Graph Visualization

Andre Suslik Spritzer

INRIA

Graph visualization

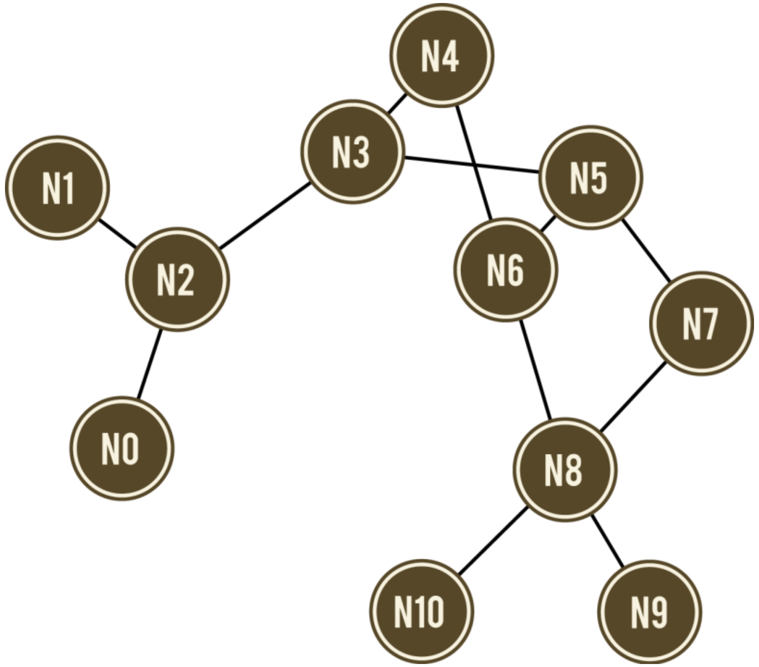
- Node-link diagrams
- Navigation and interaction
- Alternative representations
- Applications, toolkits, and libraries

Visual representations of graphs

- Analysis and communication
- Draw on human cognitive abilities
- Make graphs instantly easier to understand

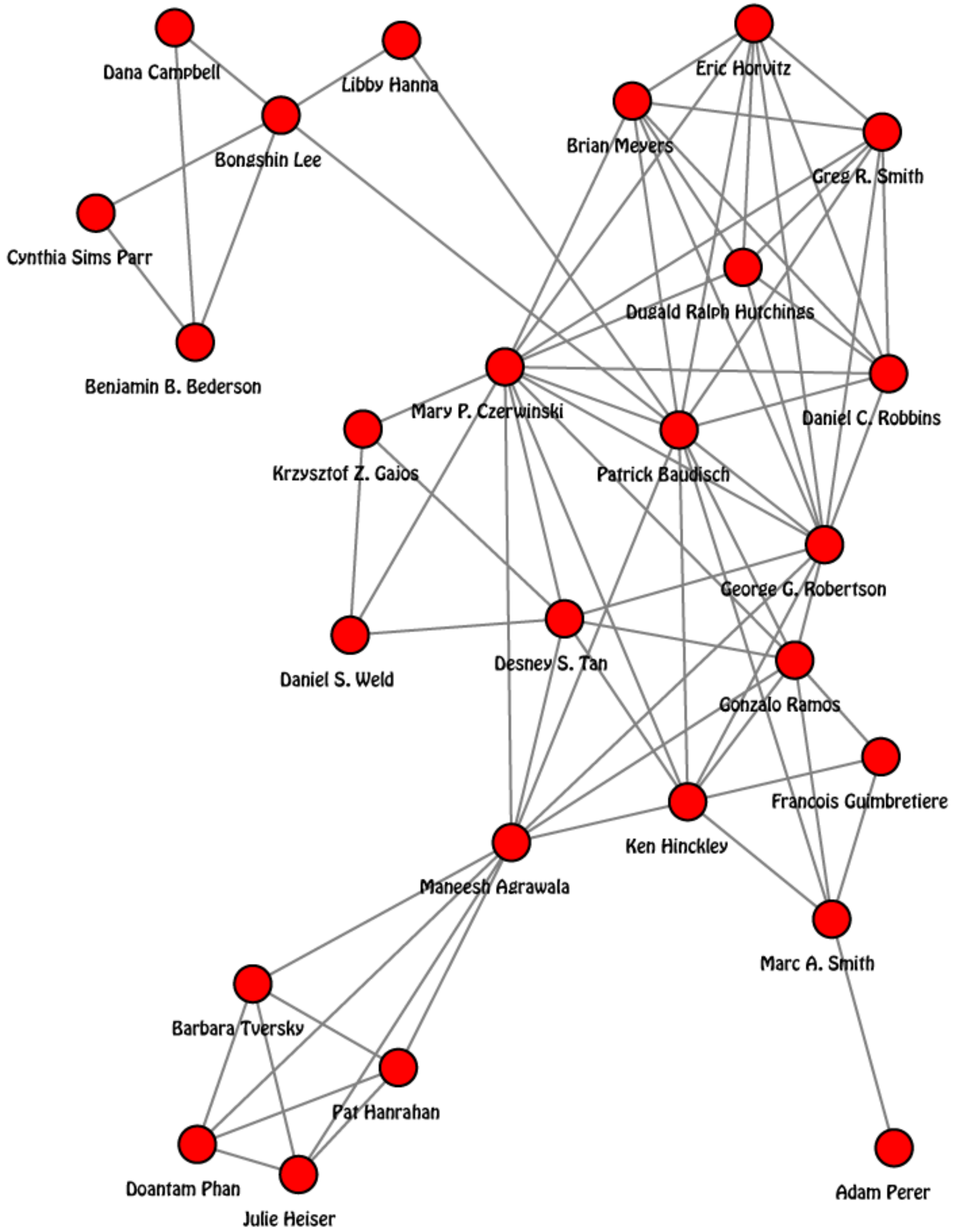
V = { N0, N1, N2, N3, N4, N5,
N6, N7, N8, N9, N10 }

E = { (N0, N2), (N1, N2), (N2, N3), (N3, N4), (N3, N5), (N4, N6), (N5, N6), (N5, N7), (N6, N8), (N7, N8), (N8, N9), (N8, N10) }



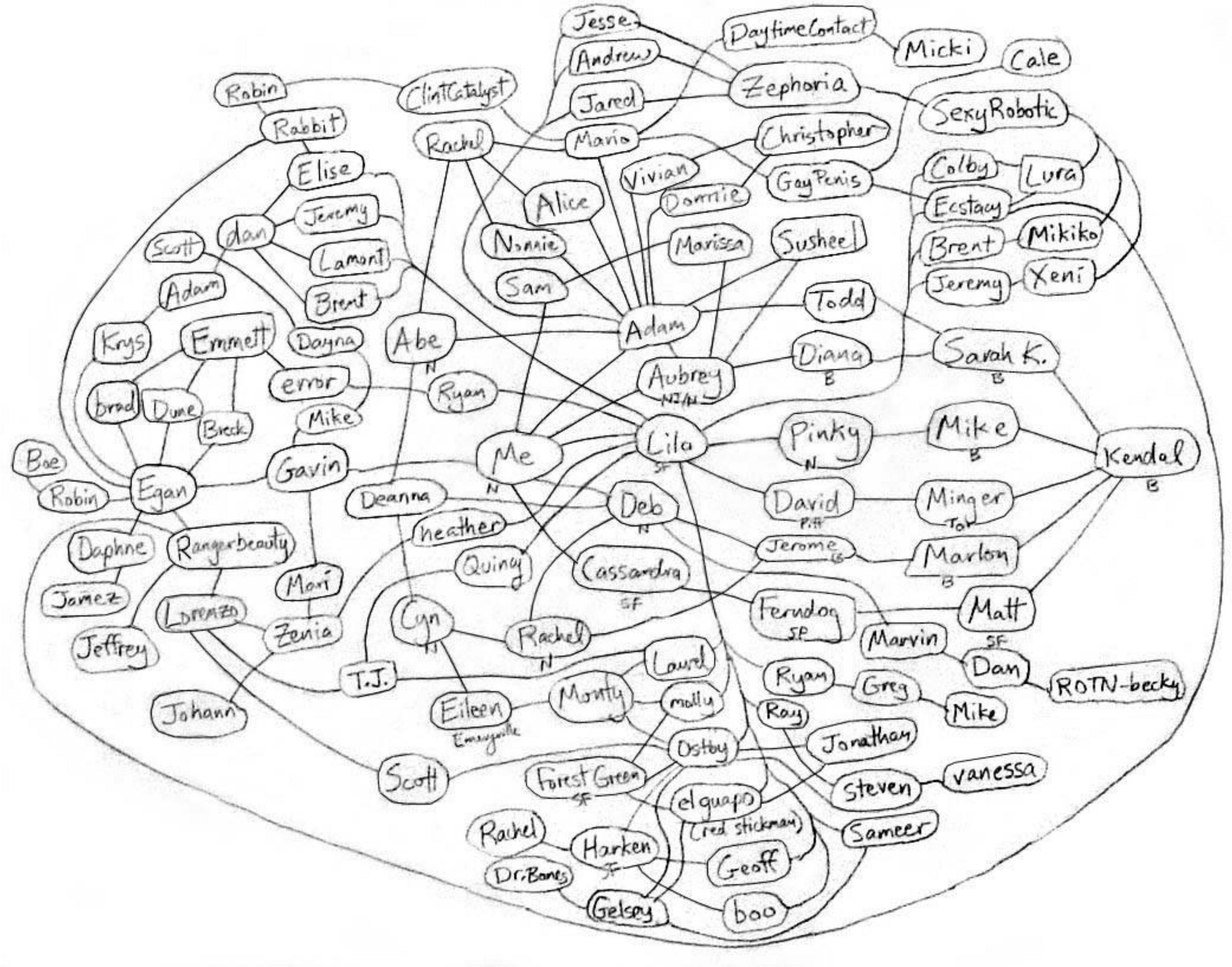
Node-link diagram

- Most typical visual representation of a graph
- Direct visual mapping of the abstract mathematical structure
- Nodes are visual objects connected by lines representing the edges



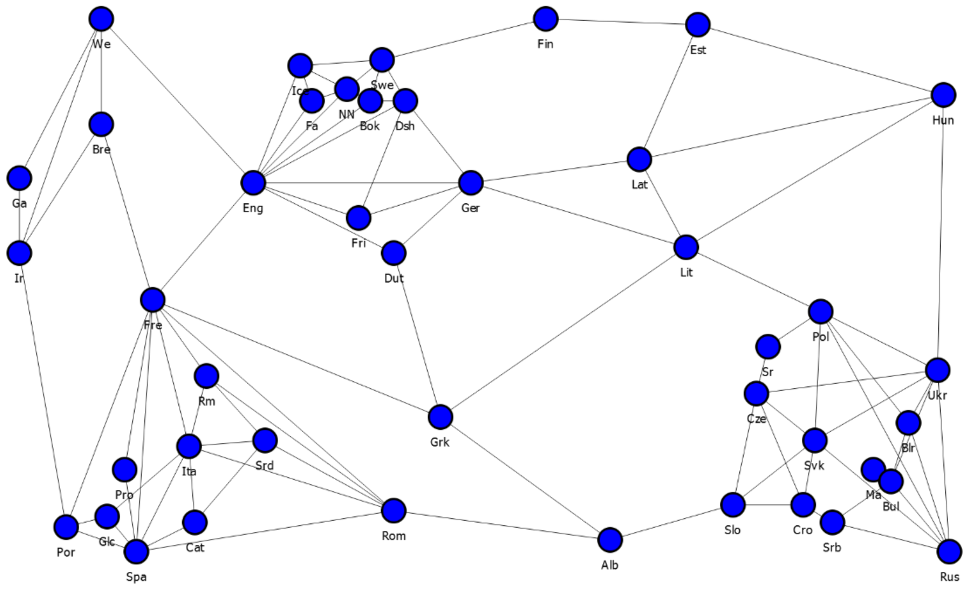
Node-link diagrams

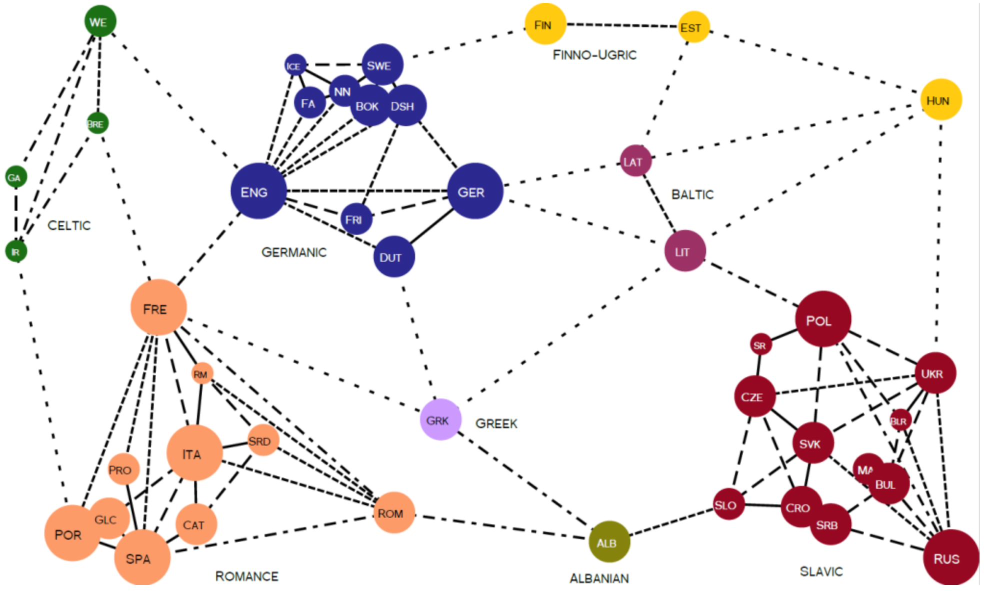
- Initially hand-drawn
  - Sociograms
    - Already used by early social scientists to study social networks
  - Not very practical...



Graph drawing

- Automated generation of node-link diagrams
- Layout algorithms
  - Calculate node positions and edge curves
- Visual attributes
  - Nodes: size, color, shape, label…
  - Edges: direction, length, color, shape…
- Large community
  - Annual Graph Drawing conference
    - http://www.graphdrawing.org

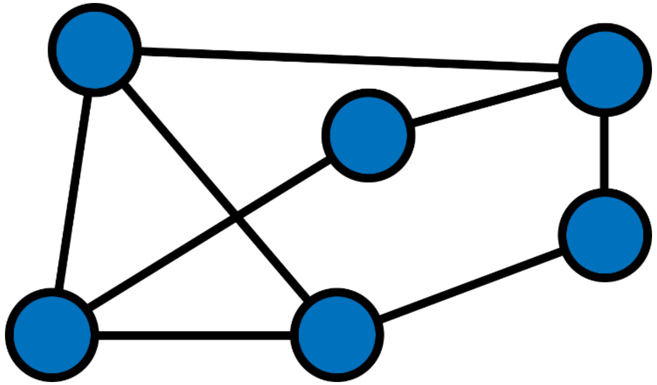


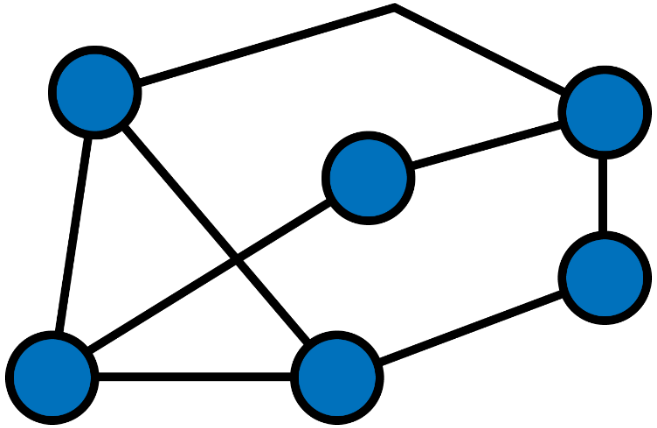


Layout algorithms

- General aesthetic constraints

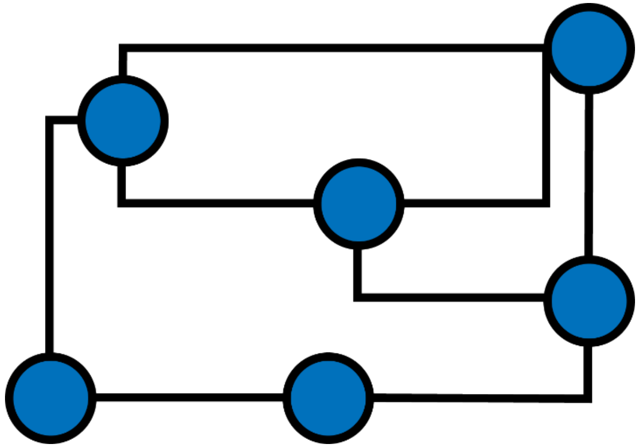
Straight lines

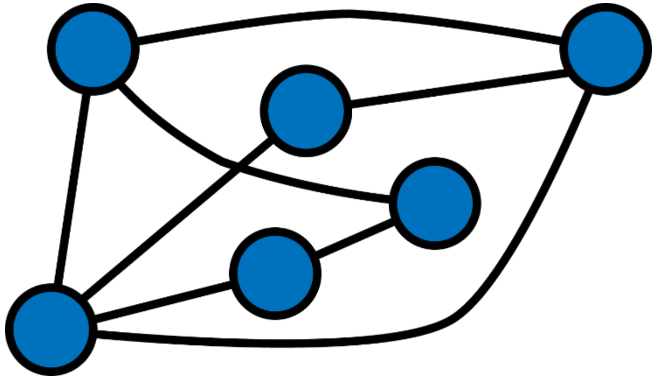




Polylines

Orthographic



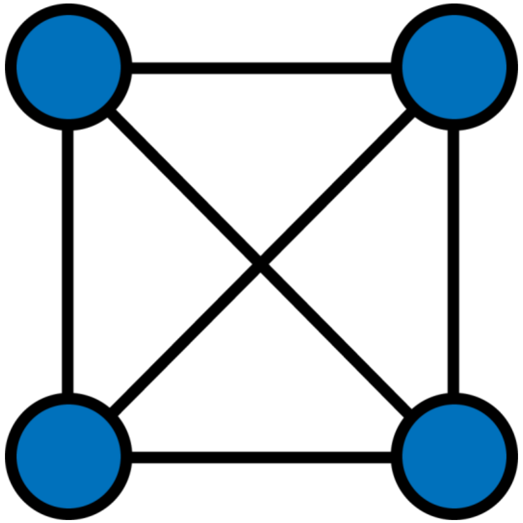


Curved

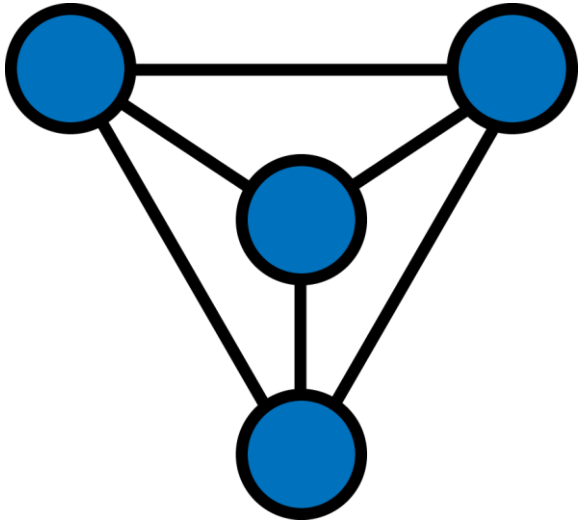
Aesthetic criteria for layout algorithms

- Layout design goals, such as:
  - Minimization of edge crossings
  - Minimization of edge bends
  - Maximization of the display of symmetric structures
  - Maximization of orthogonality
  - Uniform edge lengths
  - Even distribution of nodes

  …
- Criteria can rarely be simultaneously optimized



Maximizing symmetry



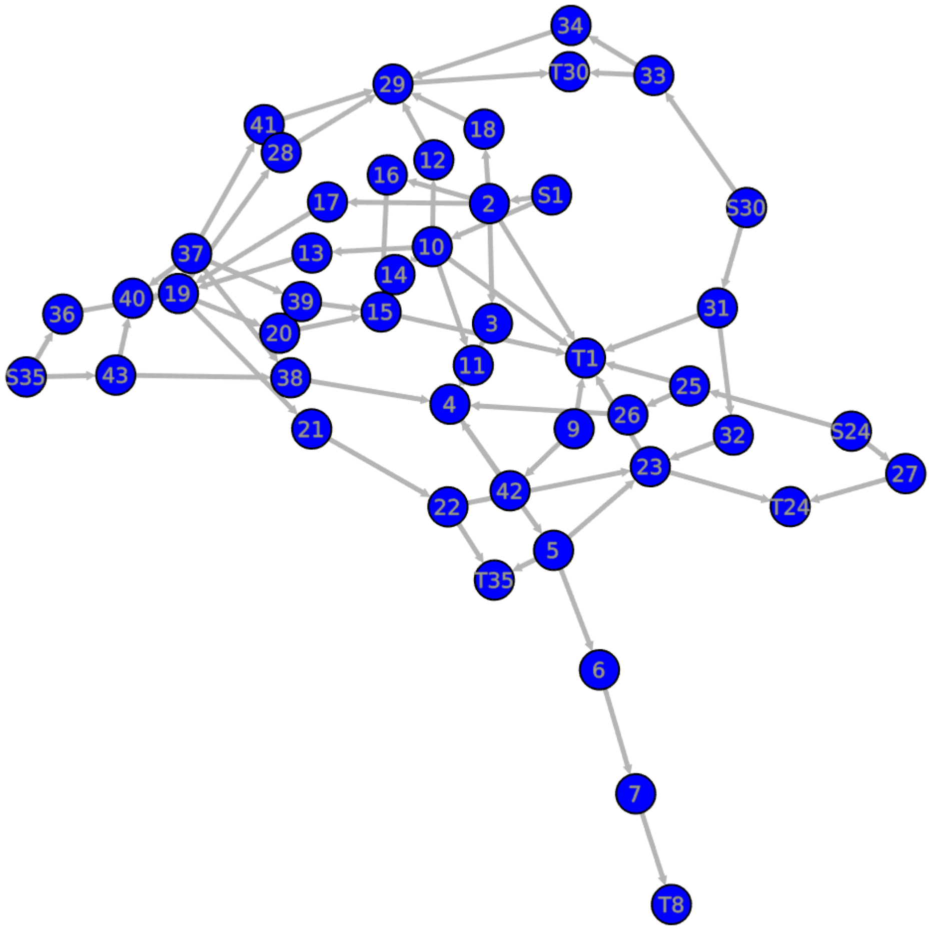
Minimizing crossings

Layout algorithms

- For general graphs or specific classes (e.g., trees, planar graphs, directed acyclic graphs, etc.)
- Many approaches:
  - Force-directed
  - Hierarchical
  - Orthogonal
  - Radial
  - Spectral
  - Attribute-driven
  - 2D, 3D

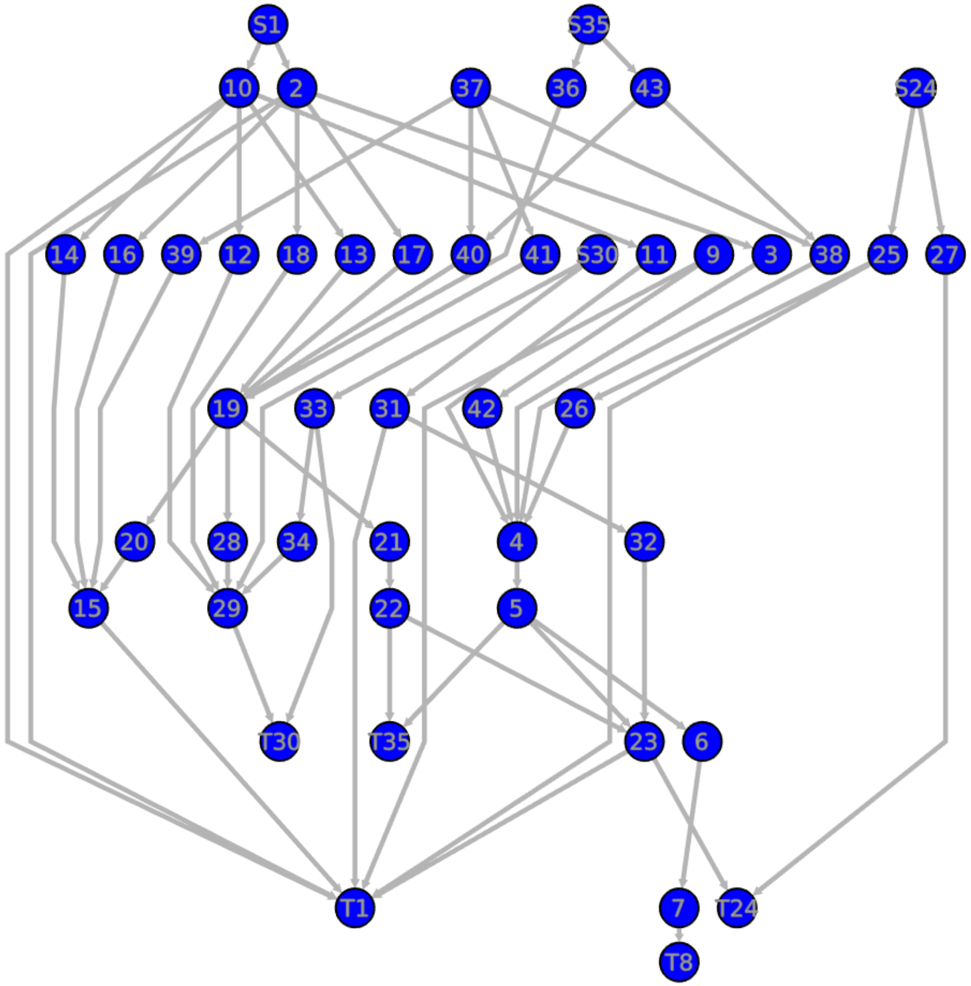
    …
- Handbook of Graph Drawing and Visualization (TAMASSIA 2013)
  - https://cs.brown.edu/~rt/gdhandbook/

Layout algorithms



Fruchterman-Reingold

Force-directed

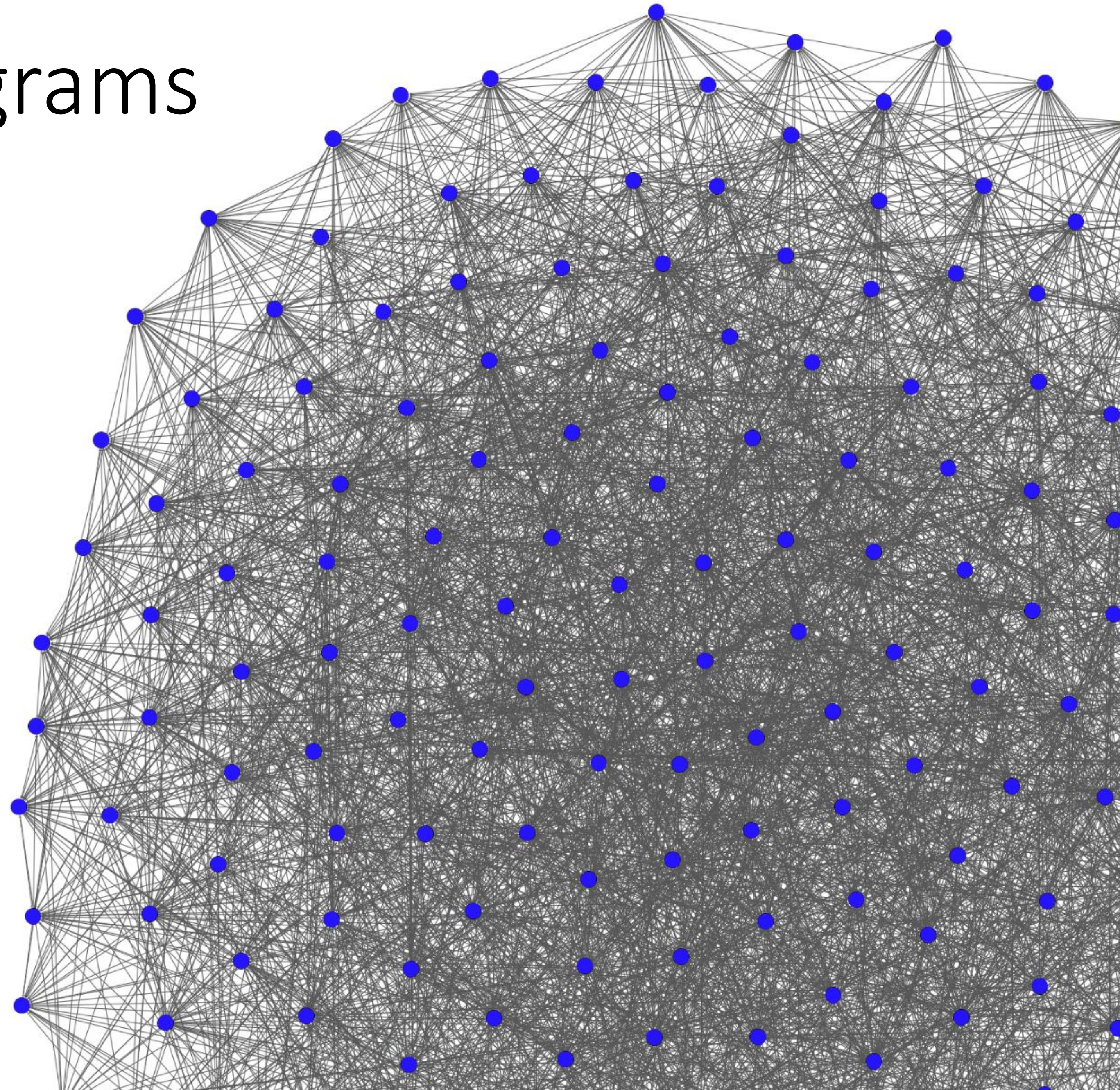


Sugiyama

Hierarchical

Simple node-link diagrams

- Good for static graphs that are neither too big nor too dense
  - But graphs can also be large, dense, or dynamic

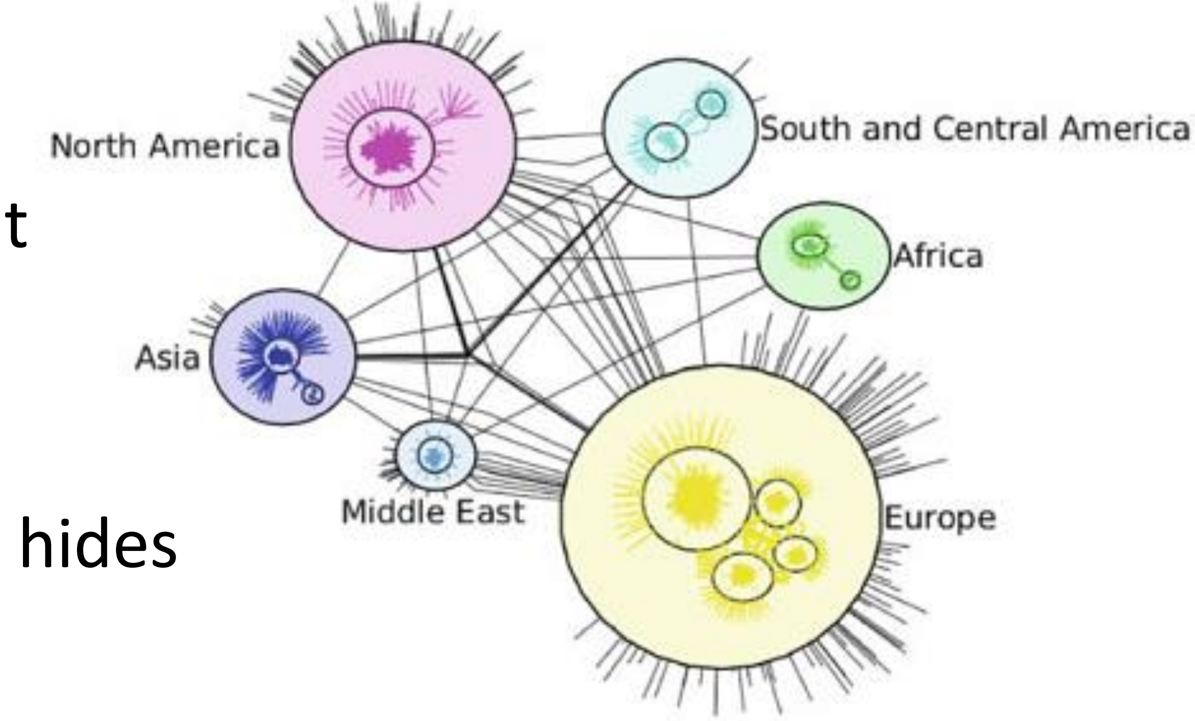


Dealing with more complex graphs

- Clustering
- Navigation + interaction
- Alternative visual representations

Clustering

- Useful for large graphs
  - Simplify them so that regular layout algorithms can be used
- Single visual element can represent several nodes
  - Metanodes
  - Edge bundling
- Makes graph structure clearer, but hides detail
  - Solution: interactive level-of-detail/semantic zooming strategy

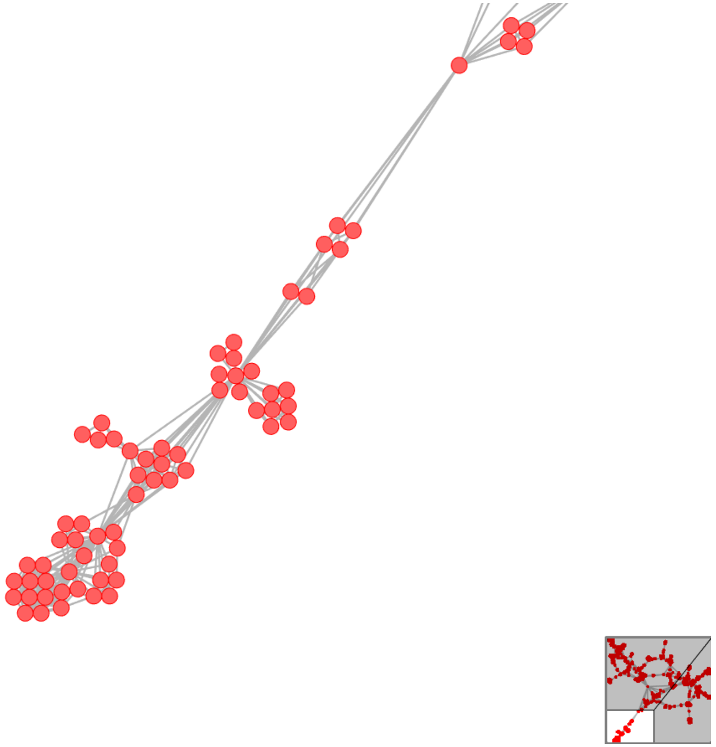


Interaction and navigation

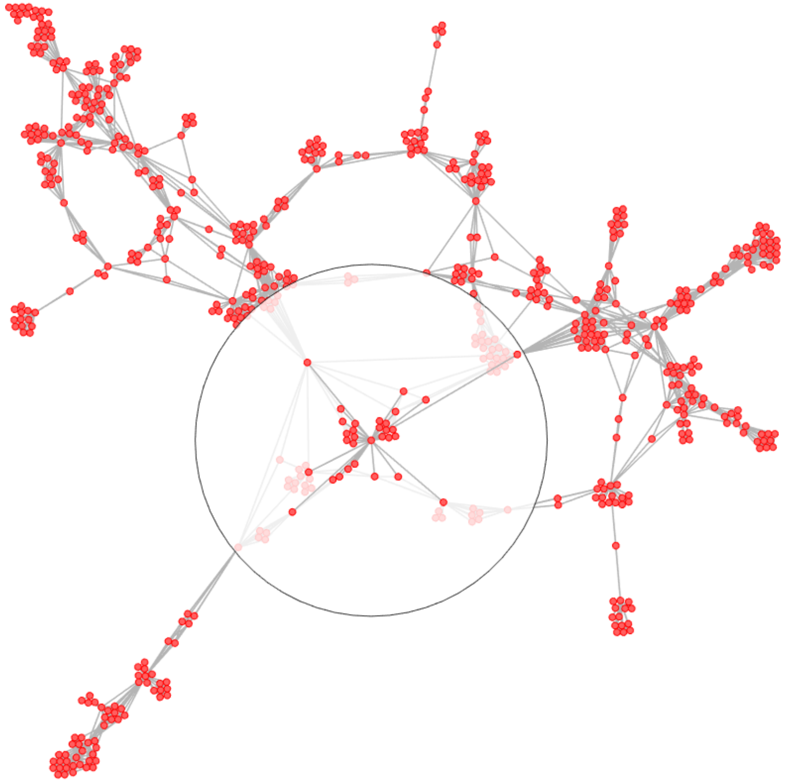
- Panning / scrolling
- Zooming
  - Geometric
    - Scale
  - Semantic
    - Level of detail
- Selection
- Search
- Filtering
- Incremental navigation and exploration
  - Large graphs or graphs of unknown size (e.g., the web)

Interaction and navigation

- Visualization strategies



Overview + Detail



Focus + Context

Interactive modification

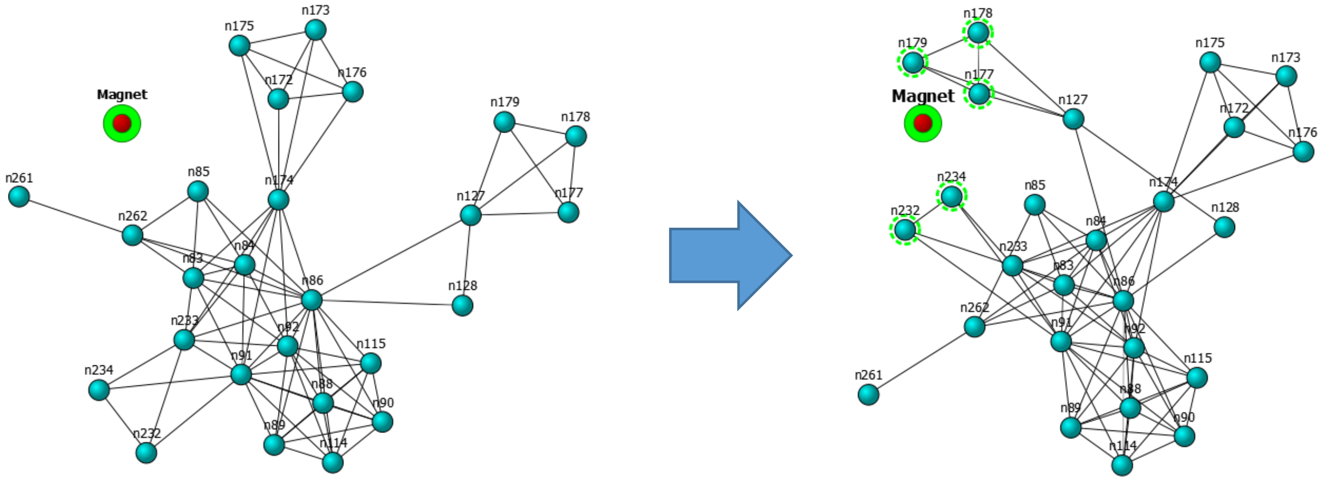
- Use graph topology, semantics, and meta-information to change a node-link diagram’s layout and/or visual attributes

- Exploration
  - Uncover otherwise unseen relationships (i.e., not explicit in the graph’s topology)

- Communication
  - Reshape a graph to help tell a story that is already known

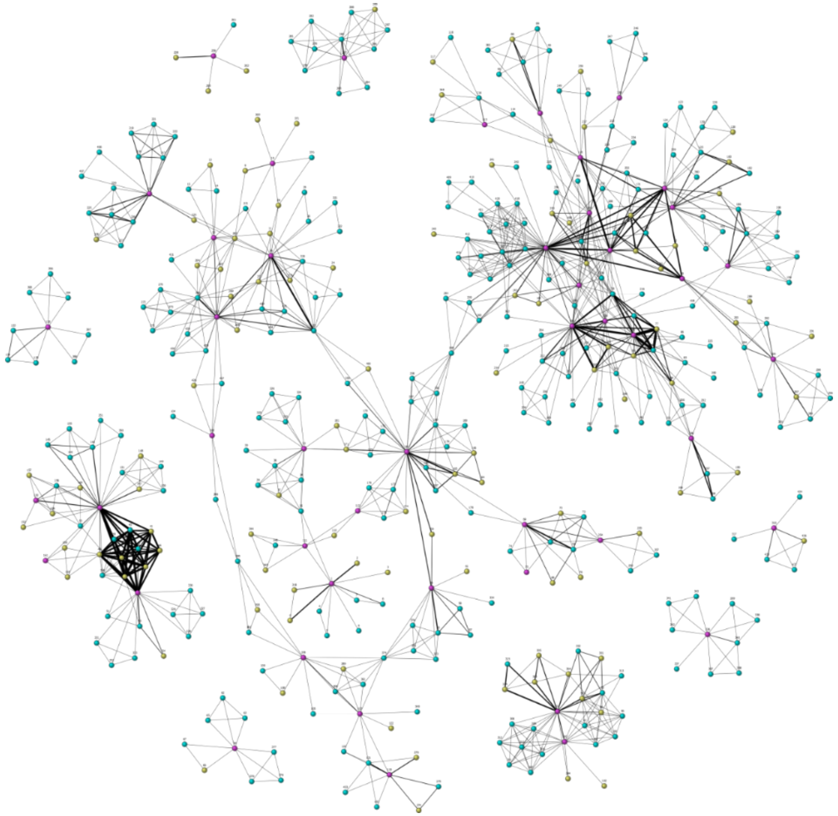
Interactive modification

- MagnetViz (SPRITZER & FREITAS, 2012)
  - Based on force-directed algorithms
  - Magnets that help users reshape layouts
    - Uses both topology and semantics

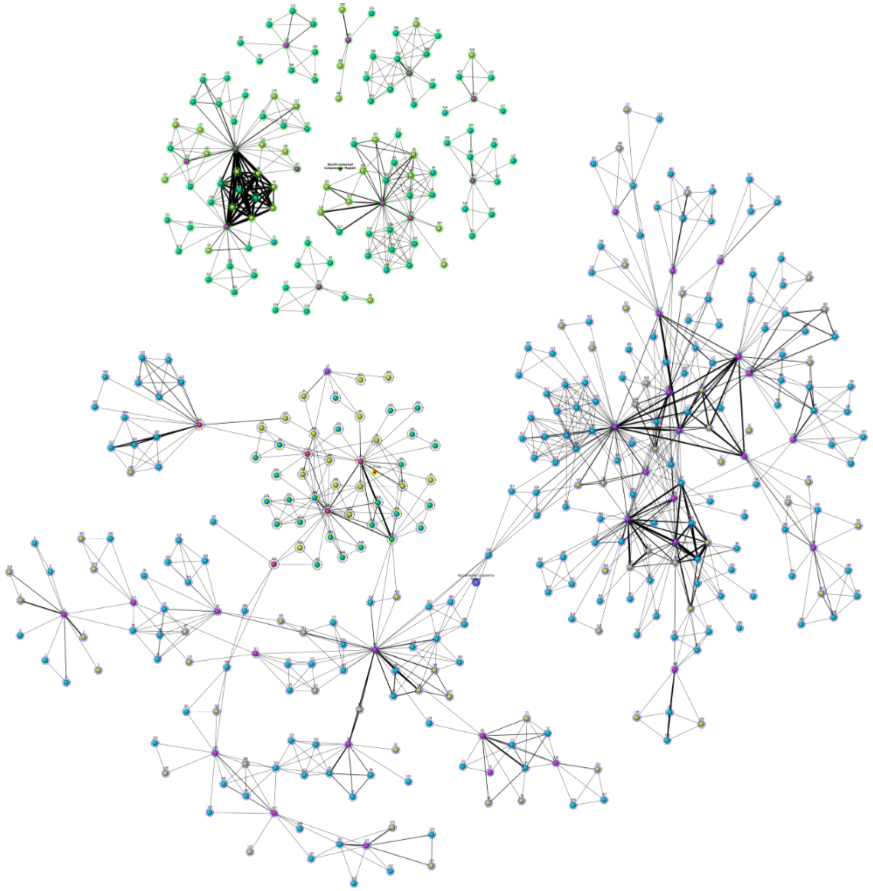


Interactive modification

- MagnetViz (SPRITZER & FREITAS, 2012)



Original Layout



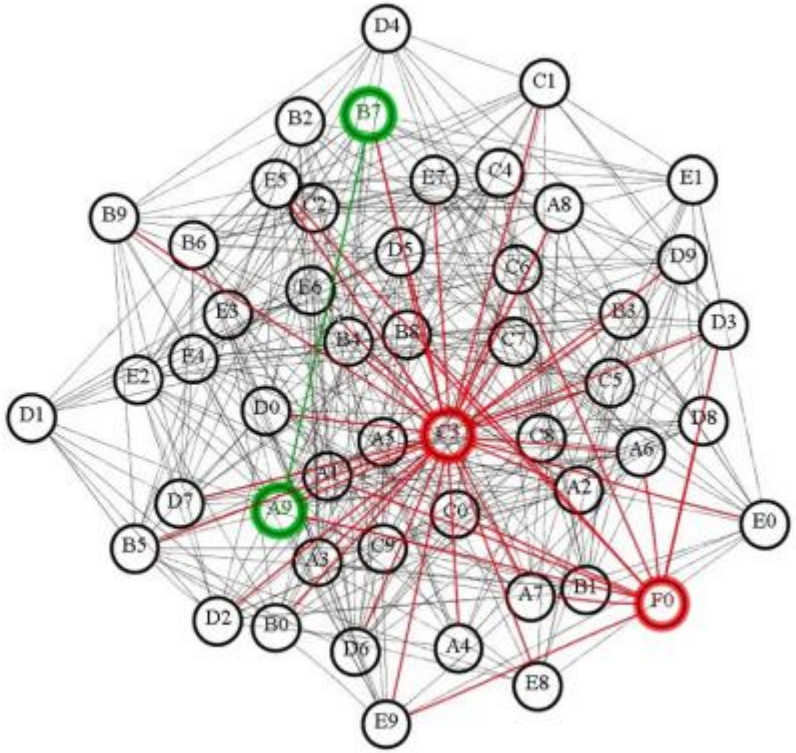
New Layout

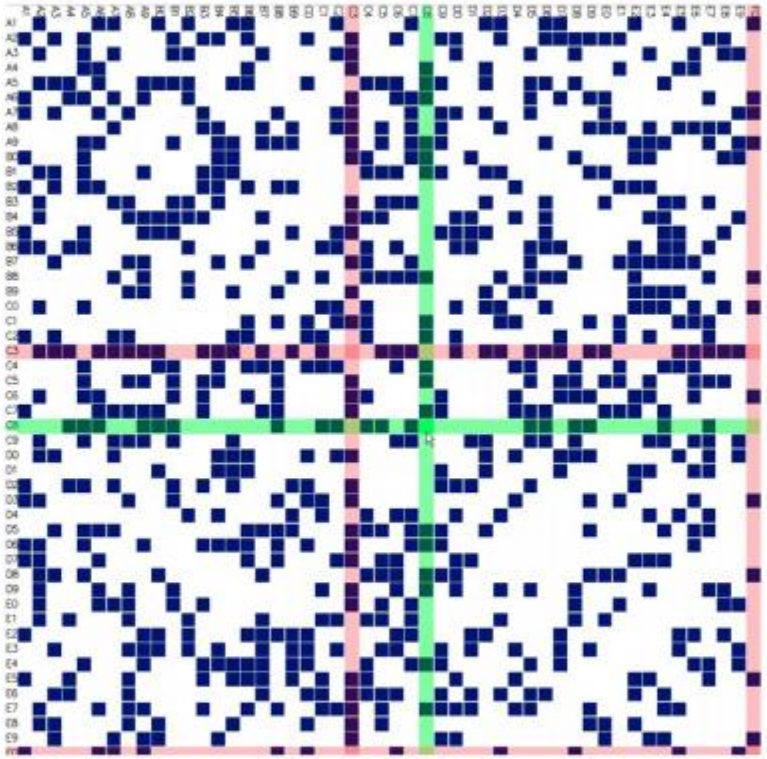
Interactive modification

- GraphCoiffure (SPRITZER et al. 2015)
  - Lets users import and beautify graphs
    - Beautification → touch up a visualization to enhance its communicative power or make it conform to a desired aesthetics

Alternative visual representations

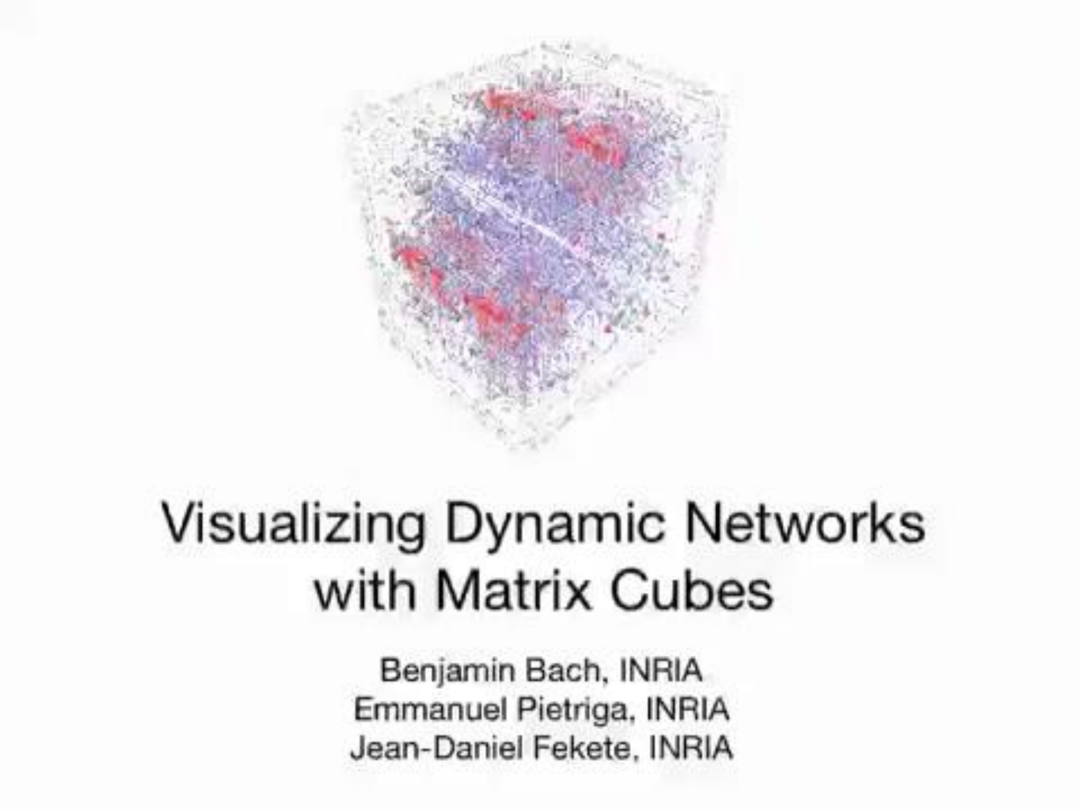
- Matrices
  - Adjacency matrix
  - Study by Ghoniem, Fekete, and Castagliola
    - Several advantages over node-link diagrams for larger/denser graphs





Alternative visual representations

- Cubix (BACH 2013)

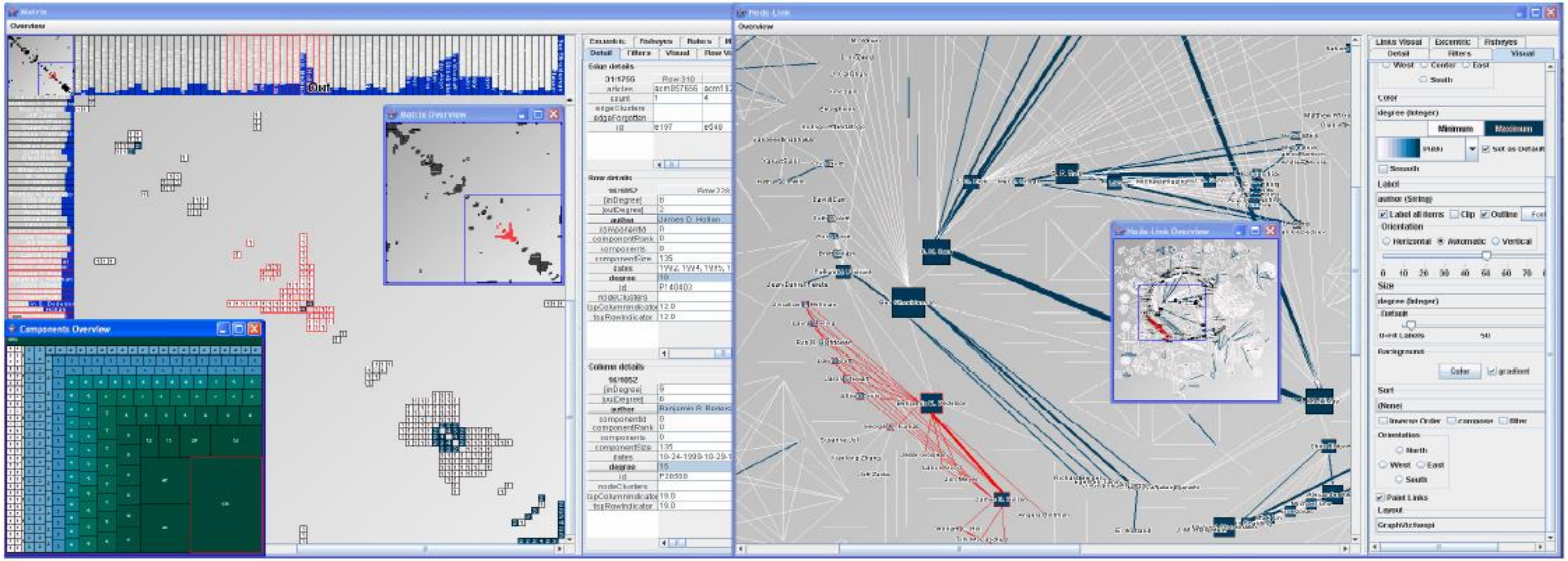


Visualizing Dynamic Networks
with Matrix Cubes

Benjamin Bach, INRIA
Emmanuel Pietriga, INRIA
Jean-Daniel Fekete, INRIA

Alternative visual representations

- Combining the best of both worlds: coordinated views
  - MatrixExplorer (HENRY 2006)



Edge details

31/1756	Row 310	
articles	acm857656	acm1
count	1	4
edgeClusters		
edgeForgotten		
id	e197	e548

Row details

98/1052	Row 228
[inDegree]	8
[outDegree]	2
author	James D. Hollan
componentId	0
componentRank	0
components	0
componentSize	135
dates	1992, 1994, 1995, 1
degree	10
id	P140403
nodeClusters	
tspColumnIndicator	12.0
tspRowIndicator	12.0

Column details

98/1052	
[inDegree]	8
[outDegree]	0
author	Benjamin B. Bederson
componentId	0
componentRank	0
components	0
componentSize	135
dates	10-24-1999-10-29-1
degree	16
id	P20550
nodeClusters	
tspColumnIndicator	19.0
tspRowIndicator	19.0

○ West ○ Center ○ East
○ South

Color
degree (Integer)
Minimum Maximum
PuBu ☑ Set as Default
□ Smooth

Label
author (String)
☑ Label all items □ Clip ☑ Outline Font
Orientation
○ Horizontal ● Automatic ○ Vertical
0 10 20 30 40 50 60 70

Size
degree (Integer)
Default
U-Fit Labels 50

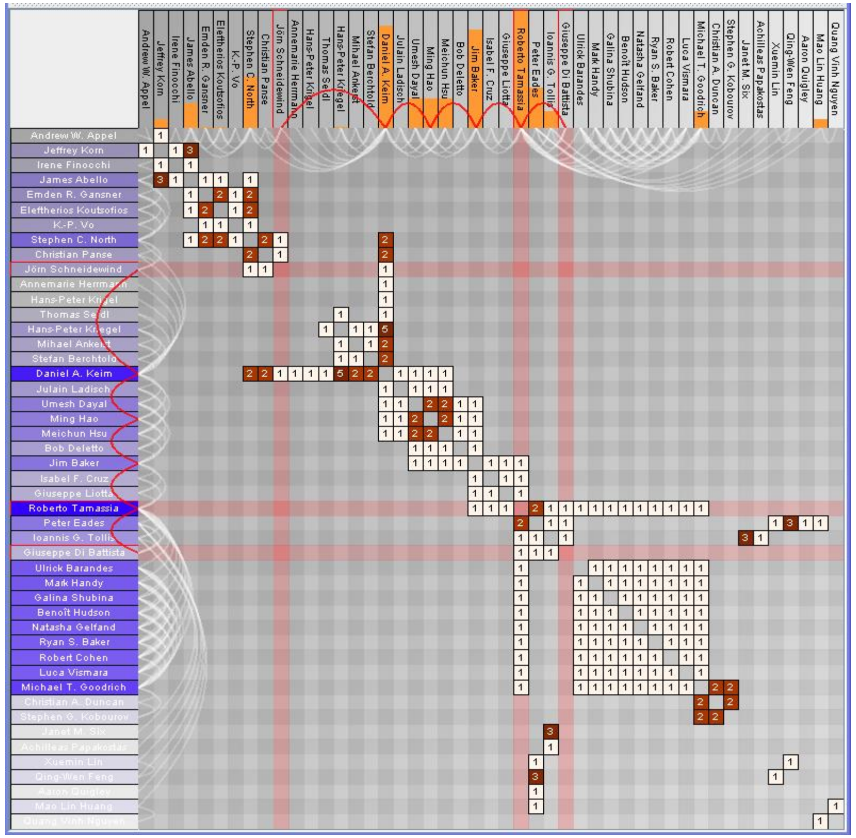
Background
Color ☑ gradient

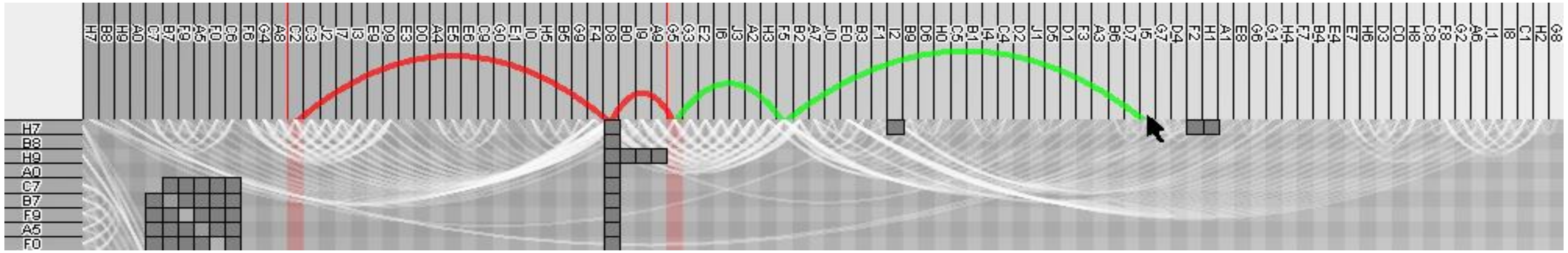
Sort
(None)
□ Inverse Order □ compose □ filter
Orientation
○ North
○ West ○ East
○ South
☑ Paint Links

Layout
GraphVizAdapt

Hybrid visualizations

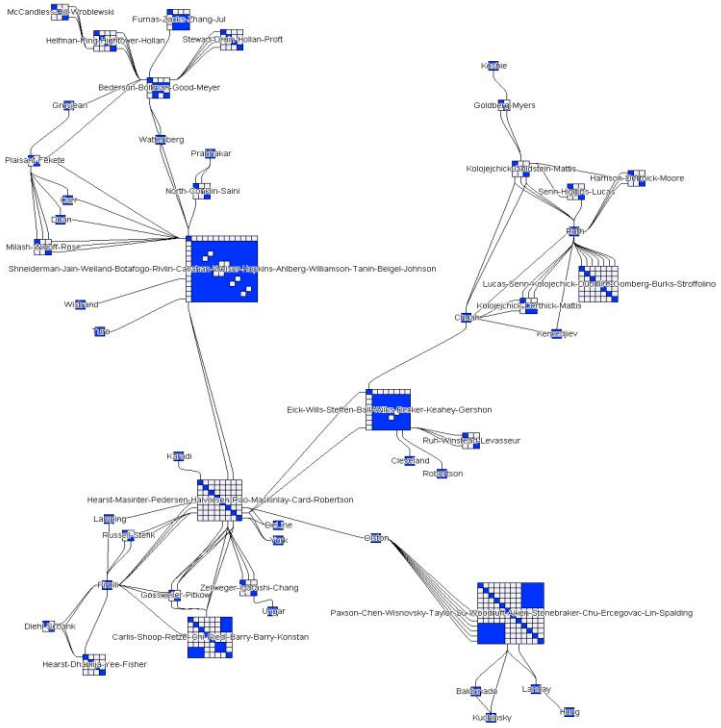
- MatLink (HENRY 2007)
  - Enhances matrix visualization
  - Edges are drawn superimposed to the matrix representation
    - Makes path-related tasks easier



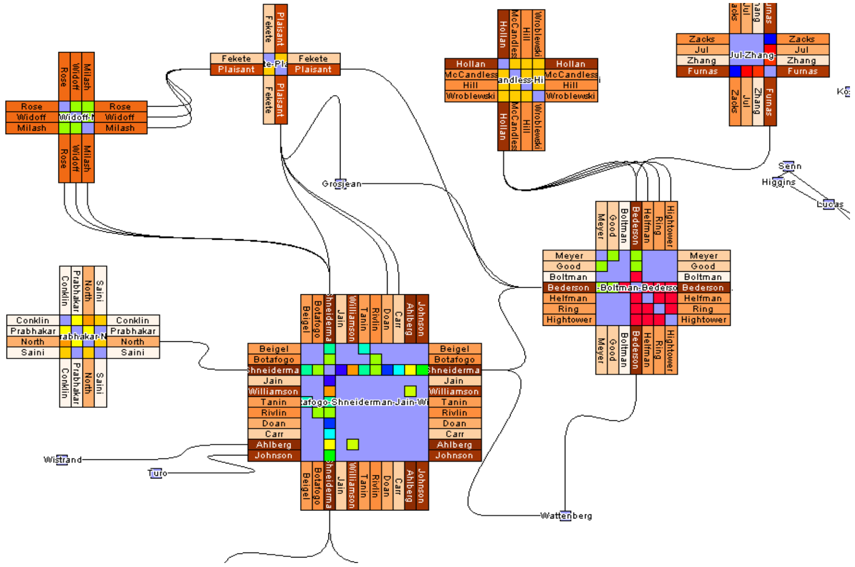


Hybrid visualizations

- NodeTrix (HENRY 2007)
    - Hybrid of matrix and node-link visualizations
    - Subgraphs are represented as matrices and linked to other subgraphs by edges

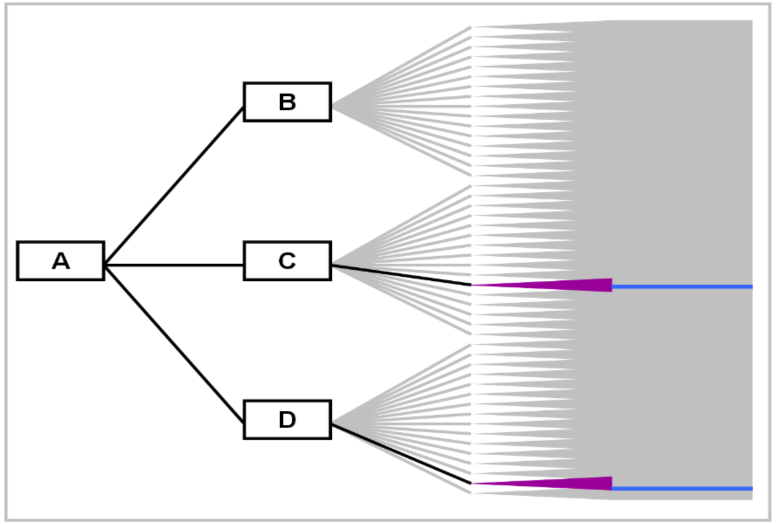


McCandless-Hill-Wroblewski
Furnas-Zacks-Zhang-Jul
Helfman-Ring-Hightower-Hollan
Stewart-Druin-Hollan-Proft
Bederson-Boltman-Good-Meyer
Grosjean
Wattenberg
Prabhakar
Plaisant-Fekete
North-Conklin-Saini
Carr
Doan
Milash-Widoff-Rose
Shneiderman-Jain-Weiland-Botafogo-Rivlin-Callahan-Weiser-Hopkins-Ahlberg-Williamson-Tanin-Beigel-Johnson
Wistrand
Turo
Kessie
Goldberg-Myers
Kolojejchick-Goldstein-Mattis
Harrison-Derthick-Moore
Senn-Higgins-Lucas
Roth
Lucas-Senn-Kolojechick-Dunmire-Gomberg-Burks-Stroffolino
Kolojejchick-Derthick-Mattis
Chuah
Kerpedjiev
Eick-Wills-Steffen-Ball-Willis-Becker-Keahey-Gershon
Ruh-Winstead-Levasseur
Cleveland
Robertson
Karadi
Hearst-Masinter-Pedersen-Halvorsen-Rao-Mackinlay-Card-Robertson
Lamping
Russell-Stefik
DeLine
York
Olston
Pirolli
Gossweiler-Pitkow
Zellweger-Igarashi-Chang
Ungar
Diehl-Srbank
Carlis-Shoop-Retzel-Shi-Riedl-Barry-Barry-Konstan
Hearst-Dhamija-Yee-Fisher
Paxson-Chen-Wisnovsky-Taylor-Su-Woodruff-Aiken-Stonebraker-Chu-Ercegovac-Lin-Spalding
Baldonado
Lanclay
Kuchinsky
Hong

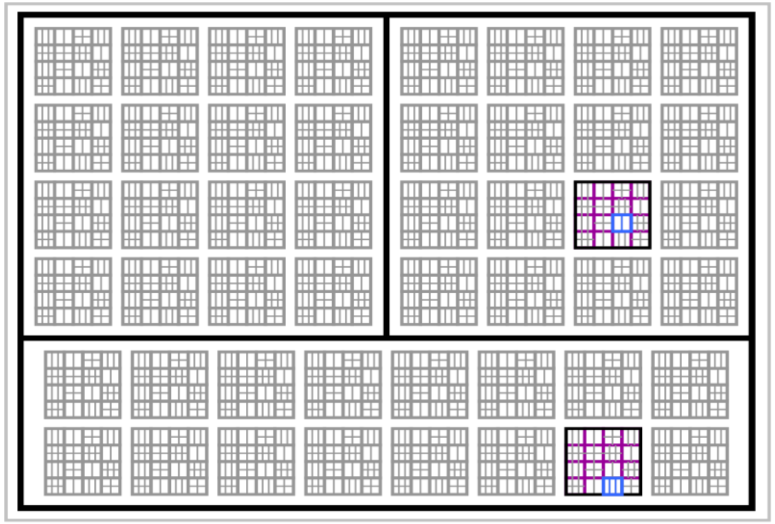


Hybrid visualizations

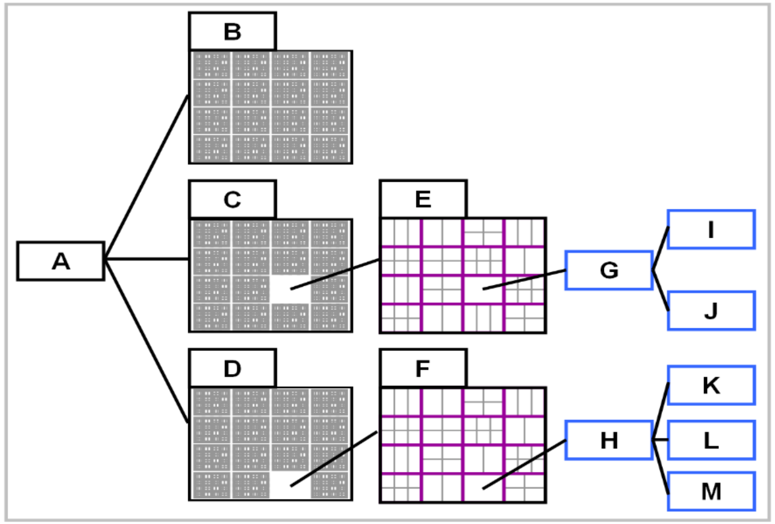
- Elastic Hierarchies [ZHAO 2005]
  - Combines node-link diagrams and treemaps



Node–Link Diagram



Treemap



Elastic Hierarchy

Graph visualization applications

- Pajek
- Cytoscape
- Tulip
- Gephi
- yEd
- Graphviz
- aiSee
- UCINet

Graph visualization toolkits and libraries

- Ubigraph
    - 3D, several platforms
- C++
    - OGDF
    - Graphviz
    - Tulip
    - Gephi
    - Boost

- Javascript
    - D3
    - Sigma
    - Vis.js
    - Alchemy.js
- .NET
    - Microsoft Automatic Graph Layout

Questions?