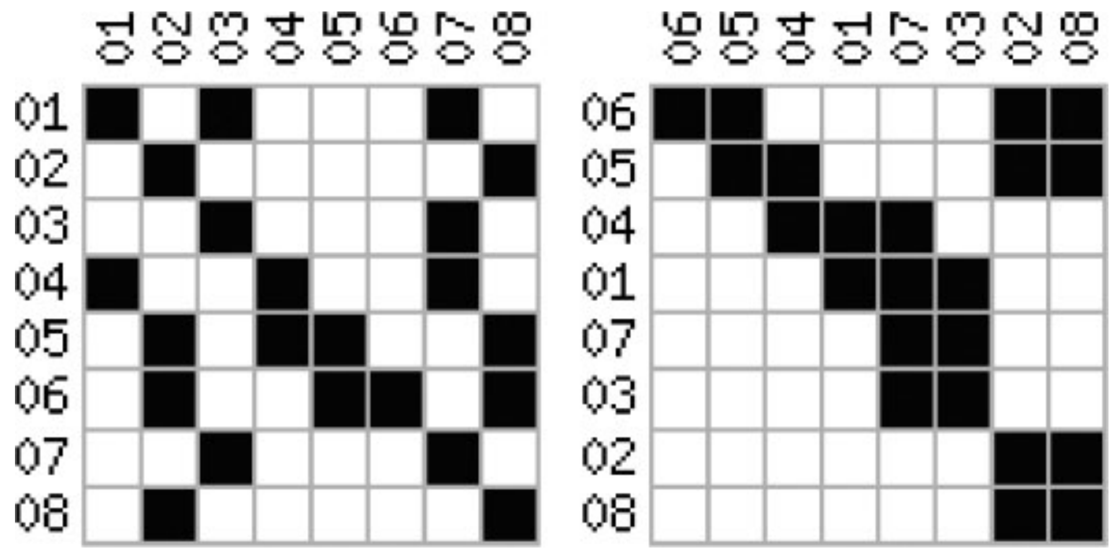

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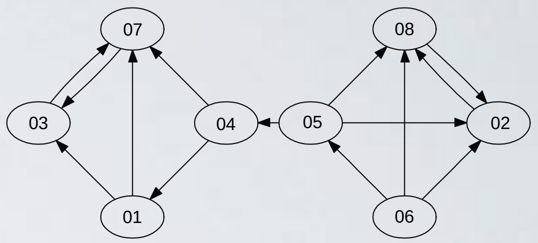


Fig. 2 An example graph.

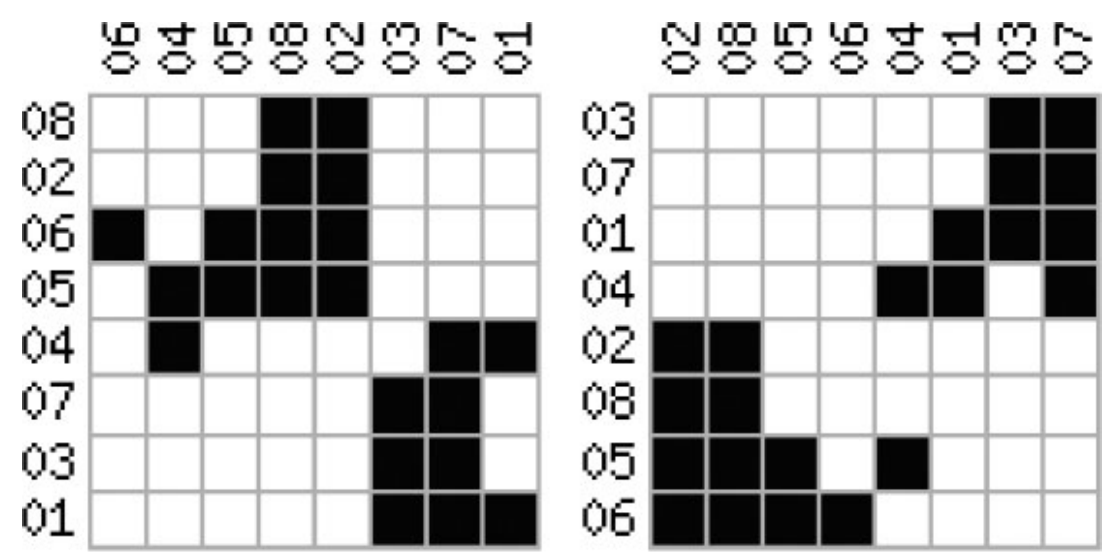
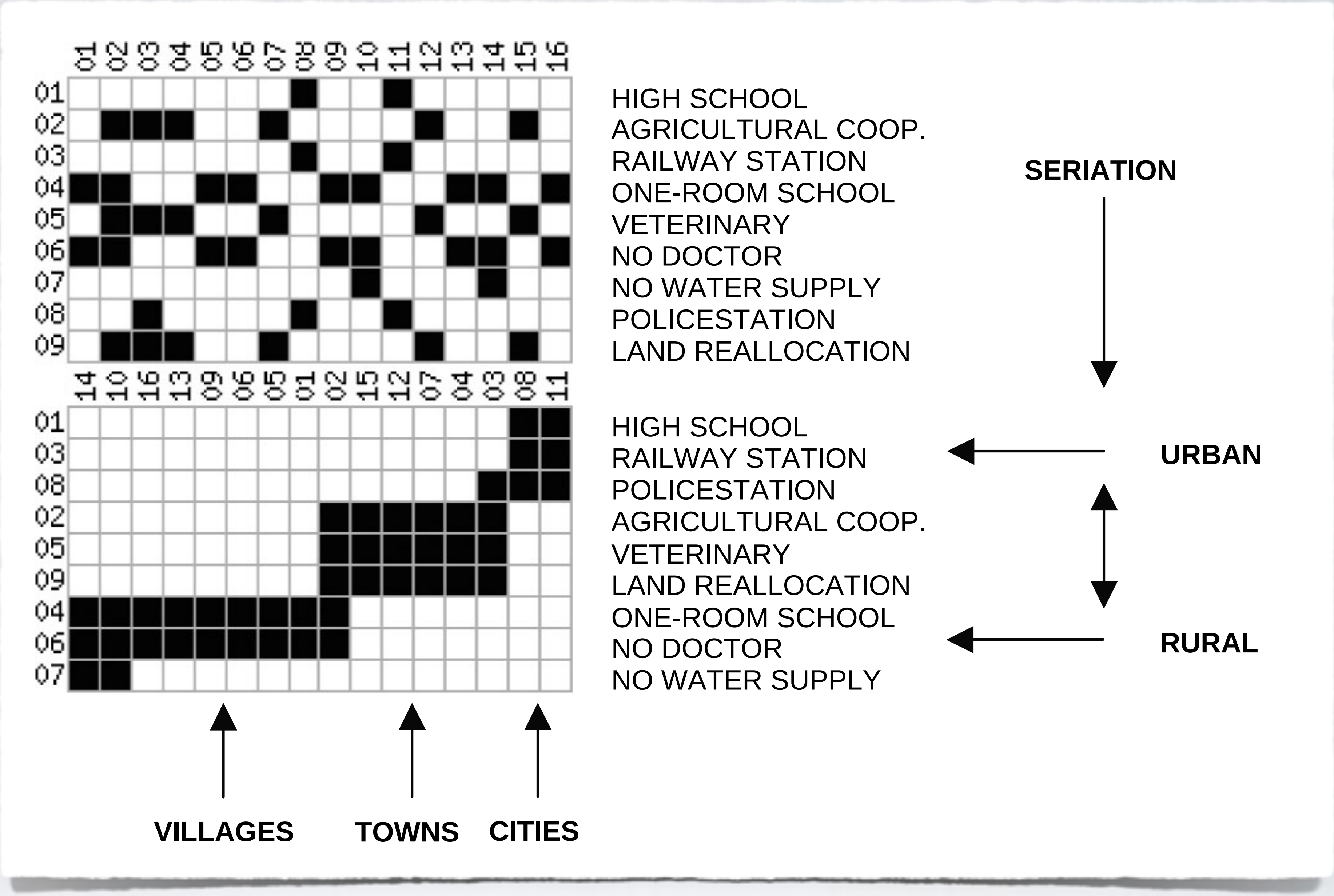


Fig. 5 Alternative permutations for the same dataset.

MATRIX-BASED VISUALIZATION

Liiv, 2010

"Seriation and Matrix Reordering Methods: An Historical Overview"



MATRIX-BASED VISUALIZATION

Liiv, 2010

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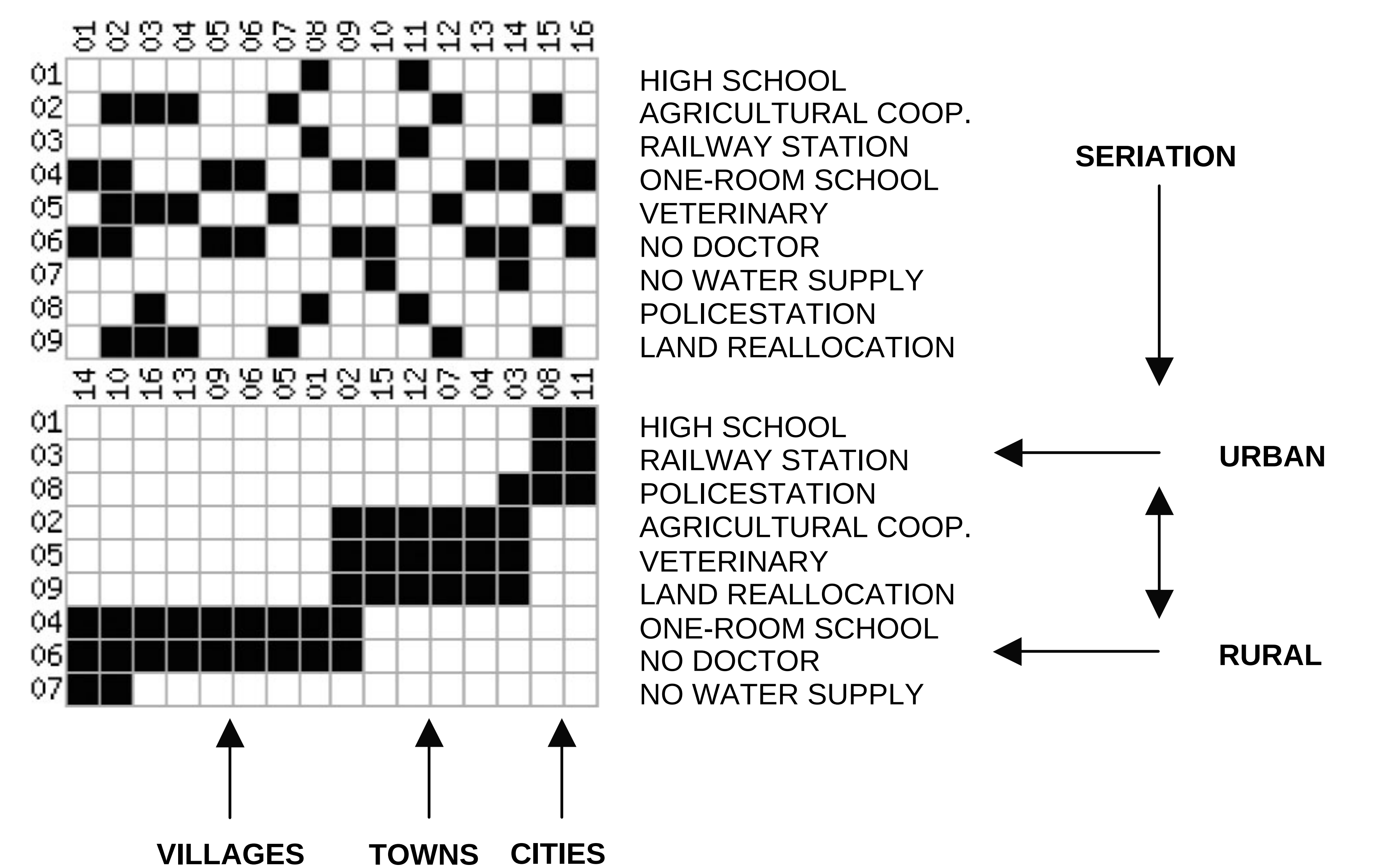


McCormick, Schweitzer, White, 1972

"Problem decomposition and data reorganization by a clustering technique"

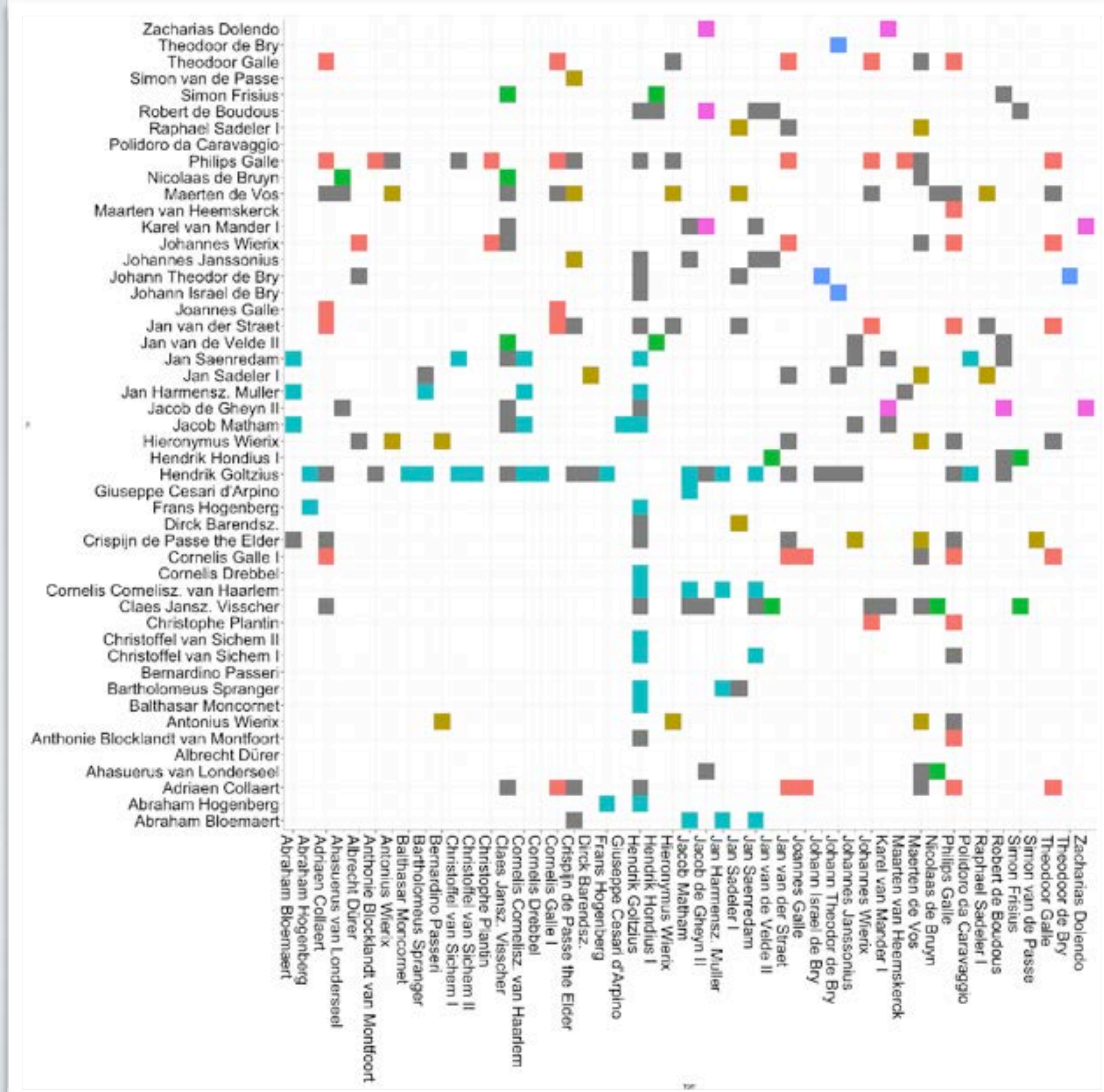
$$\mathrm{ME}(A) = \frac{1}{2} \sum_{i=1}^{i=M} \sum_{j=1}^{j=N} \alpha_{i,j}[\alpha_{i,j+1} + \alpha_{i,j-1} + \alpha_{i+1,j} + \alpha_{i-1,j}]$$

(with the convention $\alpha_{0,j} = \alpha_{M+1,j} = \alpha_{i,0} = \alpha_{i,N+1} = 0$)

$$\arg\max_{\Pi} = \sum_{i=1}^{i=M} \sum_{j=1}^{j=N} \alpha_{\pi(i),j}[\alpha_{\pi(i-1),j} + \alpha_{\pi(i+1),j}]$$

$$\arg\max_{\Phi} = \sum_{i=1}^{i=M} \sum_{j=1}^{j=N} \alpha_{i,\phi(j)}[\alpha_{i,\phi(j-1)} + \alpha_{i,\phi(j+1)}]$$

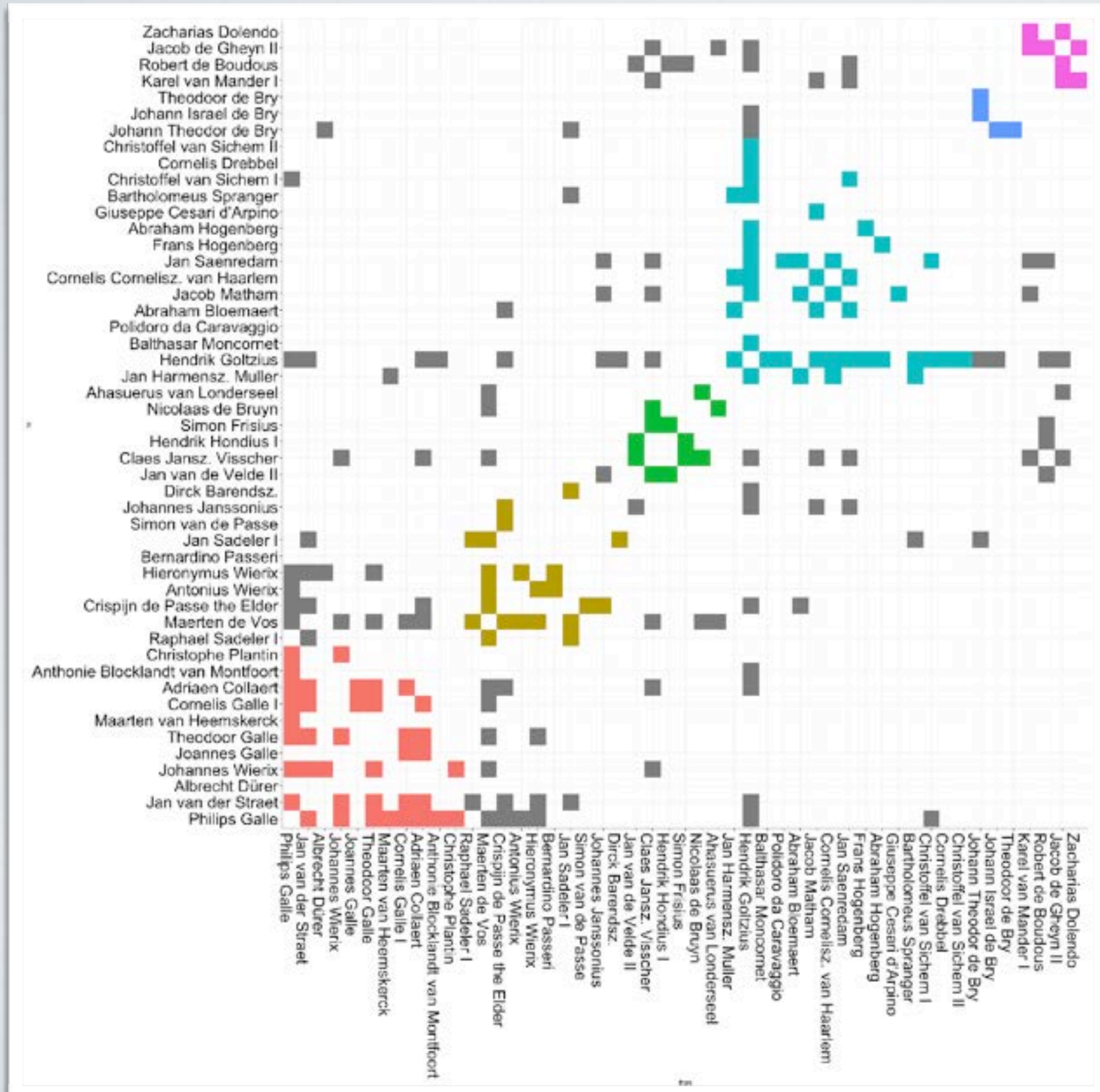
MATRIX-BASED VISUALIZATION



Examples taken from
https://matthewlincoln.net
(2014)

"connections between print engravers and publishers in the Netherlands in the late sixteenth and early seventeenth century. This extract focuses on the artists in the ambit of Hendrick Goltzius, a virtuoso who ran his own print shop in Haarlem in the 1580s and 90s before turning to painting after 1600."

MATRIX-BASED VISUALIZATION



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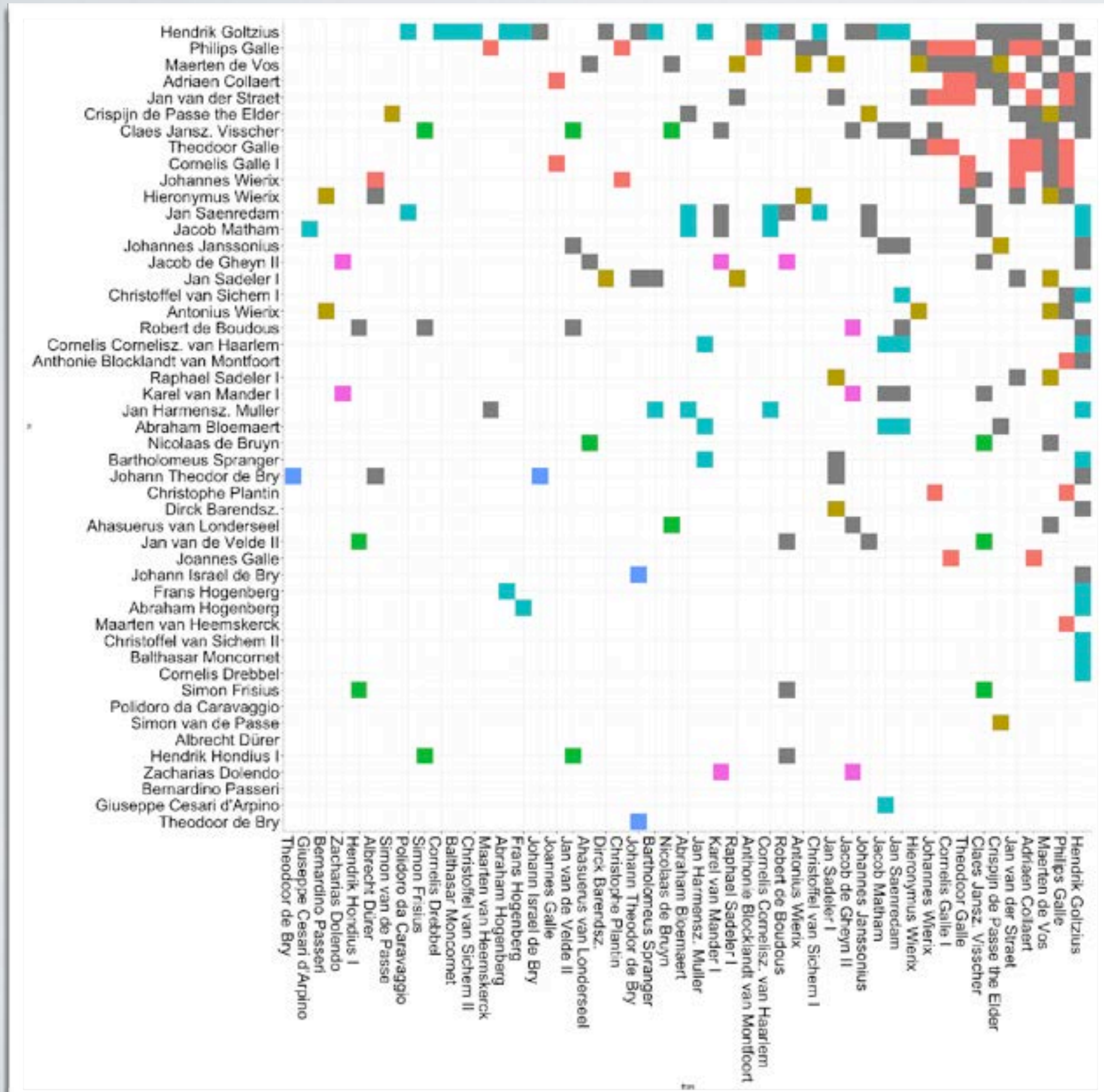
MATRIX-BASED VISUALIZATION



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MATRIX-BASED VISUALIZATION

Ghoniem, Fekete, Castagliola, 2005

"On the readability of graphs using node-link and matrix-based representations: a controlled experiment and statistical analysis"

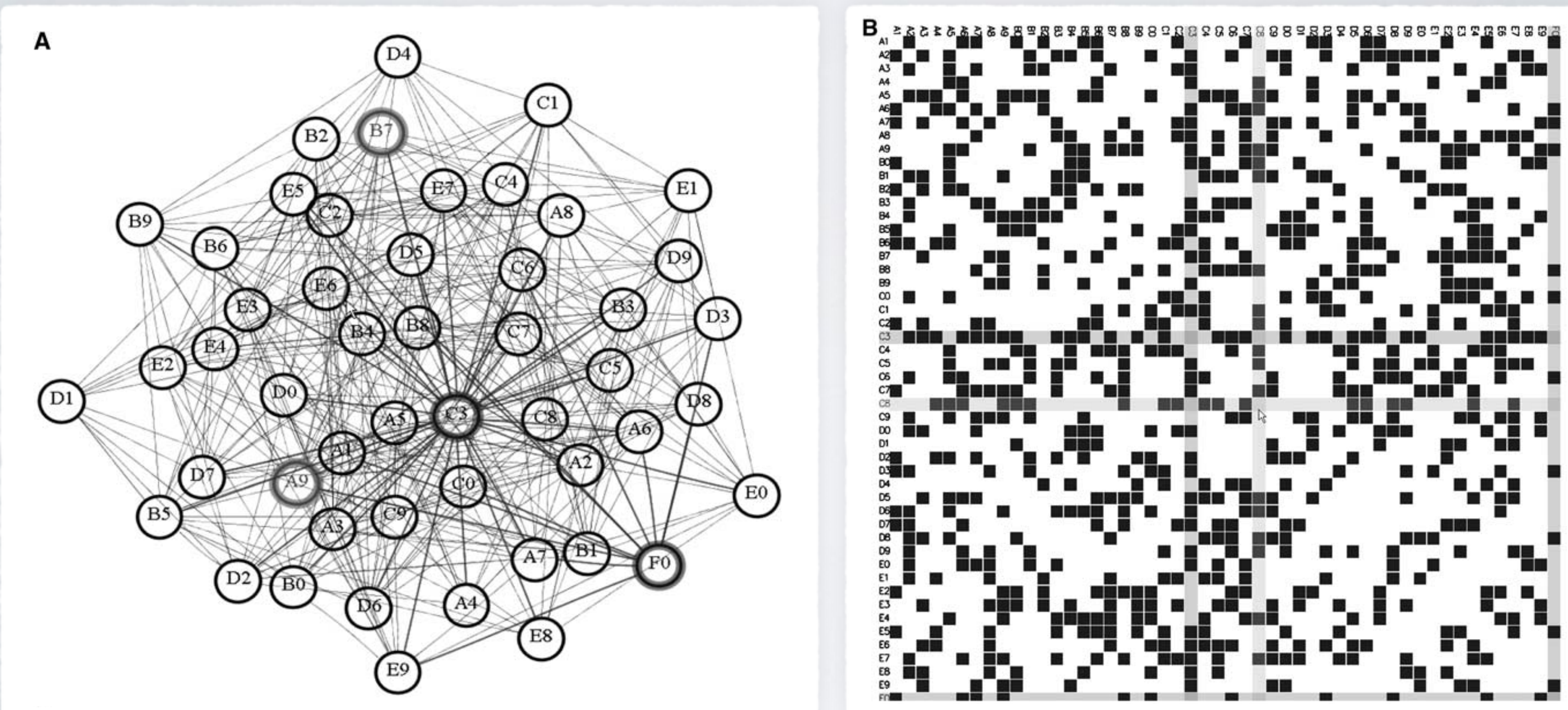


Figure 1 Two visualizations of the same undirected graph containing 50 vertices and 400 edges. The node-link diagram (A) is computed using the 'neato' program and the matrix representation (B) is computed using our VisAdj program.

MATRIX-BASED VISUALIZATION

Ghoniem, Fekete, Castagliola, 2005

"On the readability of graphs using node-link and matrix-based representations: a controlled experiment and statistical analysis"

- Task 1: approximate estimation of the number of nodes in the graph, referred to as 'nodeCount'.
- Task 2: approximate estimation of the number of links in the graph, referred to as 'edgeCount'.
- Task 3: finding the most connected node, referred to as 'mostConnected'.
- Task 4: finding a node given its label, referred to as 'findNode'.
- Task 5: finding a link between two specified nodes, referred to as 'findLink'.
- Task 6: finding a common neighbor between two specified nodes, referred to as 'findNeighbor'.
- Task 7: finding a path between two nodes, referred to as 'findPath'.

Table 1 The nine types of graphs used for our experiment

Size\density	*0.2*	*0.4*	*0.6*
20	Graph 1	Graph 2	Graph 3
50	Graph 4	Graph 5	Graph 6
100	Graph 7	Graph 8	Graph 9

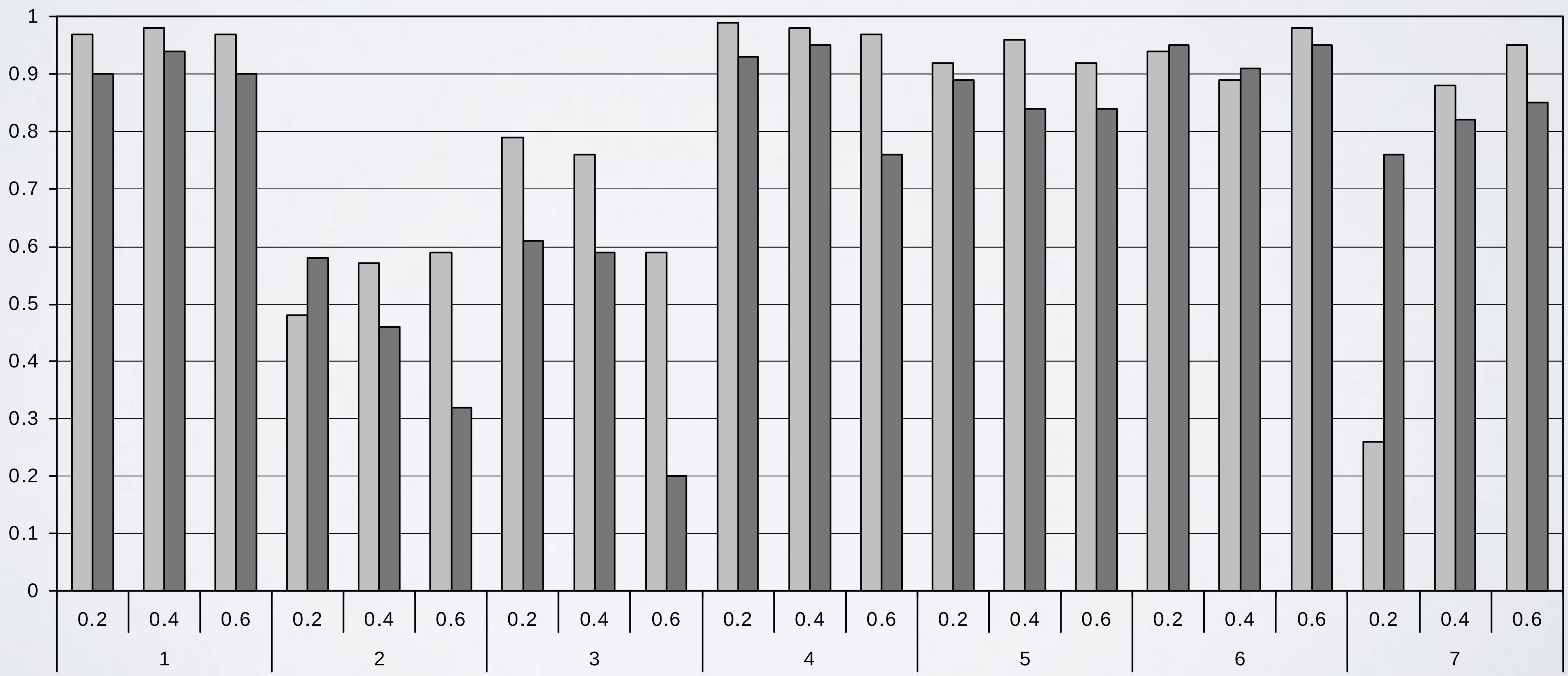
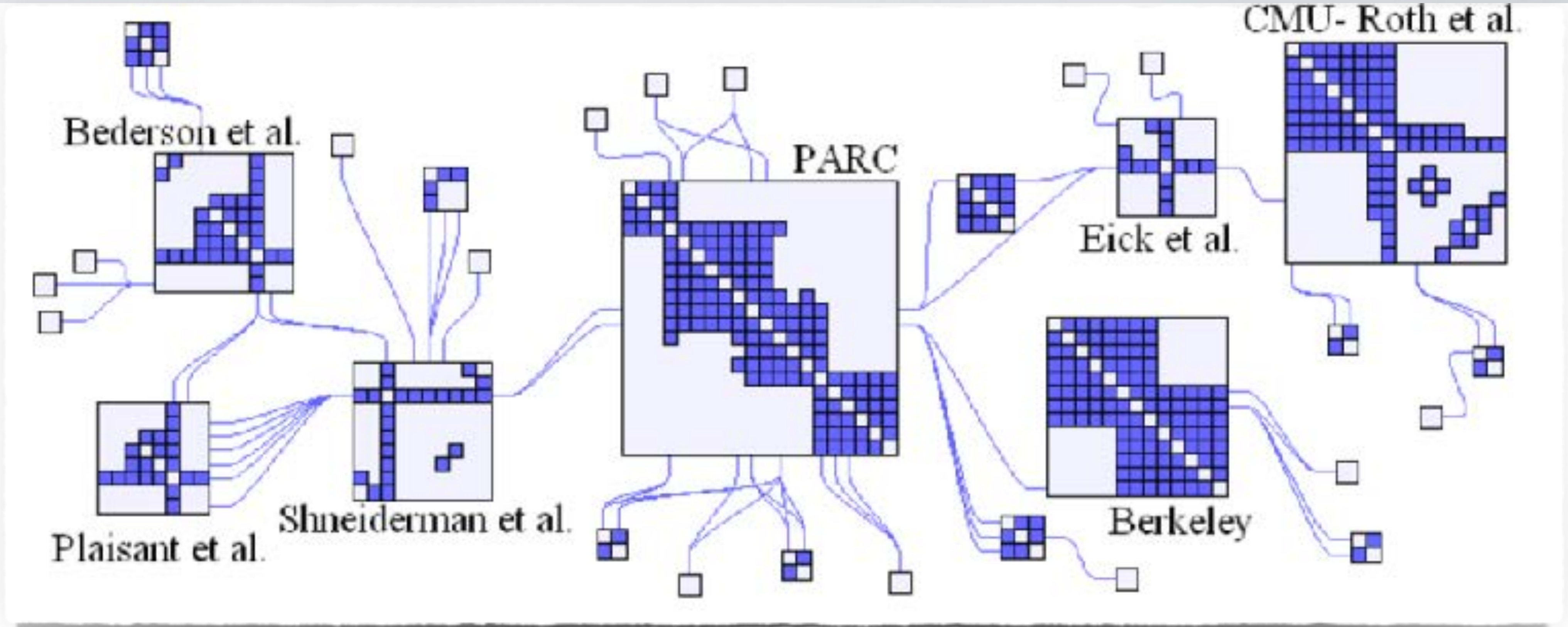


Figure 3 Percentage of correct answers by task and by density. Matrices appear in light gray; node-links in dark gray.

NodeTrix

Henry, Fekete, McGuffin, 2007

"NodeTrix: A Hybrid Visualization of Social Networks"

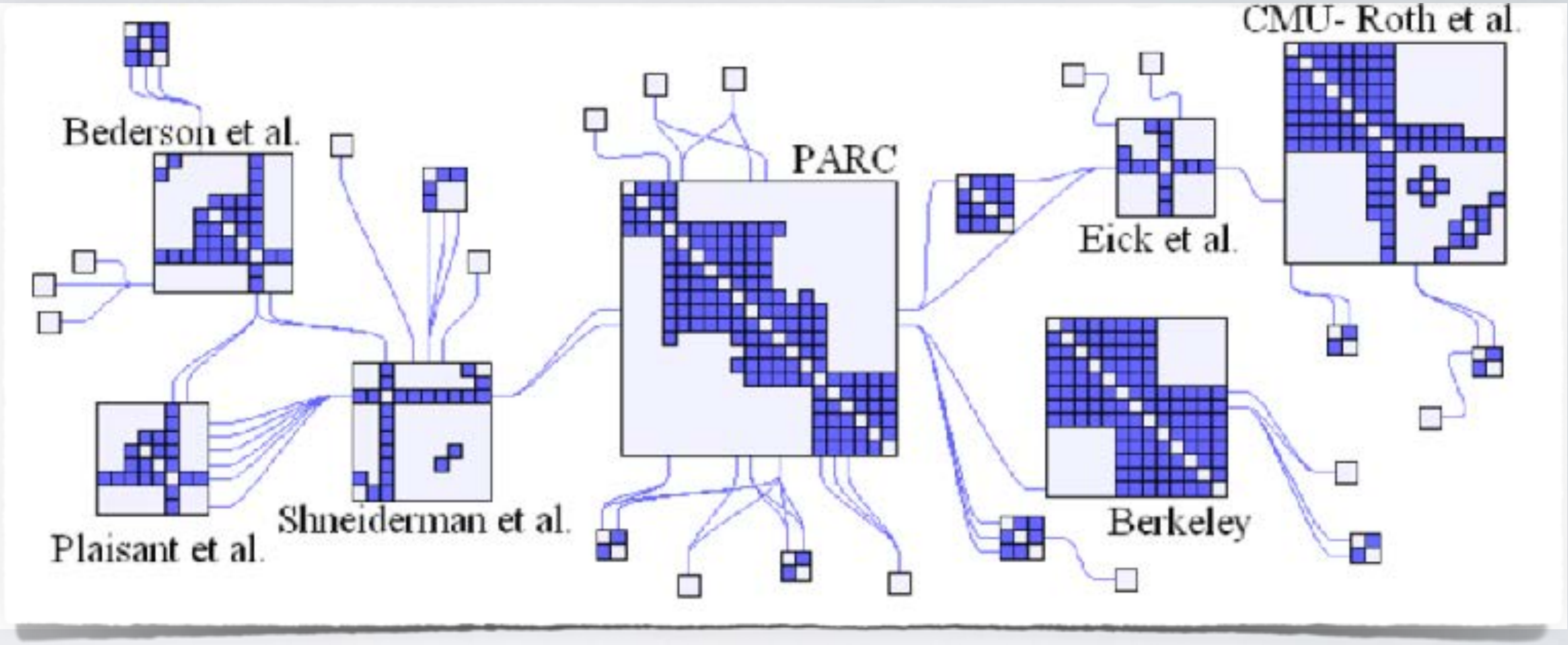


Largest component of the InfoVis collaboration network

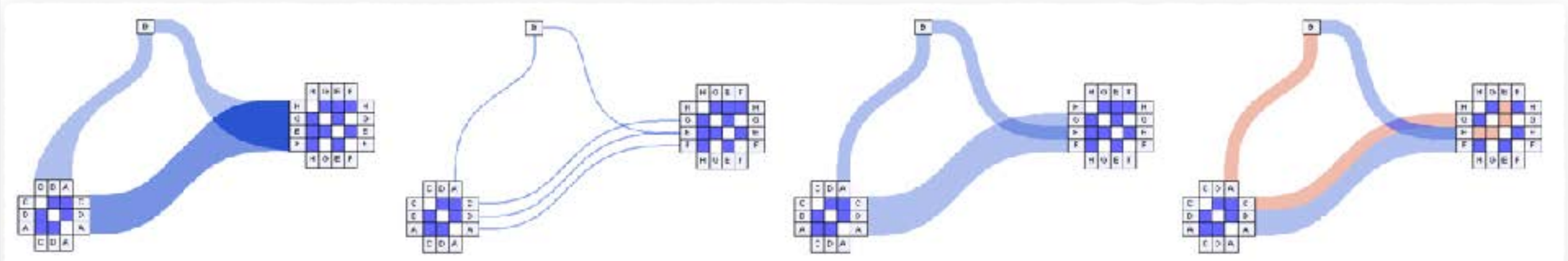
NodeTrix

Henry, Fekete, McGuffin, 2007

"NodeTrix: A Hybrid Visualization of Social Networks"



Largest component of the InfoVis collaboration network

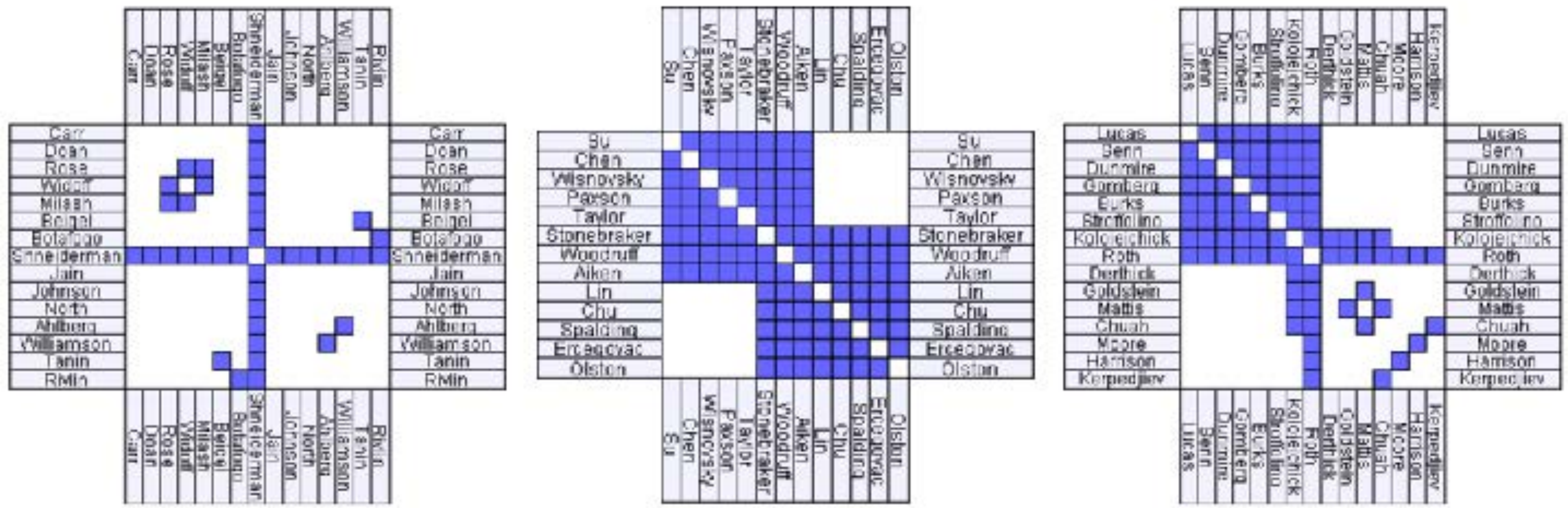


(a) Aggregated links (b) Underlying links (c) Underlying links with full size (d) Underlying links with attributes

NodeTrix

Henry, Fekete, McGuffin, 2007

"NodeTrix: A Hybrid Visualization of Social N



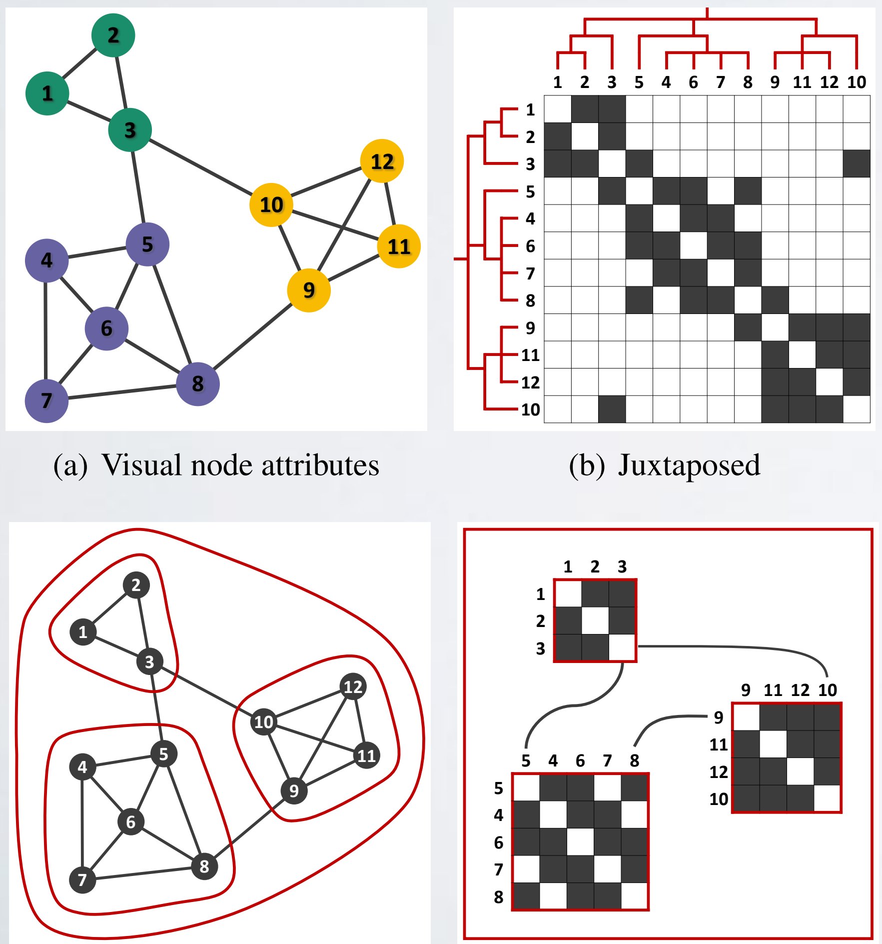
(a) Cross pattern (b) Block pattern (c) Intermediate pattern

Fig. 6: Three collaboration patterns: (a) Shneiderman and his collaborators, (b) Researchers at Berkeley, (c) Roth and his collaborators at CMU.

SHOWING GROUP STRUCTURE

Velhow, Beck, Weiskopf, 2015

"The State of the Art in Visualizing Group Structures in Graphs"



(a) Visual node attributes (b) Juxtaposed

(c) Superimposed (d) Embedded

Group Visualization Taxonomy		Group Structure Taxonomy: Disjoint flat	Overlapping flat	Disjoint hierarchical	Overl. hier.
Visual node attributes	Color Section 5.1 Figure 1(a)	1^{st} [DS13, SKL*14, vHW08] 2^{nd} [BPF14, CDA*14, EHKP14, ET07, GHK10, HGK10, HKV14, SMM13, vdEvW14, VBAW14]	1^{st} [–] 2^{nd} [AHRRC11, BT06, BBT06, DvKSW12, DEKB*14, IMMS09, LQB12, LWC*14, NIST12, HRD10, TLTC05, XDC*13]	1^{st} [–] 2^{nd} [BD05, BD07, KG06, SBG00]	1^{st} [–] 2^{nd} [VRW13]
	Glyph Section 5.1 Figure 3		1^{st} [IMMS09, LWC*14, NIST12, TLTC05] 2^{nd} [ST08, XDC*13]		1^{st} [–] 2^{nd} [VRW13]
Juxtaposed	Separate Section 5.2.1 Figures 4(a)-(b)	1^{st} [SMM13, vdEvW14]	1^{st} [SJUS08]	1^{st} [AKY05, AvHK06, CC07]	
	Attached Section 5.2.2 Figures 4(c)-(e)			1^{st} [AZ13, BPD11, BBV*12, BD13, BD08, BFBD10, BVB*11, BHW11, BSW13, GF03, GZ11, GBD09, Hol06, HCvW07, NSC05, PvW06, vH03, vHSD09, VBSW13] 2^{nd} [RMF12]	
Superimposed	Line overlay Section 5.3.1 Figure 5(a)		1^{st} [AHRRC11, XDC*13]		
	Contour overlay Section 5.3.2 Figure 5(b)	1^{st} [BPF14, EHKP14, ET07, GHK10, HGK10, HKV14] 2^{nd} [VBAW14]	1^{st} [BT06, BBT06, BT09b, DvKSW12, DEKB*14, LQB12, HRD10, ST08]	1^{st} [BD05, BD07, DGC*05, Hol06, KG06, SBG00] 2^{nd} [NSC05]	
	Partitioning Section 5.3.3 Figure 6	1^{st} [SKB*14, SA06, ZCCB13]	1^{st} [LSKS10]	1^{st} [AFH*10, DWS*14, FWD*03, Hol06]	
Embedded	Node-link Section 5.4.1 Figure 7(a)	1^{st} [CDA*14, SMER06, VBAW14]	1^{st} [RHR*10, SZPM10]	1^{st} [ASH14, AMA07a, AMA08, AMA09, AMA11, DM12, DM14a, HN07b, HN07a, RPD09, vHvW04]	1^{st} [VRW13]
	Hybrid Section 5.4.2 Figure 7(b)	1^{st} [HFM07]	1^{st} [HBF08, MZ11]	1^{st} [RMF12]	

GENEALOGIC NETWORKS

Bezerianos, Dragicevic, Fekete, Bae, Watson, 2010

"GeneaQuilts: A System for Exploring Large Genealogies"

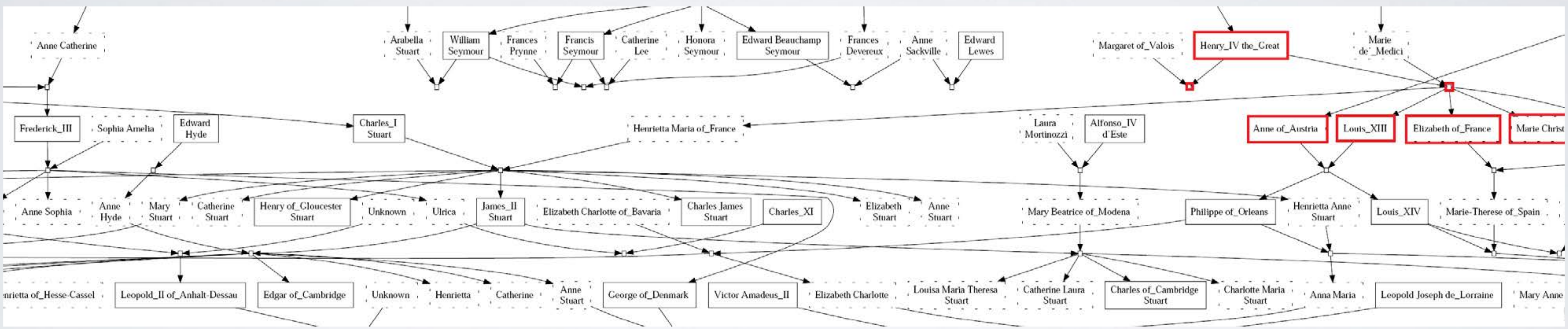
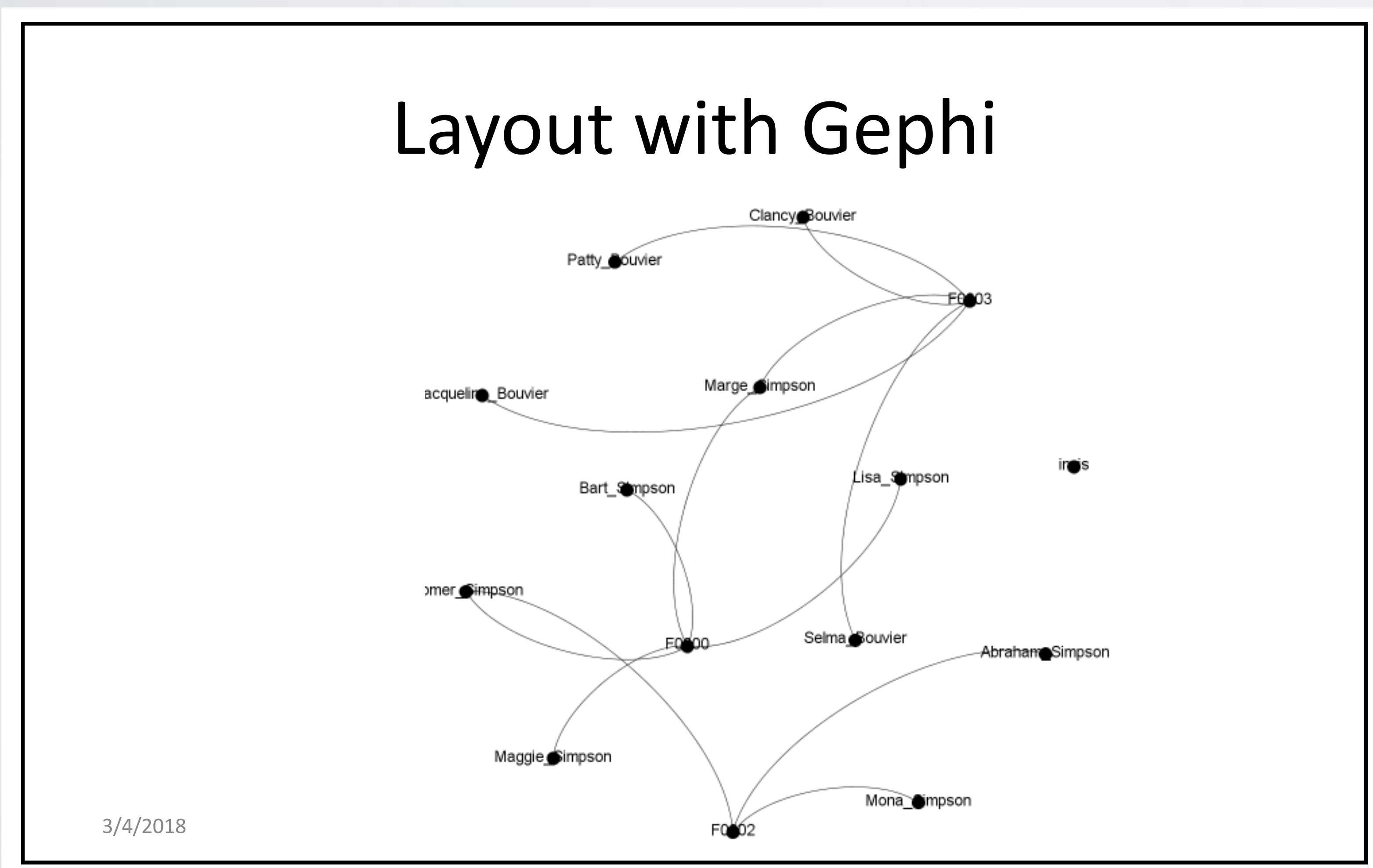


Fig. 2. European Royal families (same as that of Fig. 4) depicted by a standard Node-Link representation using the “dot” program to compute the layout [10]. Notice long edges and crossings.

GENEALOGIC NETWORKS

Bezerianos, Dragicevic, Fekete, Bae, Watson, 2010

"GeneaQuilts: A System for Exploring Large Genealogies"



http://www.aviz.fr/geneaquilts

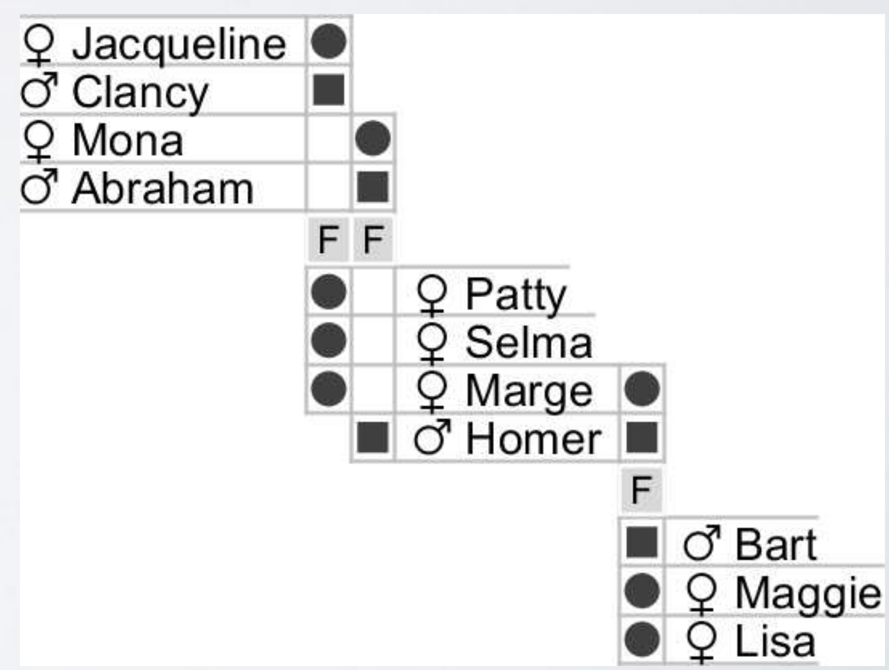


Fig. 5. GeneaQuilts Visualization of the Simpson Family.

GENEALOGICAL NETWORKS

Bezerianos, Dragicevic, Fekete, Bae, Watson, 2010

"GeneaQuilts: A System for Exploring Large Genealogies"

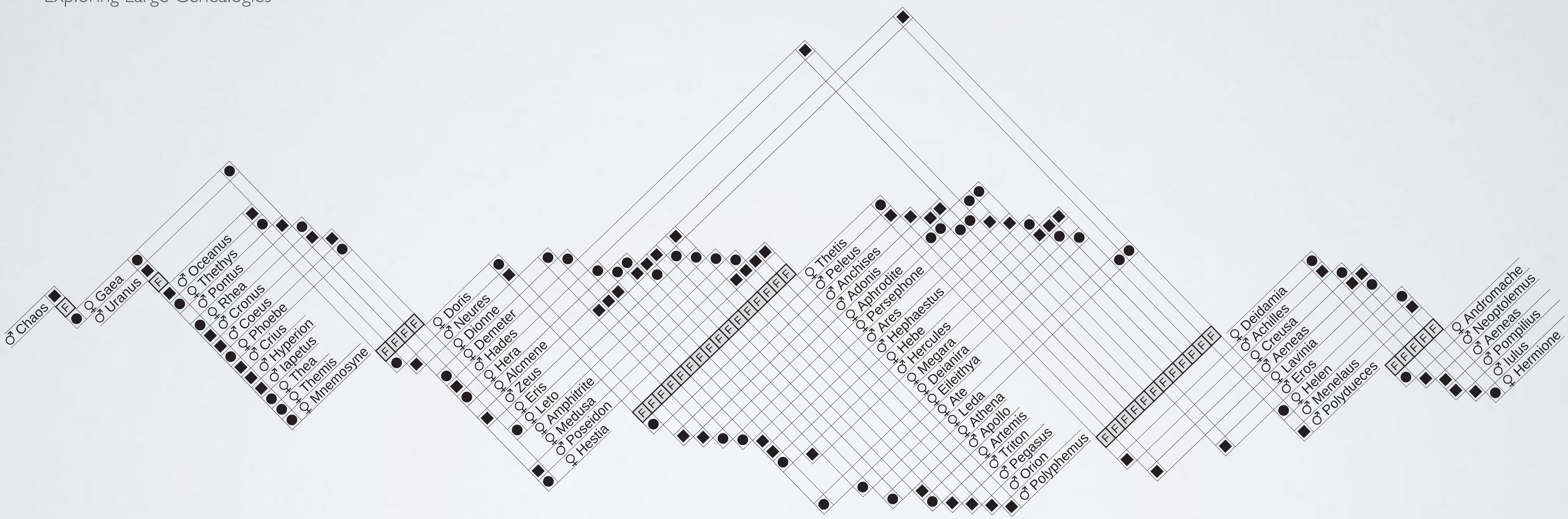


Fig. 1. The genealogy of Greek Gods depicted by GeneaQuilts (rotated 45^o for better layout in this paper). Each F icon represents a nuclear family composed of parents (black dots above the icon) and children (black dots below).

GENEALOGICAL NETWORKS

Bezerianos, Dragicevic, Fekete, Bae, Watson, 2010

"GeneaQuilts: A System for Exploring Large Genealogies"

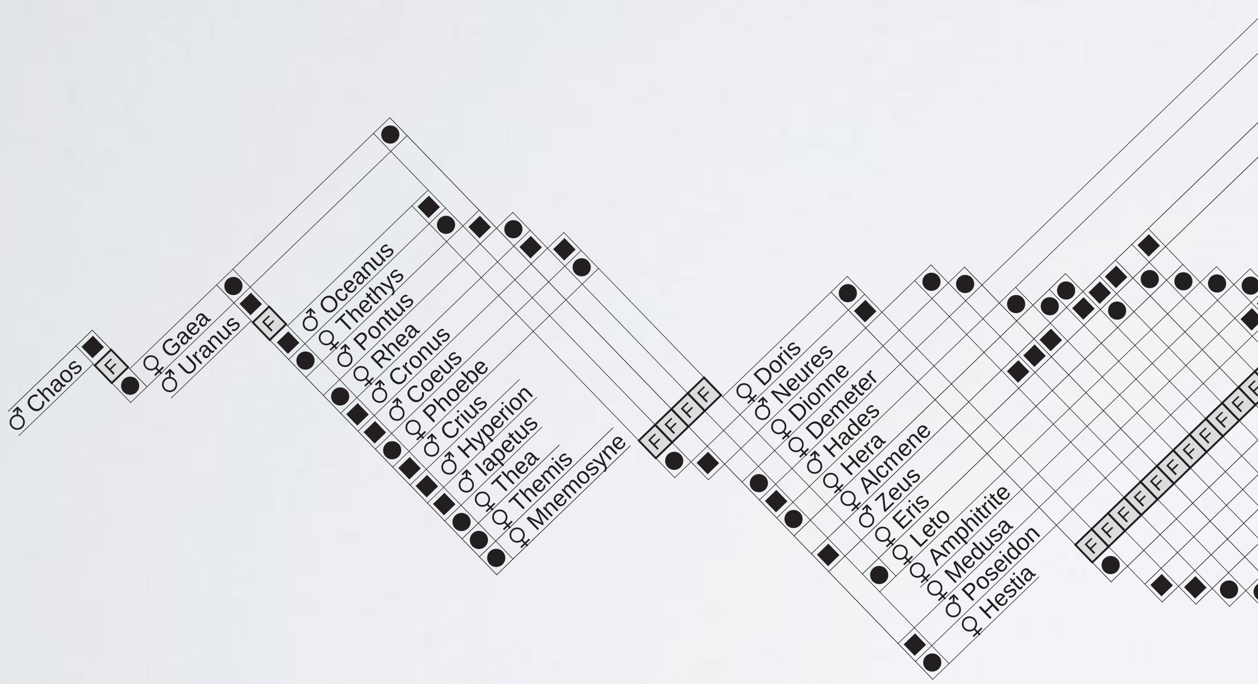


Fig. 1. The genealogy of Greek Gods depicted by GeneaQuilts
nuclear family composed of parents (black dots above the icon

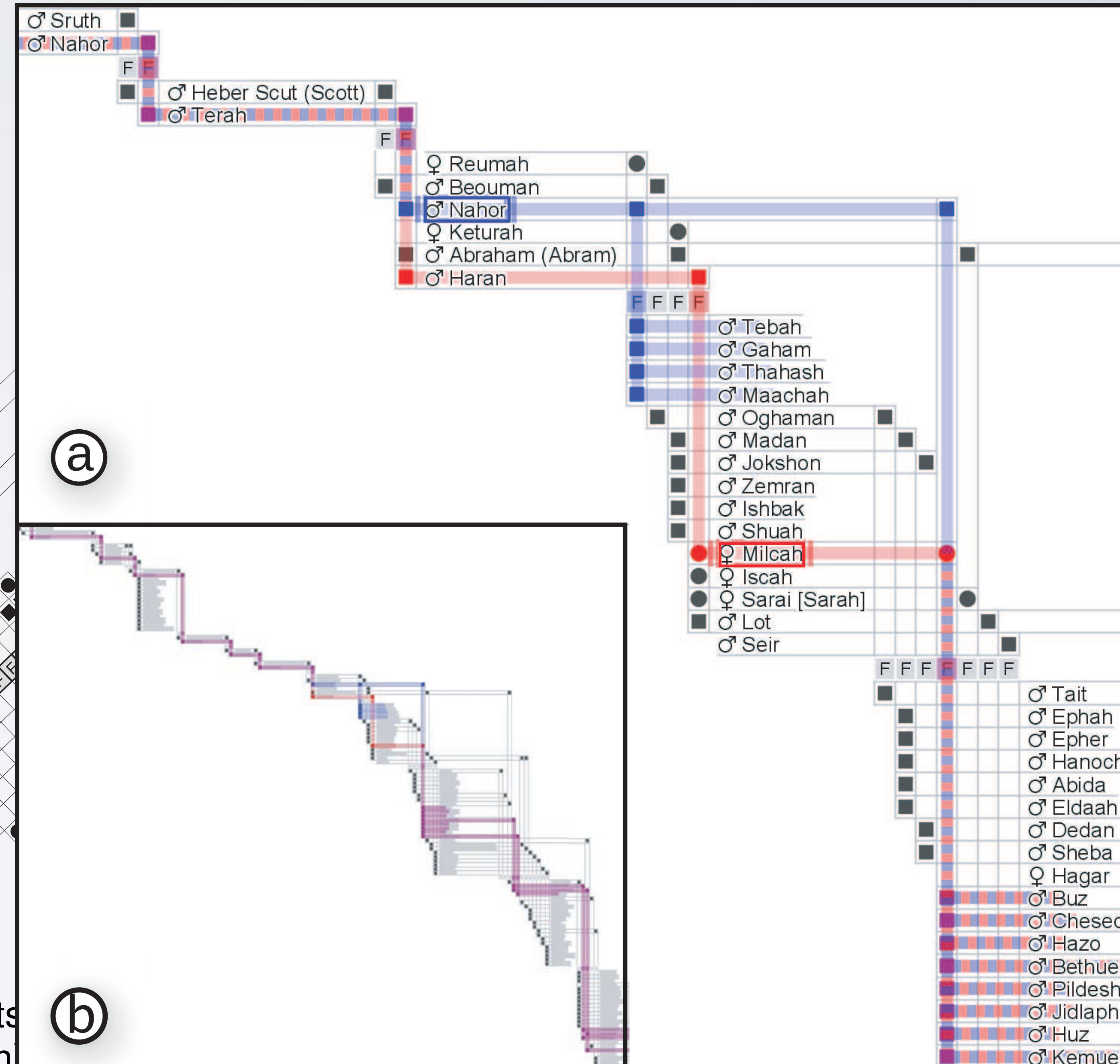
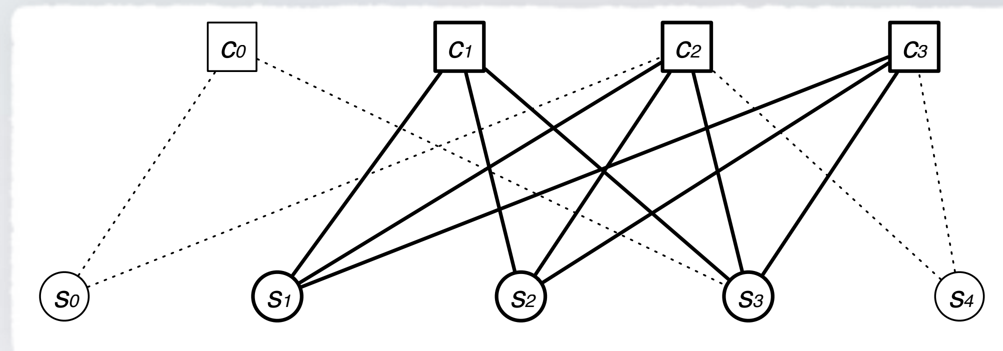


Fig. 6. Multiple selections in the Bible. (a) Selecting Milcah's bloodline in red and her husband's in blue reveals their common descendants, but also a close common ancestor (Terah) shown by the two lines blended in a dashed pattern. (b) The blending of these bloodlines in the overview.

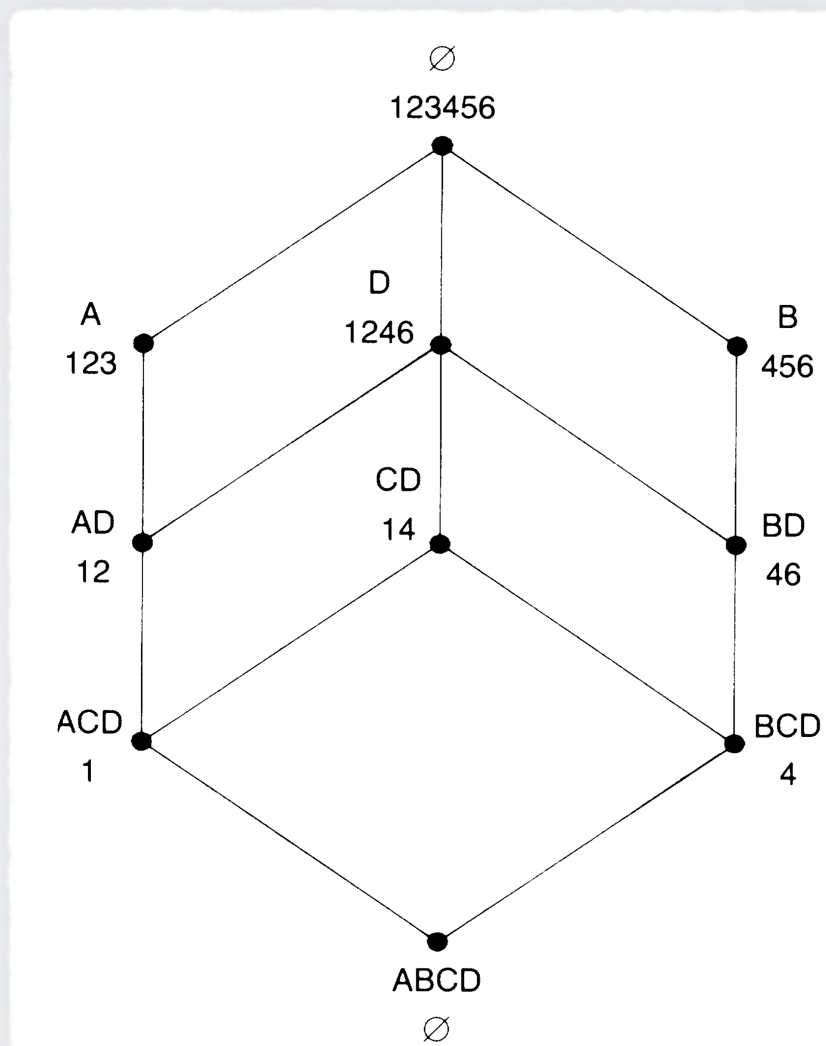
BIPARTITE GRAPHS AND GALOIS LATTICES

Freeman, White, 1993

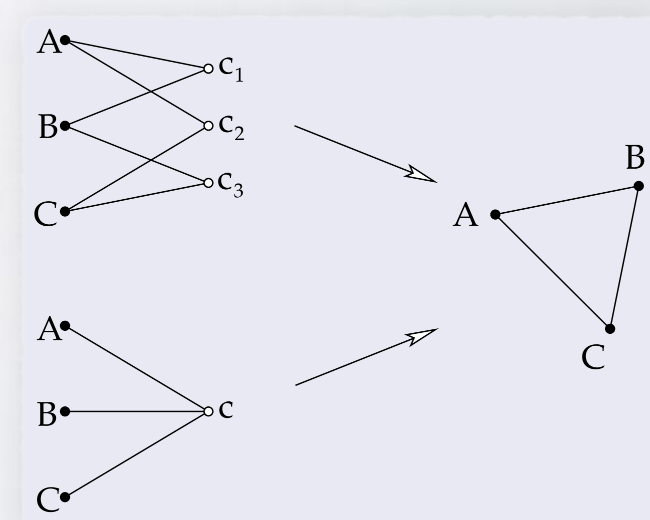
"Using Galois Lattices to Represent Network Data"



	EVENT			
ACTOR	A	B	C	D
1	1	0	1	1
2	1	0	0	1
3	1	0	0	0
4	0	1	1	1
5	0	1	0	0
6	0	1	0	1



a purely bipartite pattern



BIPARTITE GRAPHS AND GALOIS LATTICES

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ACTOR	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	1	1	1	1	1	1	0	1	1	0	0	0	0	0
2	1	1	1	0	1	1	1	1	0	0	0	0	0	0
3	0	1	1	1	1	1	1	1	1	0	0	0	0	0
4	1	0	1	1	1	1	1	1	0	0	0	0	0	0
5	0	0	1	1	1	0	1	0	0	0	0	0	0	0
6	0	0	1	0	1	1	0	1	0	0	0	0	0	0
7	0	0	0	0	1	1	1	1	0	0	0	0	0	0
8	0	0	0	0	0	1	0	1	1	0	0	0	0	0
9	0	0	0	0	1	0	1	1	1	0	0	0	0	0
10	0	0	0	0	0	0	1	1	1	0	0	1	0	0
11	0	0	0	0	0	0	0	1	1	1	0	1	0	0
12	0	0	0	0	0	0	0	1	1	1	0	1	1	1
13	0	0	0	0	0	0	1	1	1	1	0	1	1	1
14	0	0	0	0	0	1	1	0	1	1	1	1	1	1
15	0	0	0	0	0	0	1	1	0	1	1	1	0	0
16	0	0	0	0	0	0	0	1	1	0	0	0	0	0
17	0	0	0	0	0	0	0	0	1	0	1	0	0	0
18	0	0	0	0	0	0	0	0	1	0	1	0	0	0

FIGURE 5. Davis, Gardner, and Gardner's two mode data.

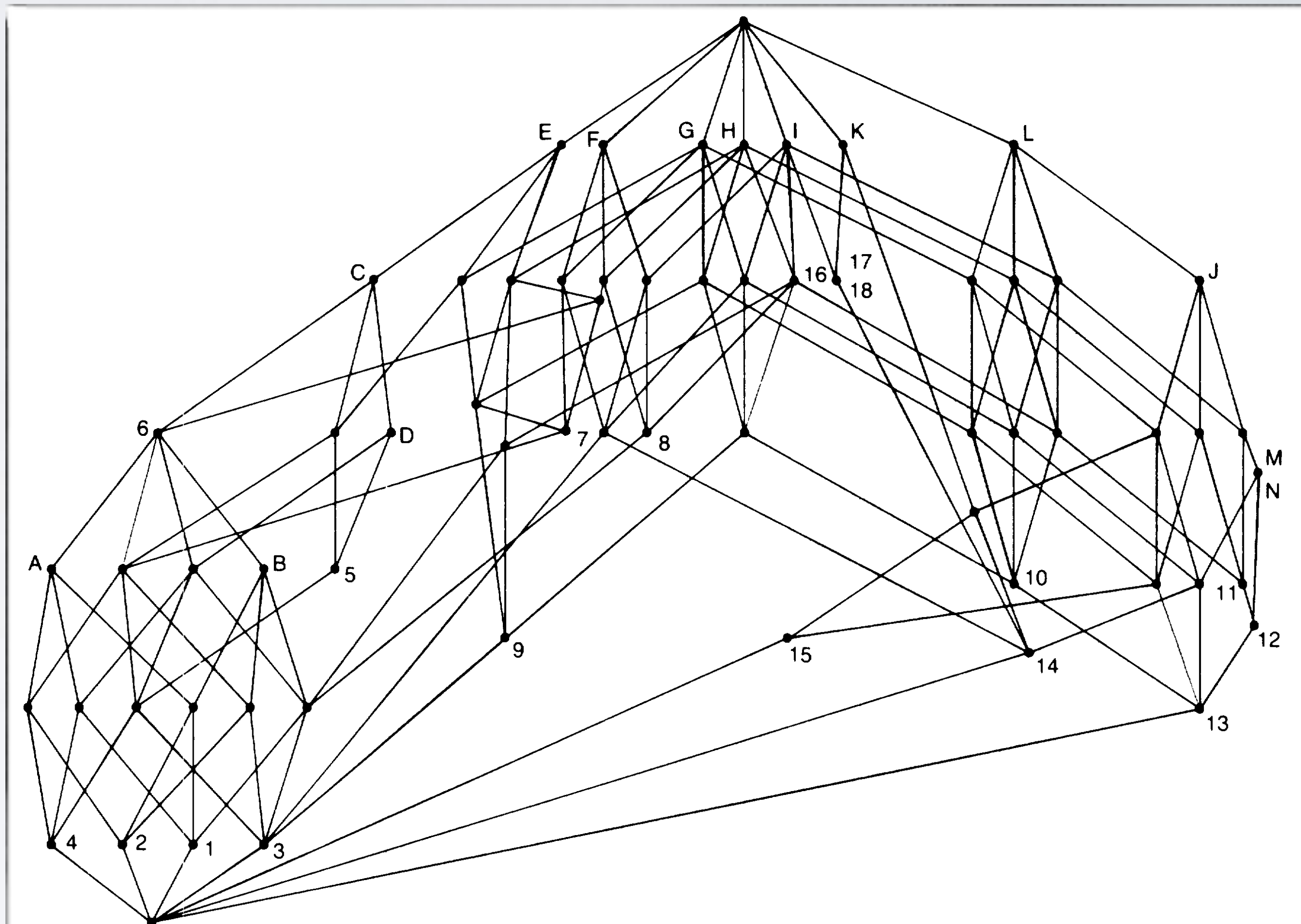

FIGURE 6. Lattice of the Davis, Gardner, and Gardner data.

SOCIO-SEMANTIC NETWORKS