15 Views of a Node-Link Graph: An InfoVis Portfolio

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Information Esthetics Lecture Series One
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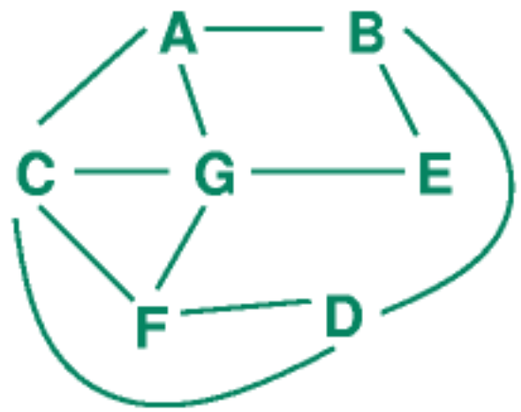
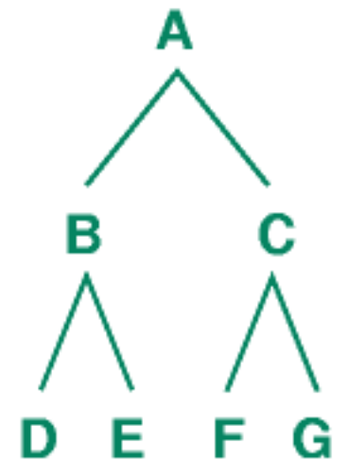
15 Views of a Node-Link Graph: An InfoVis Portfolio

node-link graph

- common abstraction: nodes connected by edges
- trees are special case: hierarchy with no cycles





infovis: information visualization

- visual representation of abstract data
  computer-based: interactivity possible
- help human perform some task more effectively

Information Esthetics

manifesto

- information content can enhance esthetic experience and esthetic consideration can enhance information content

successful infovis as example

- design guidelines for visual encoding as interplay of perception, cognition, esthetics, and data/task characterization

Visual Channels

visual attribute of geometric mark

- position, color, size, shape, orientation, ...

separable vs. integral

color	color	color	size	x-size	red-green
position	motion	shape	orientation	y-size	yellow-blue

[Ware. Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Outline

Introduction

15 Views

- Traditional Graphs
- Nontraditional Representations
- Focus+Context Trees

Wrapup

1: Edge List

data: semantic network from Hofstadter book Godel, Escher, Bach

- nodes: topics
- links: discussion of ideas together in book

Turing – Halting problem
Halting problem – Infinity
Infinity – Paradoxes
Paradoxes – Lewis Carroll
Infinity – Lewis Carroll
Infinity – Unpredictably long searches
Infinity – Recursion
Infinity – Zeno
Infinity – Paradoxes
Lewis Carroll – Zeno
Lewis Carroll – Wordplay
Halting problem – Decision procedures
BlooP and FlooP – AI

Halting problem – Unpredictably long searches
BlooP and FlooP – Unpredictably long searches
BlooP and FlooP – Recursion
Tarski – Truth vs. provability
Tarski – Epimenides
Tarski – Undecidability
Paradoxes – Self-ref
Epimenides – Tarski
Epimenides – Paradoxes
Epimenides – Self-ref
[...]

Critique

strengths

- easy to create

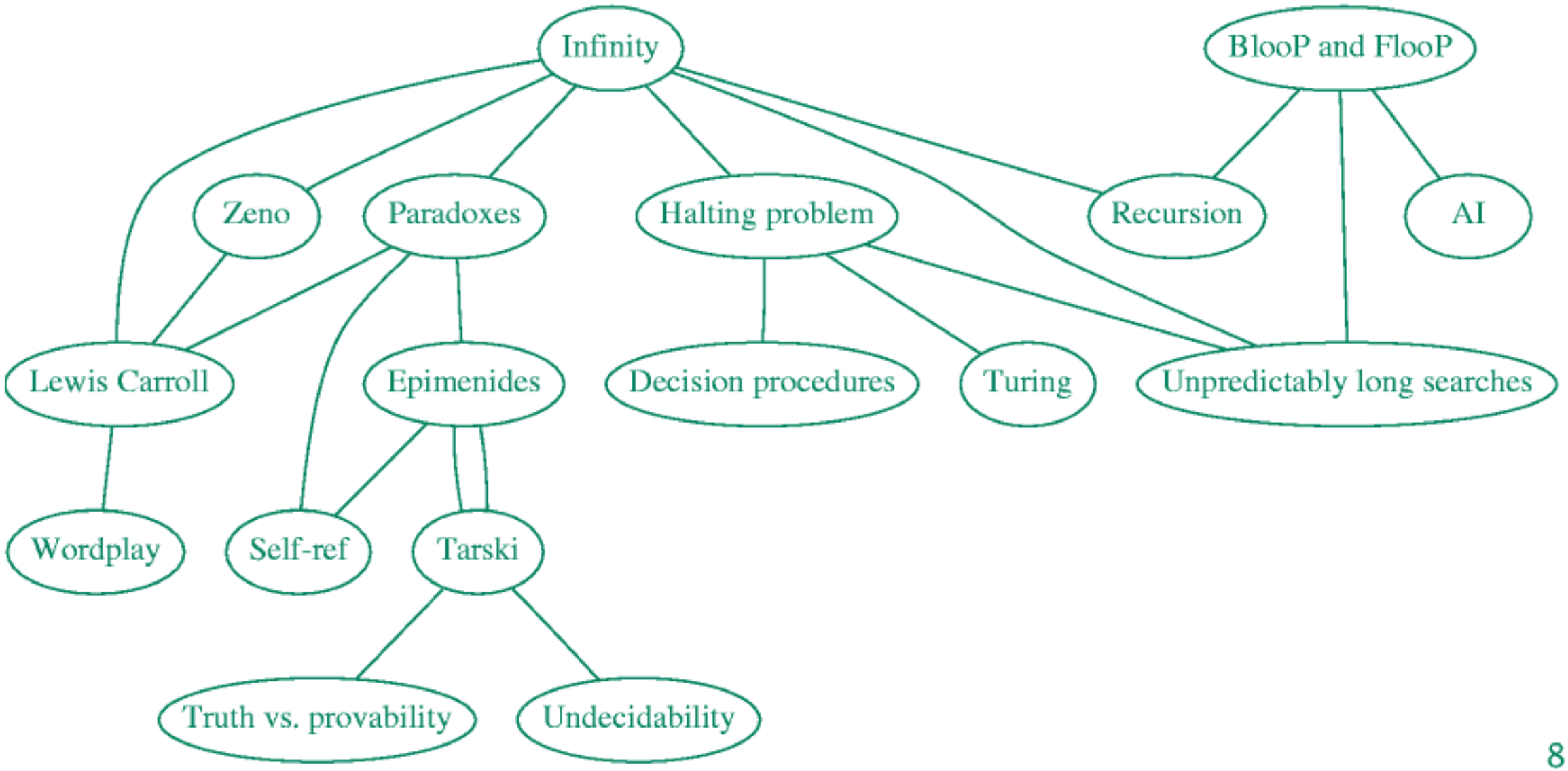
weaknesses

- requires too much memory and cognition
- does not exploit human perceptual system

Visual External Representation

read off answers from node-link graph drawing

- connections drawn between nodes
- offload cognition to visual system



2: Hand-Drawn

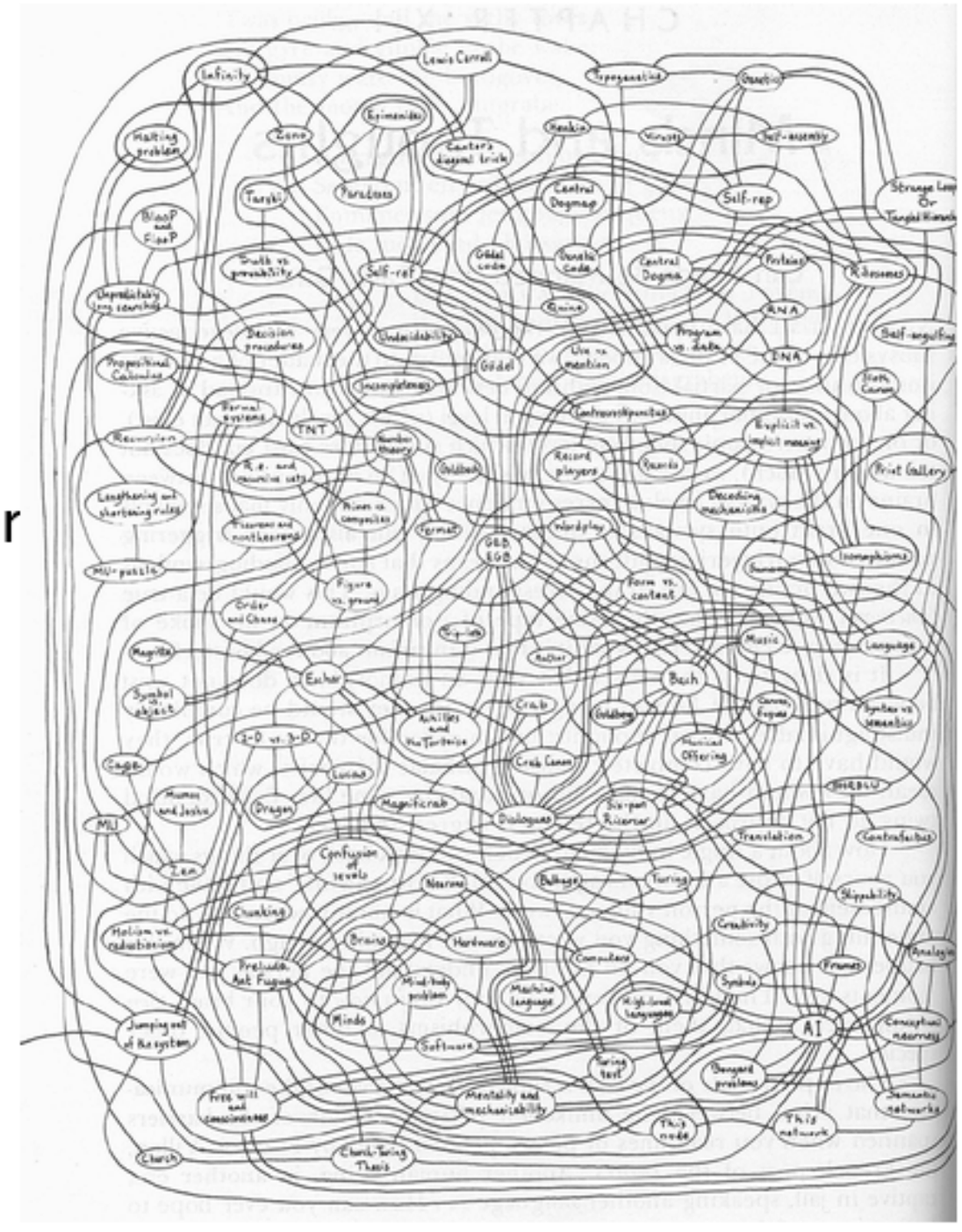
data: GEB semantic network

strengths

- high information density
  - ratio of marks to whitespace
  - foreground vs. background layer
- subtleties of spatial layout

weaknesses

- hours or days to create



[Hofstadter. Godel, Escher, Bach: an Eternal Golden Braid. Basic Books 1979]

3: Dot

data: semantic network

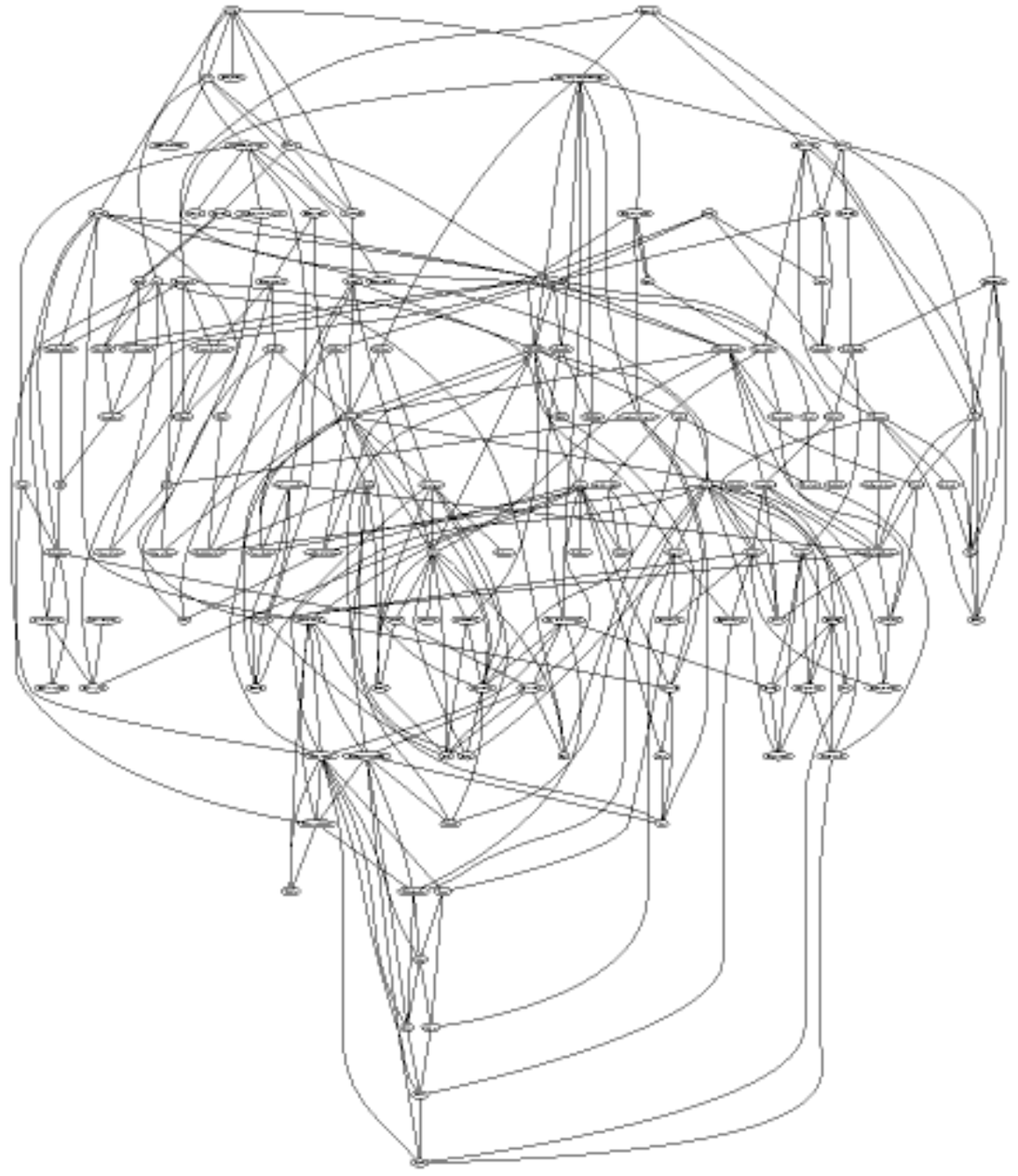
automatically compute positions for nodes, edges

strengths

- fast: one second to create
- careful routing of curved edges

weaknesses

- low information density
  can't read labels



[Gansner, Koutsofois, North and Vo.
A Technique for Drawing Directed Graphs.
IEEE Trans. Software Engineering, 19(3):214–229]

Graph Layout Criteria

minimize

- crossings, area, bends/curves

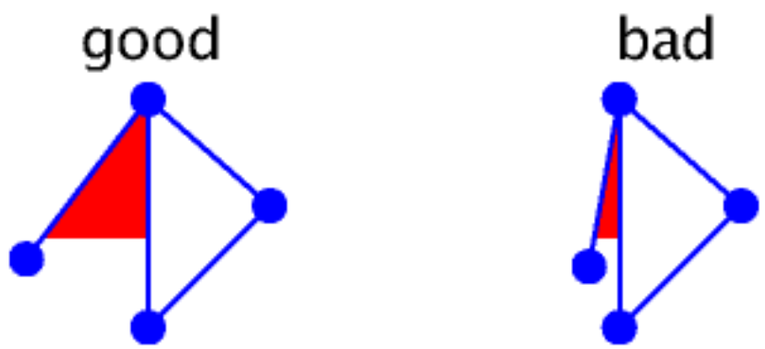
Graph Layout Criteria

minimize

- crossings, area, bends/curves

maximize

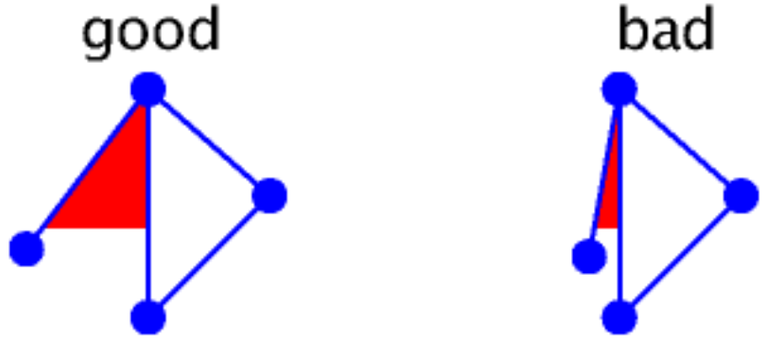
- angular resolution, symmetry



Graph Layout Criteria

minimize

- crossings, area, bends/curves



maximize

- angular resolution, symmetry

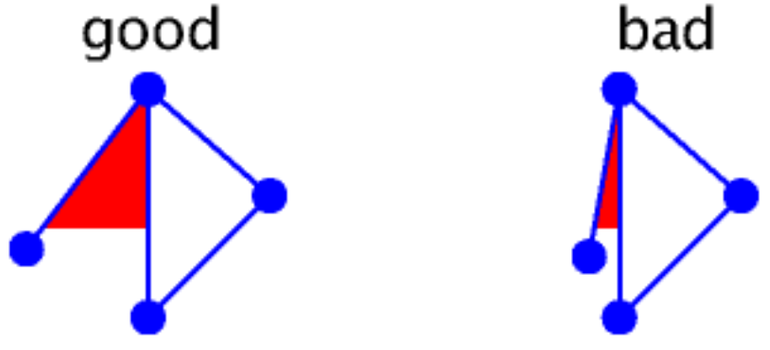
most criteria individually NP-hard

- cannot just compute optimal answer
- heuristics: try to find something reasonable

Graph Layout Criteria

minimize

- crossings, area, bends/curves



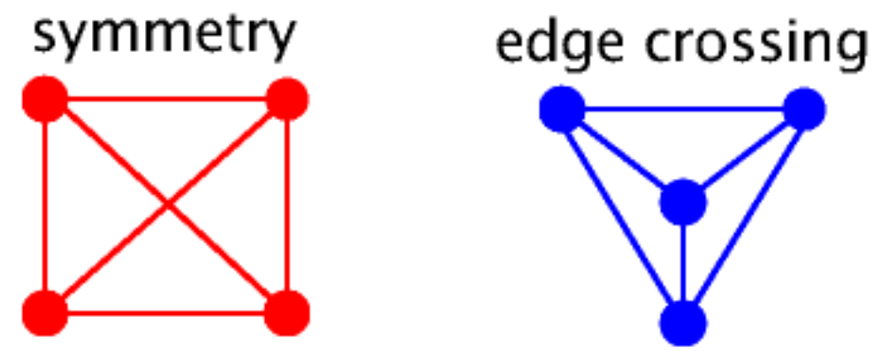
maximize

- angular resolution, symmetry

most criteria individually NP-hard

- cannot just compute optimal answer
- heuristics: try to find something reasonable

criteria mutually incompatible

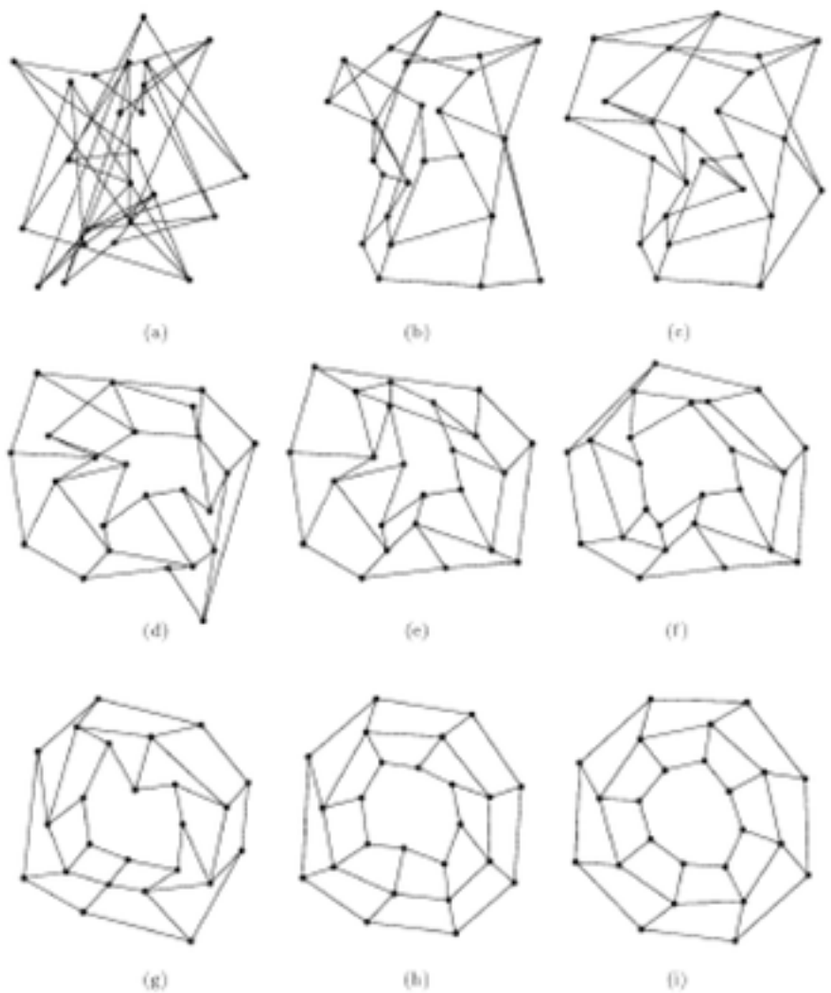


[Ware, Purchase, Colpys, and McGill. Cognitive Measures of Graph Aesthetics. Information Visualization 1(2):103-110, Palgrave 2002]
[Brandenburg. Nice Drawings of Graphs are Computationally Hard. Visualization in Human-Computer Interaction, Springer Verlag 1988]

4: Force-Directed Placement

nodes: repel like magnets
edges: attract like springs
- start from random positions, run to convergence

encoding: geometric for graph proximity



[www.csse.monash.edu.au/~berndm/CSE460/Lectures/cse460-7.pdf]

Critique

strengths

- intuitive model
- many mathematical approaches

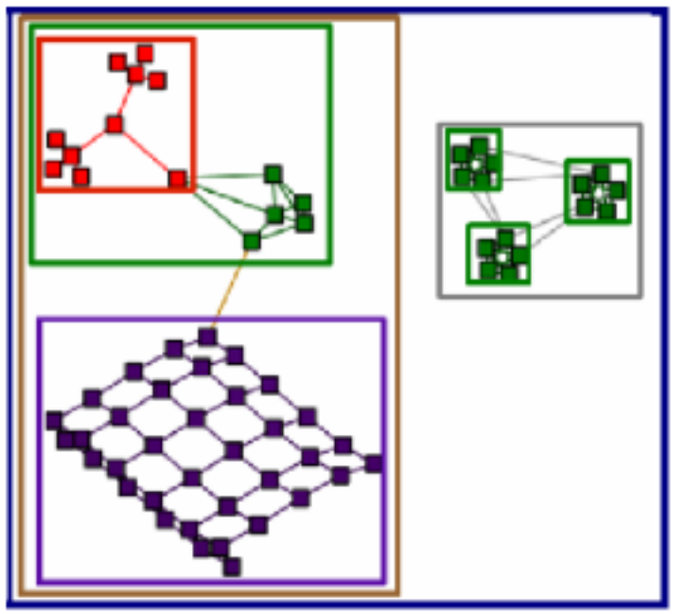
weaknesses

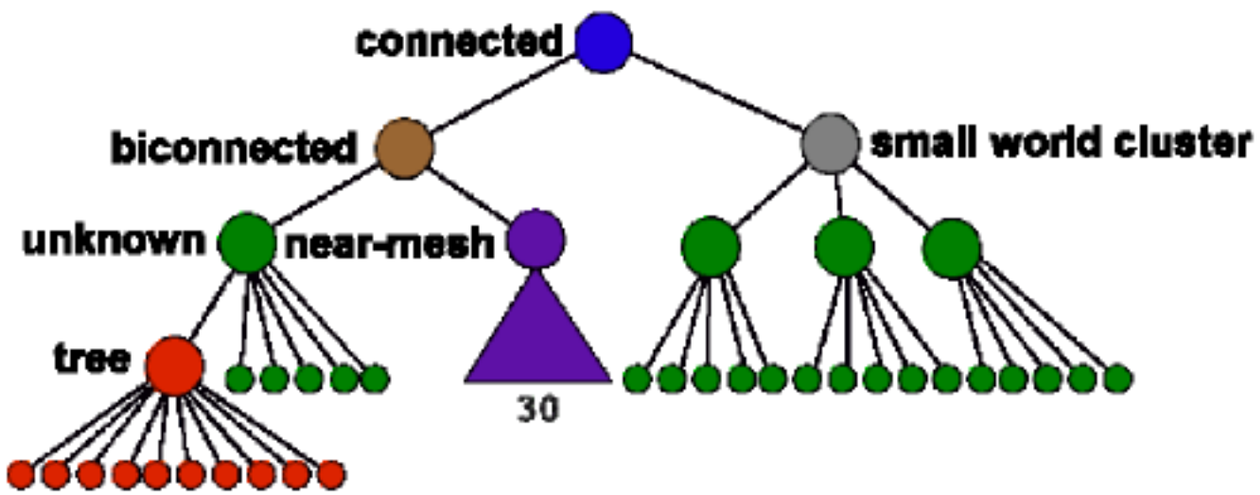
- does not scale to large datasets

5: TopoLayout

multilevel decomposition and layout

- automatic detection of topological features
  chop into hierarchy of manageable pieces
- lay out using feature-appropriate algorithms



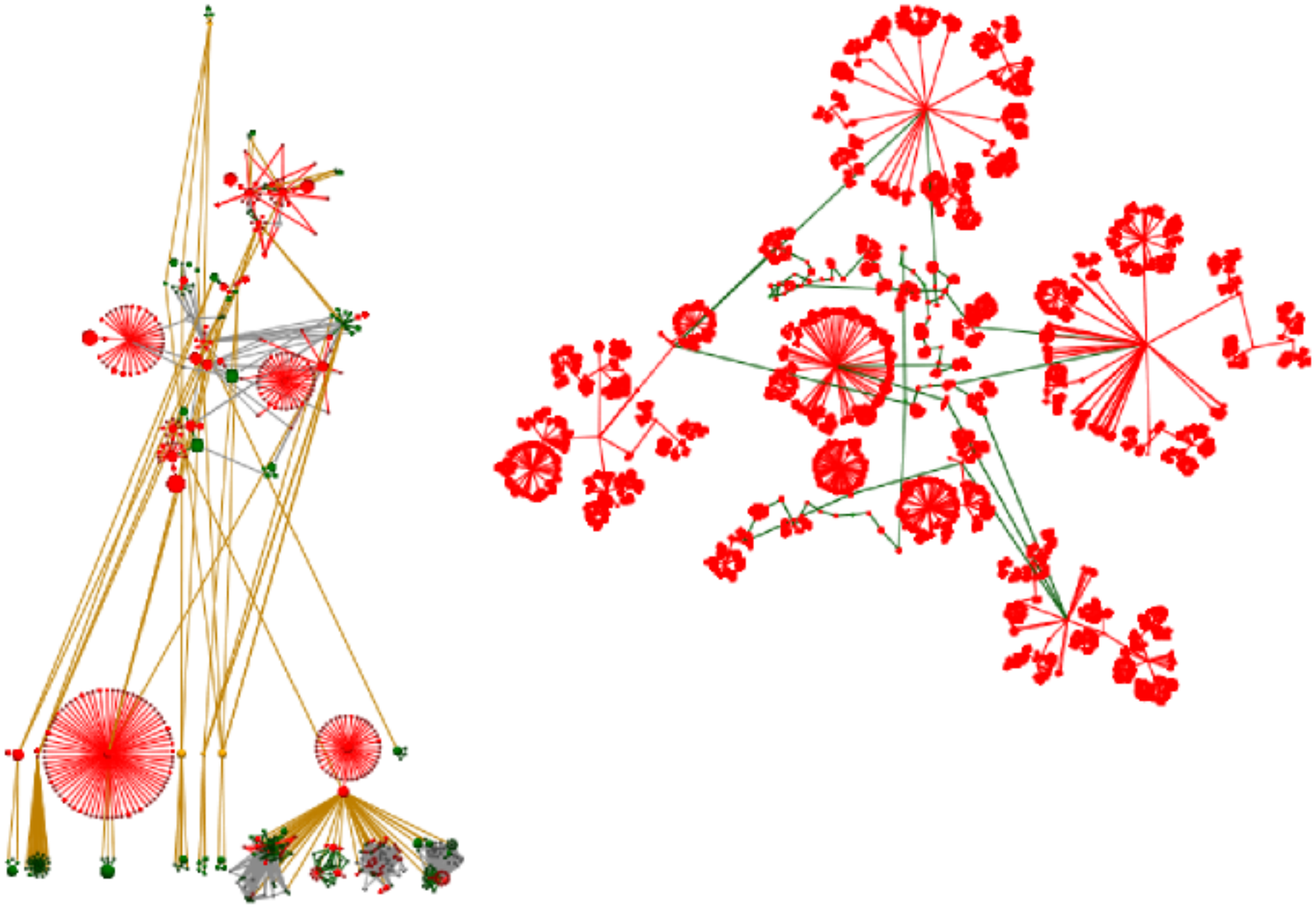


[work in progress: Daniel Archambault, Tamara Munzner, and David Auber]

Multilevel Hierarchies

data: web sites, network backbones

- strengths: handles large class of graphs
- weaknesses: poor if no detectable features



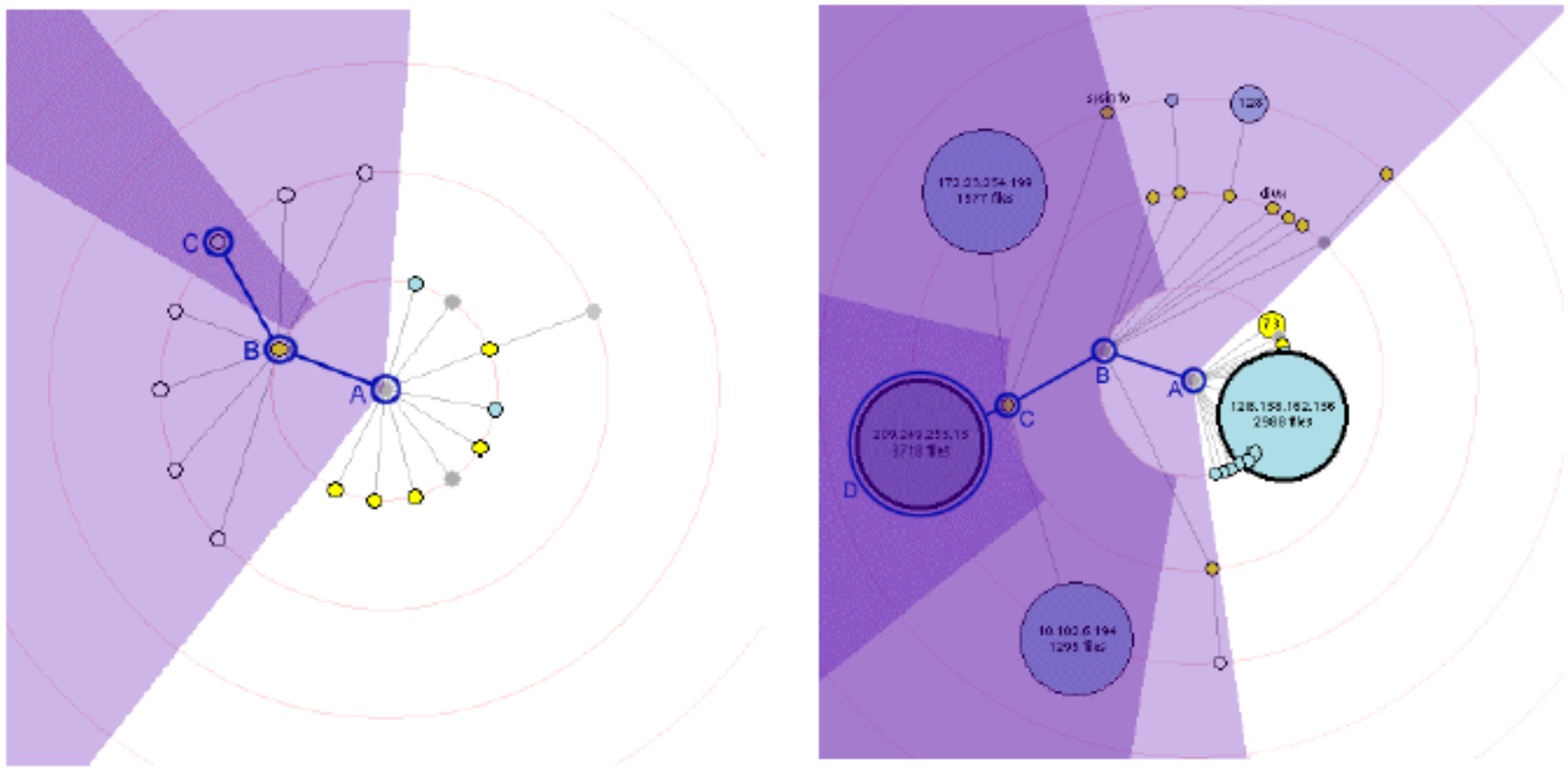
[work in progress: Daniel Archambault, Tamara Munzner, and David Auber]

6: Animated Radial Layouts

dynamic graphs that change over time

- minimize visual changes
- stay true to current dataset structure

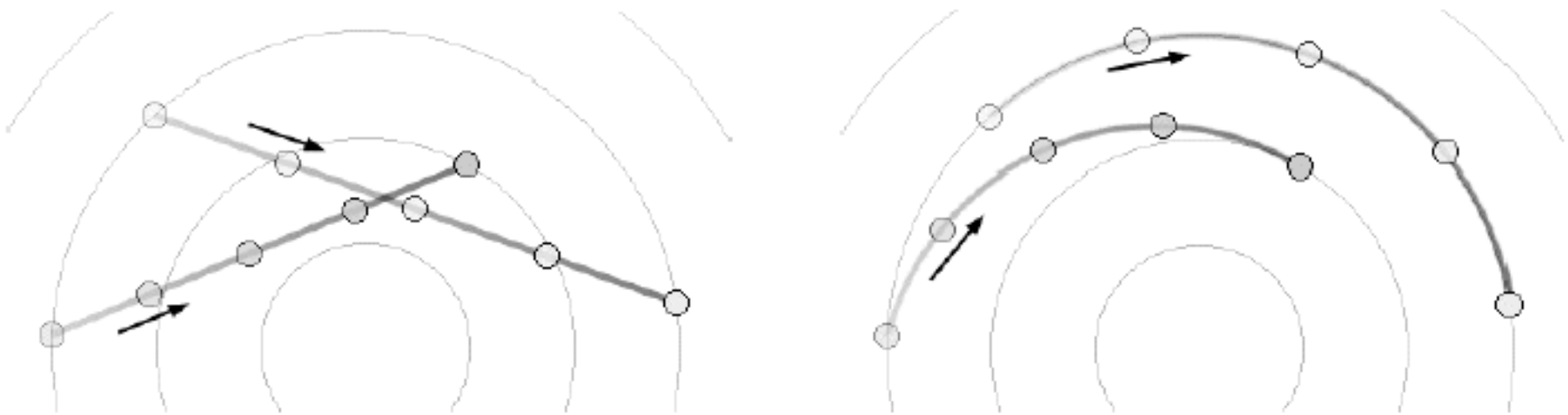
[video: www.sims.berkeley.edu/~ping/gv]



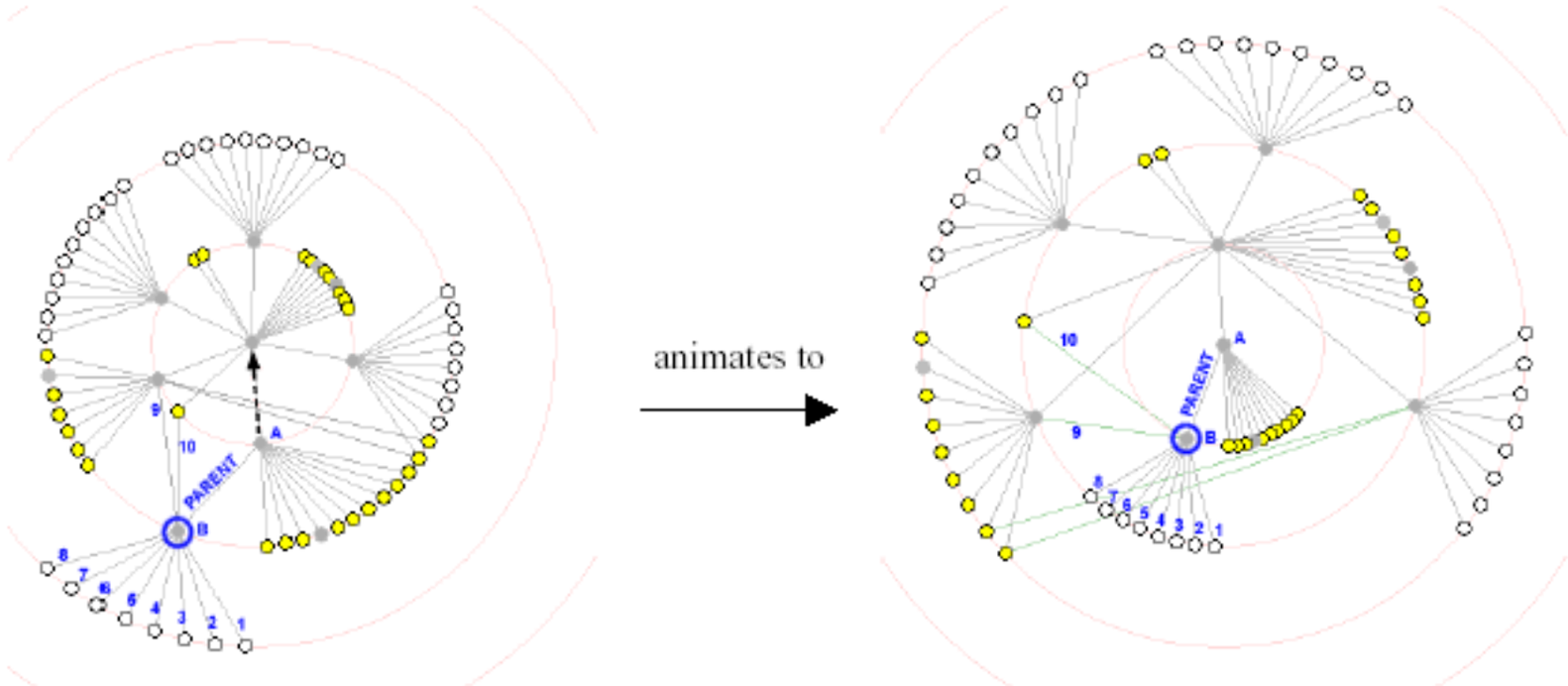
[Yee, Fisher, Dhamija, and Hearst. Animated Exploration of Graphs with Radial Layout. Proc. InfoVis 2001. bailando.sims.berkeley.edu/papers/infovis01.htm]

Animation

polar interpolation



maintain neighbor order



[Yee, Fisher, Dhamija, and Hearst. Animated Exploration of Graphs with Radial Layout. Proc. InfoVis 2001. bailando.sims.berkeley.edu/papers/infovis01.htm]

Critique

strengths

- smoother transtions

weaknesses

- not scalable to large datasets

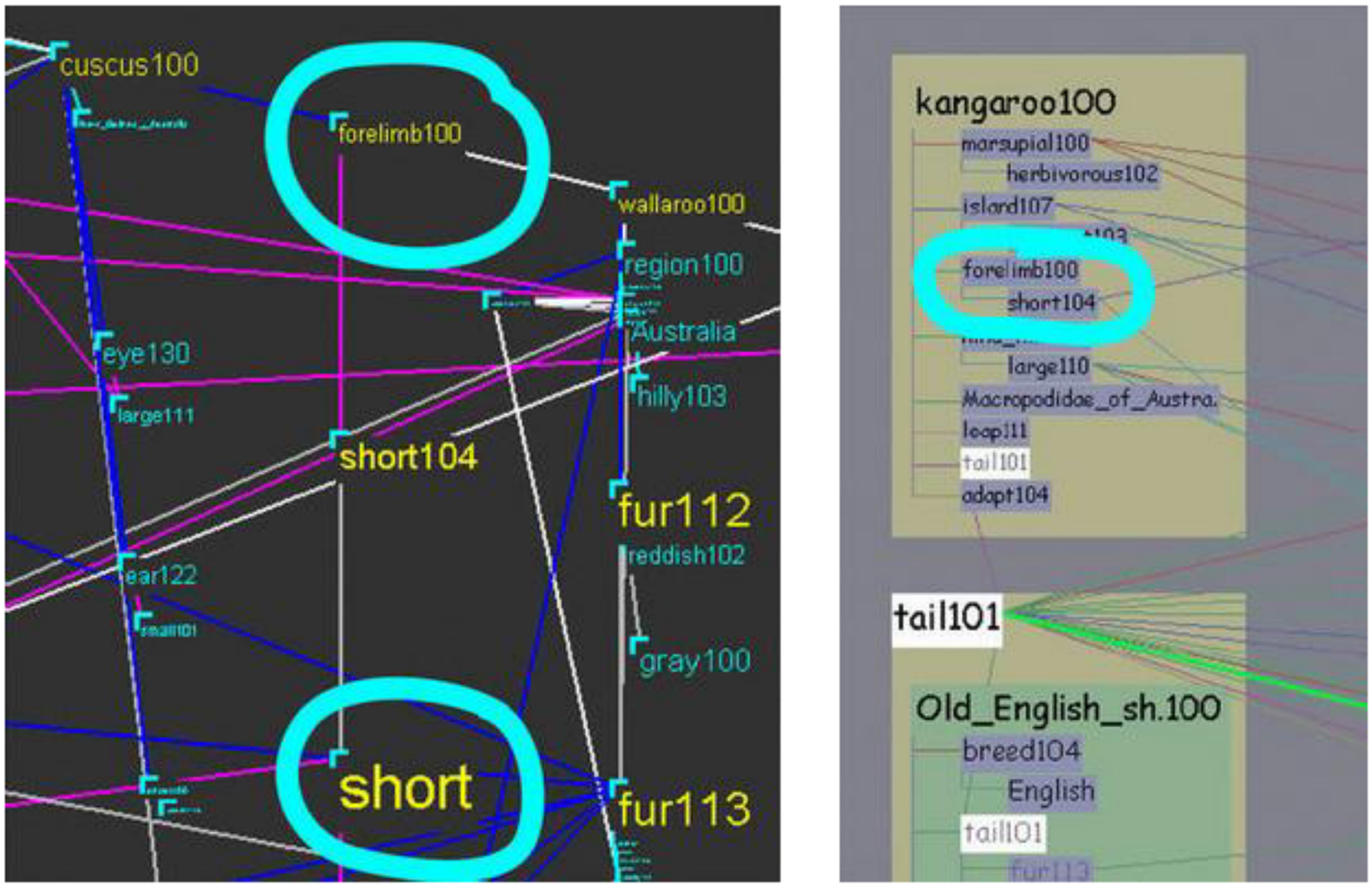
7: Constellation

data: semantic network from dictionary entry

· nodes: English words, links: used together in entry

information density

· design tradeoff with visual salience



[Munzner, Guimbretiere and Robertson. Constellation: A Visualization Tool For Linguistic Queries from MindNet. Proc. InfoVis 1999. graphics.stanford.edu/papers/const]

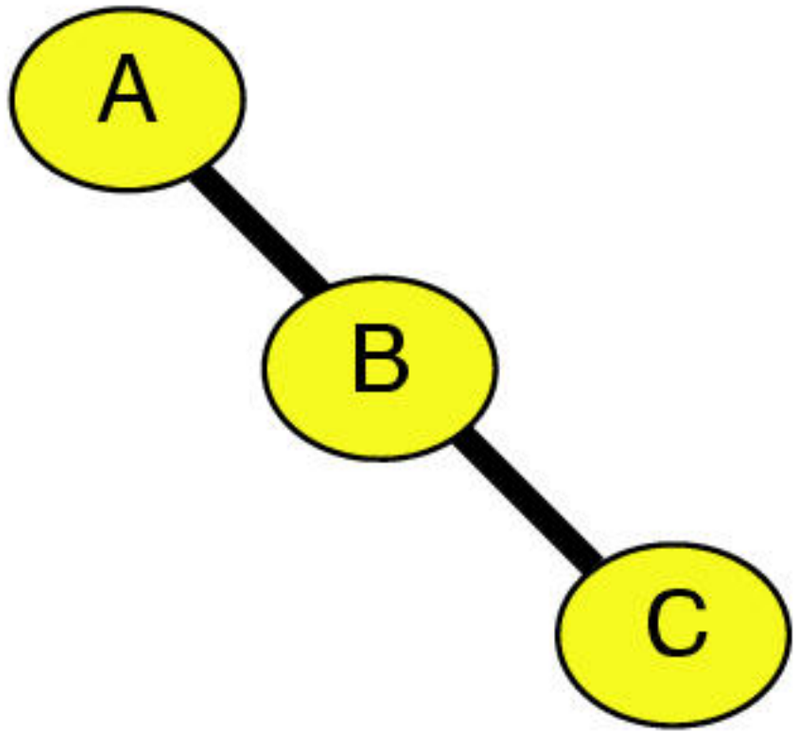
[graphics.stanford.edu/papers/munzner_thesis/html/node11.html#noncanonfig]

Traditional Layout

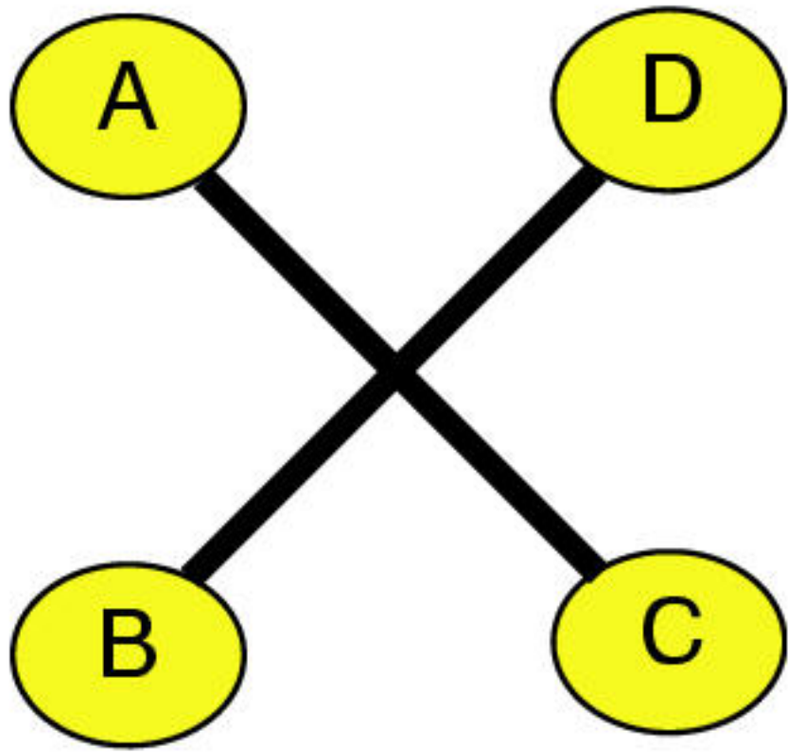
avoid crossings

- considered "aesthetic criterion"

reason: avoid false attachments



ambiguity



artifact salience

[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#tradlayoutfig]

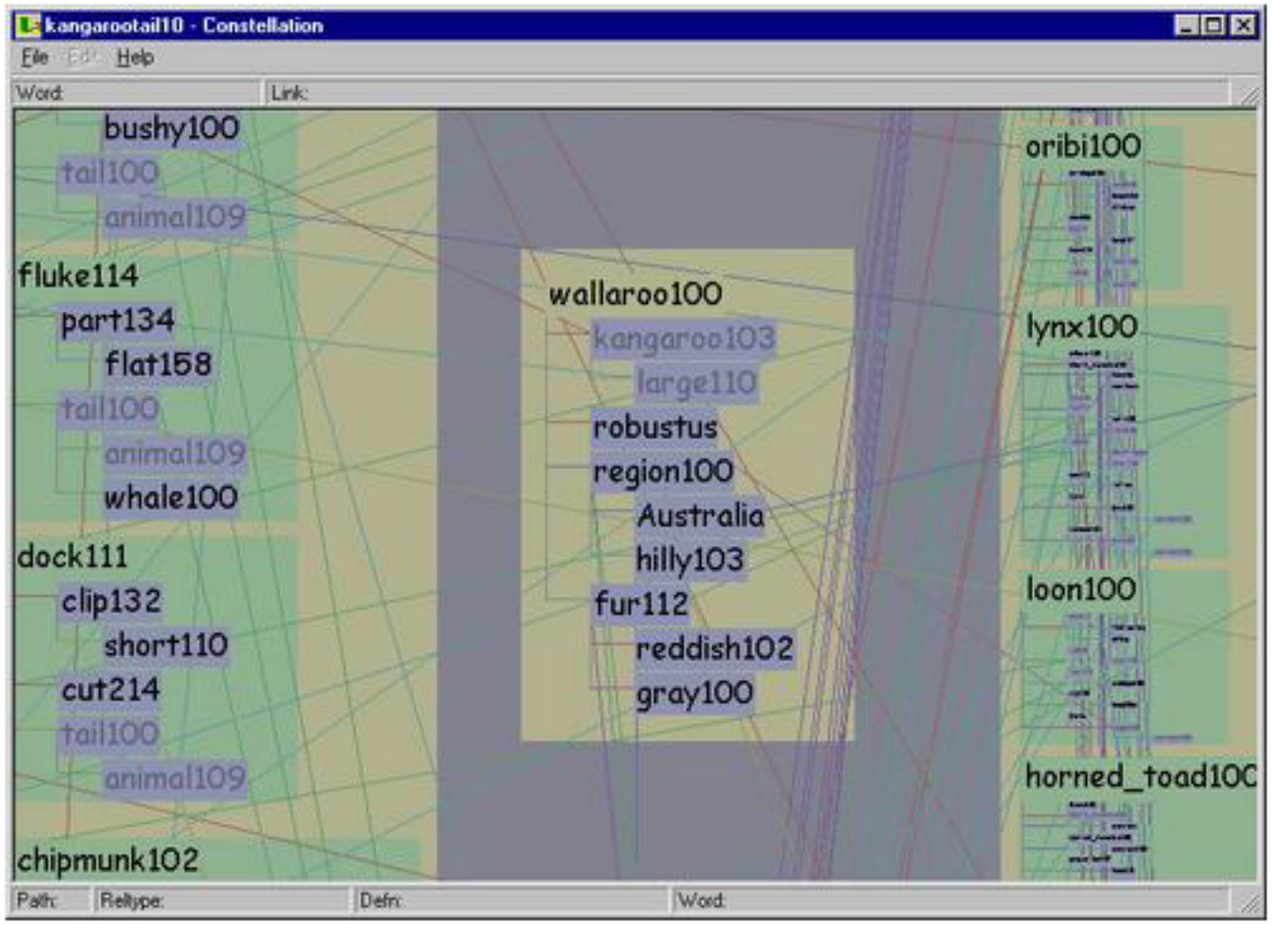
Selective Emphasis

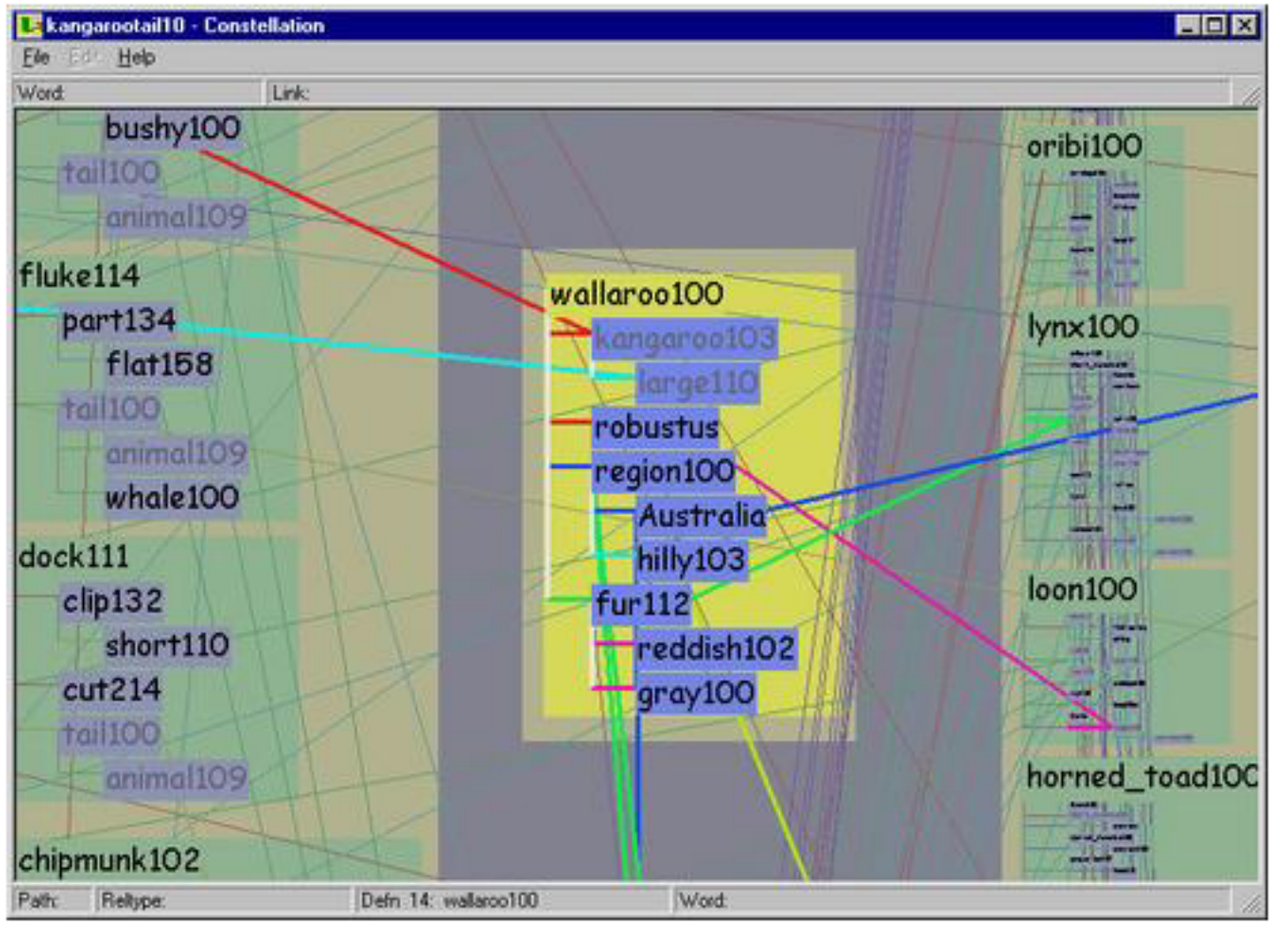
highlight sets of boxes and edges

- additional perceptual channels based on interaction

avoid perception of false attachments

- avoid hidden state
- [video: graphics.stanford.edu/videos/const]





[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#selemphfig]

Critique

strengths

- highly specialized
- good information density in final version
- perceptual layering successful

weaknesses

- highly specialized
- custom system design is expensive

Outline

Introduction

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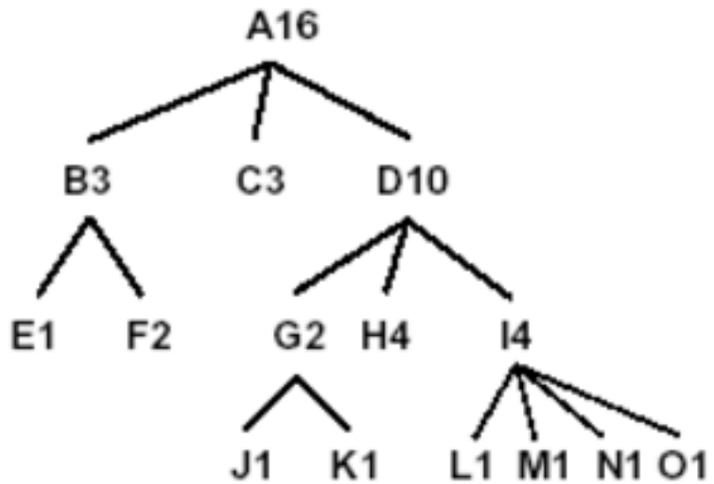
Wrapup

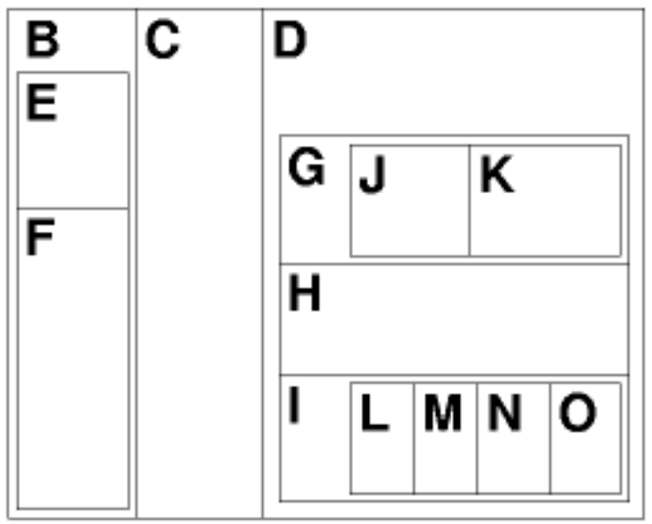
8: Treemaps

data: filesystems, stock performance

show structure with containment not connection

- size according to node attribute

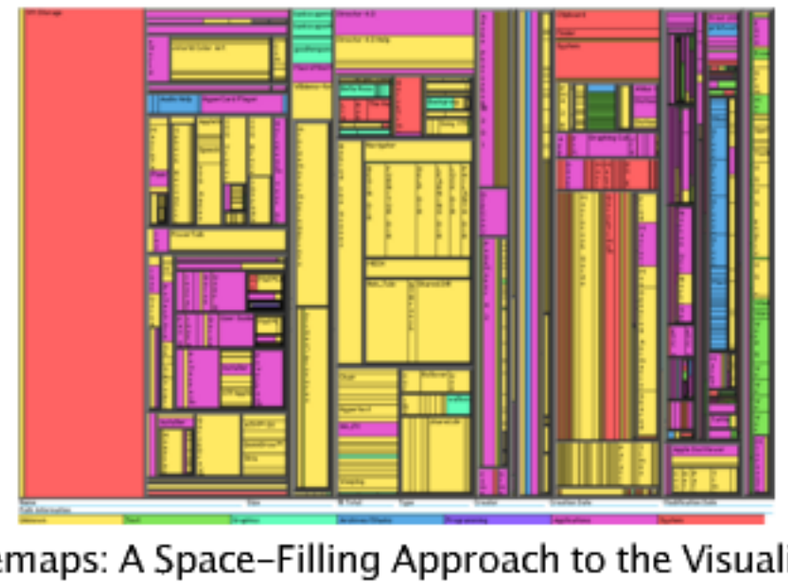




[Johnson and Shneiderman. Treemaps: A Space-Filling Approach to the Visualization of Hierarchical Information Structures. Proc. IEEE Visualization 1991.]

Critique

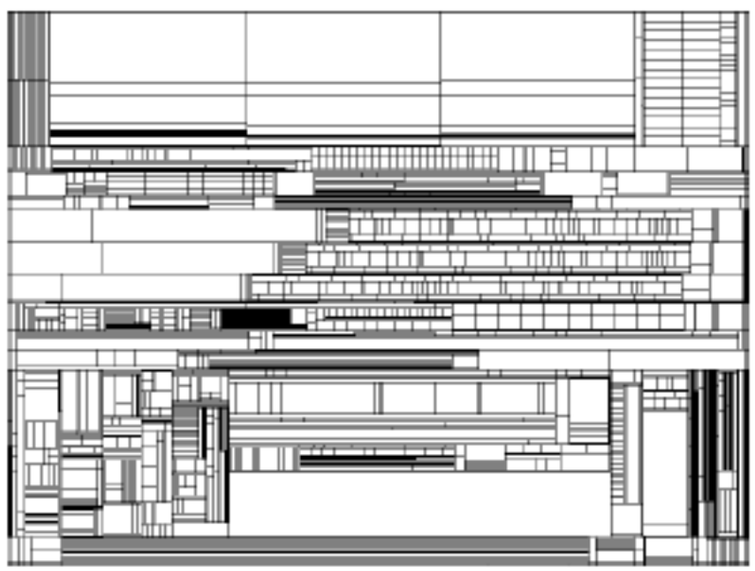
strength: popout for extreme attributes

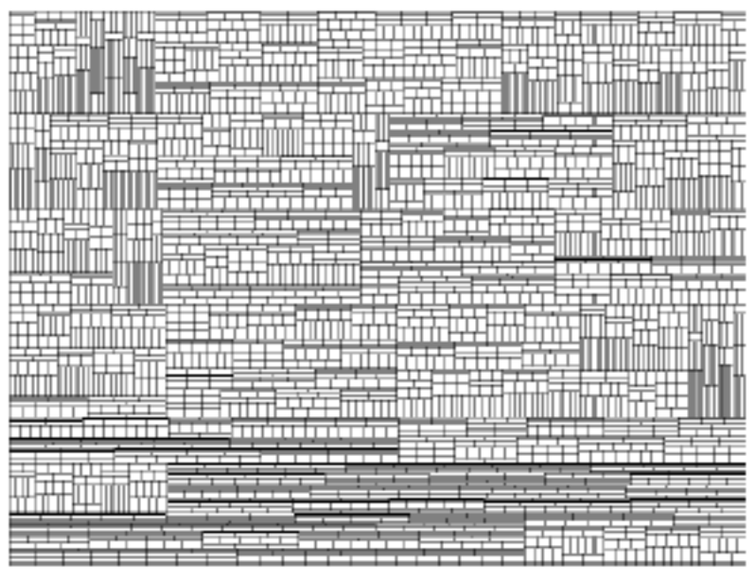


[Johnson and Shneiderman. Treemaps: A Space-Filling Approach to the Visualization of Hierarchical Information Structures. Proc. IEEE Visualization 1991.]

[www.smartmoney.com/marketmap]

weaknesses: difficulties seeing structure



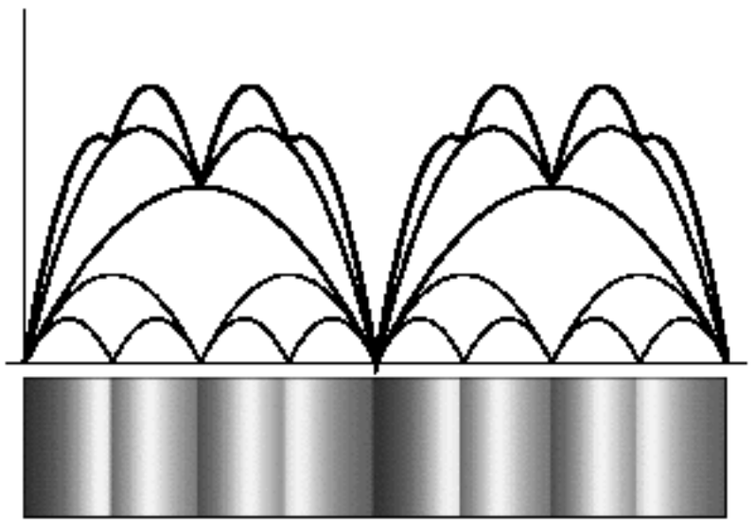


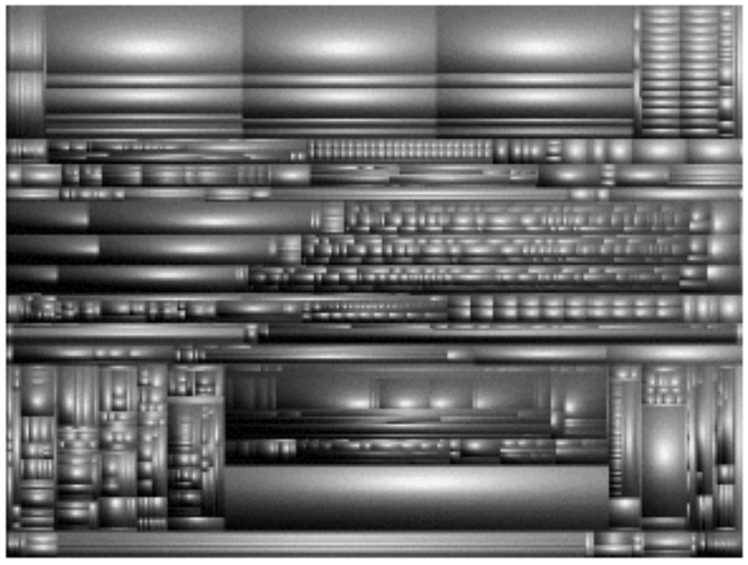
[van Wijk and van de Wetering. Cushion Treemaps. Proc. InfoVis 1999]

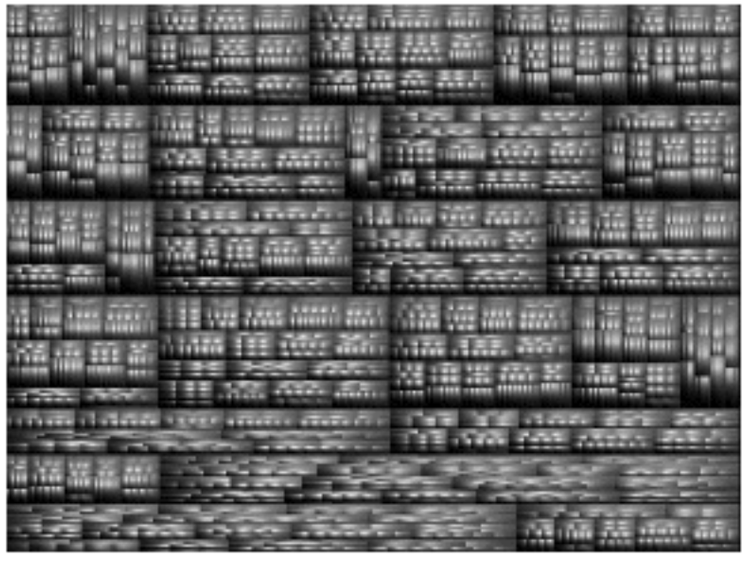
9: Cushion Treemaps

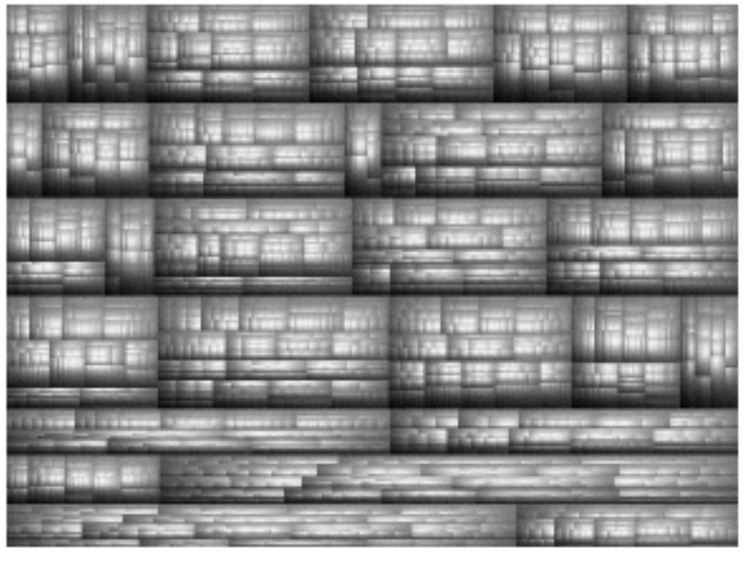
data: filesystems
show structure with shading

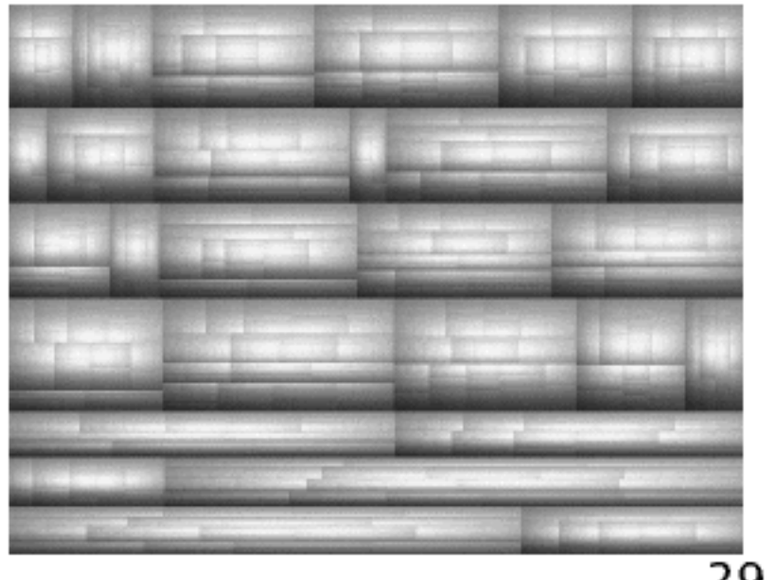
- scale parameter controls global vs. local











[van Wijk and van de Wetering. Cushion Treemaps. Proc. InfoVis 1999]

Critique

strengths

- shows more topological structure than plain treemaps
- keeps power to show attribute outliers
- allows color to be used to encode other info

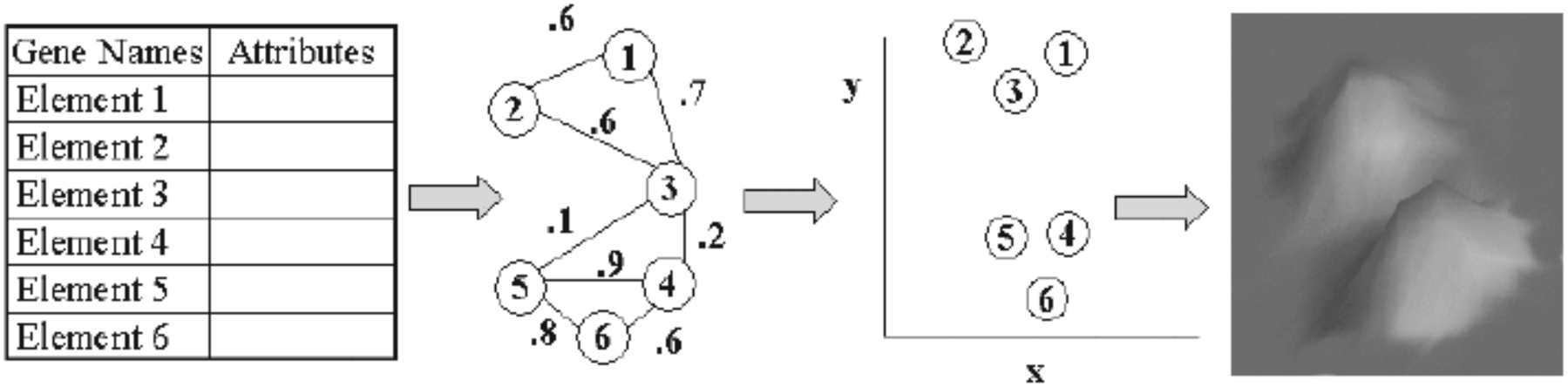
weaknesses

- still considerably worse than node-link representation for showing topological structure

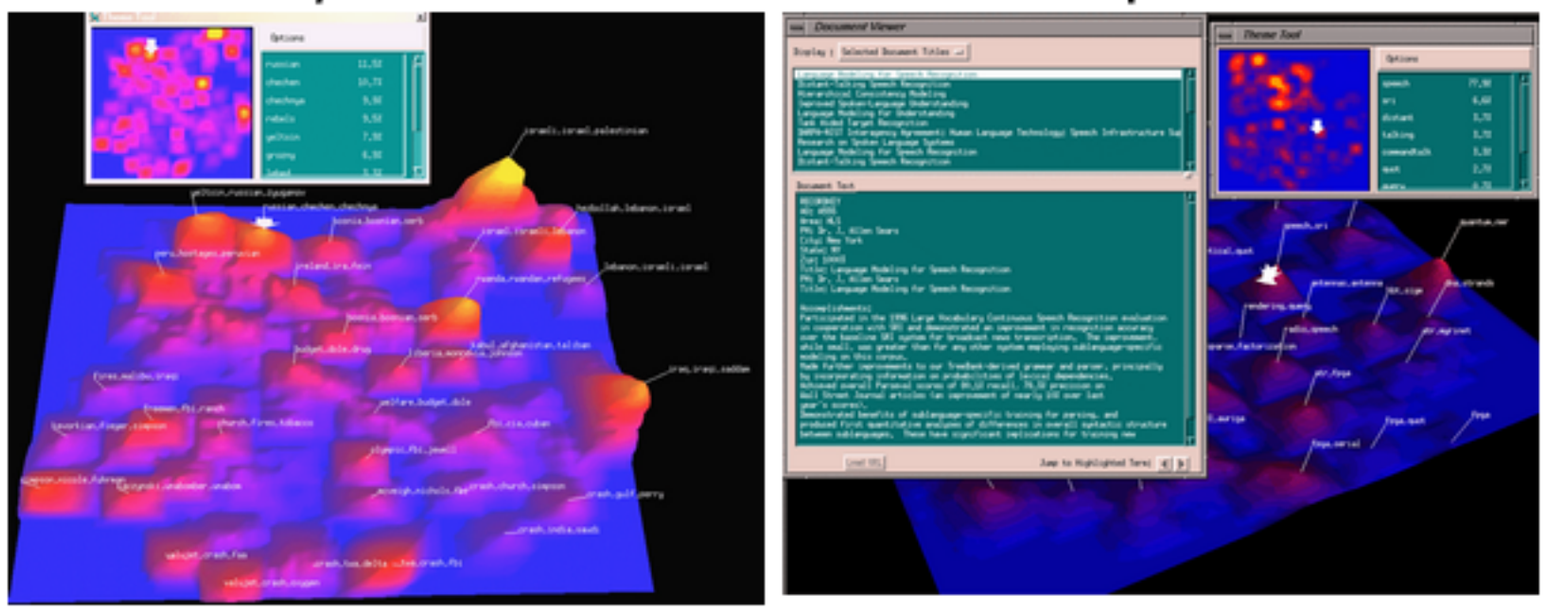
10: Themescapes

data: news stories, gene expression

- from graph to terrain



Davidson et al. Cluster Stability and the Use of Noise in Interpretation of Clustering. InfoVis 01



[Wise et al. Visualizing the non-visual: spatial analysis and interaction with information from text documents. Proc. InfoVis 1995. www.pnl.gov/infoviz/graphics.html]

Critique

strengths

- terrain model intuitive for people
- good for overview

weaknesses

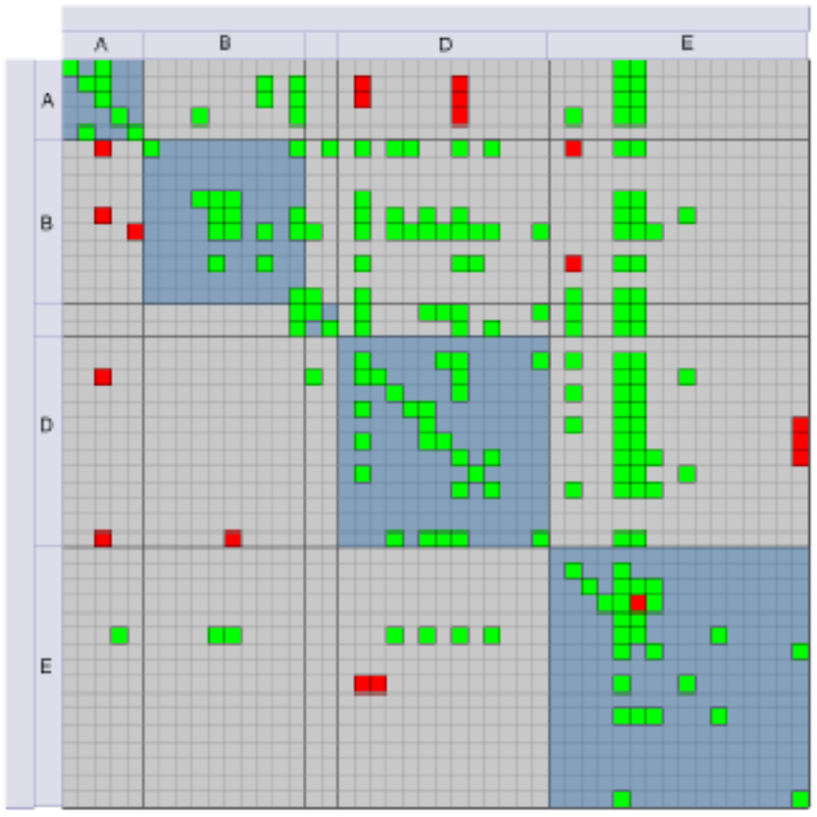
- possibly misleading implication of continuous data typically made from discrete samples

11: Multilevel Call Matrices

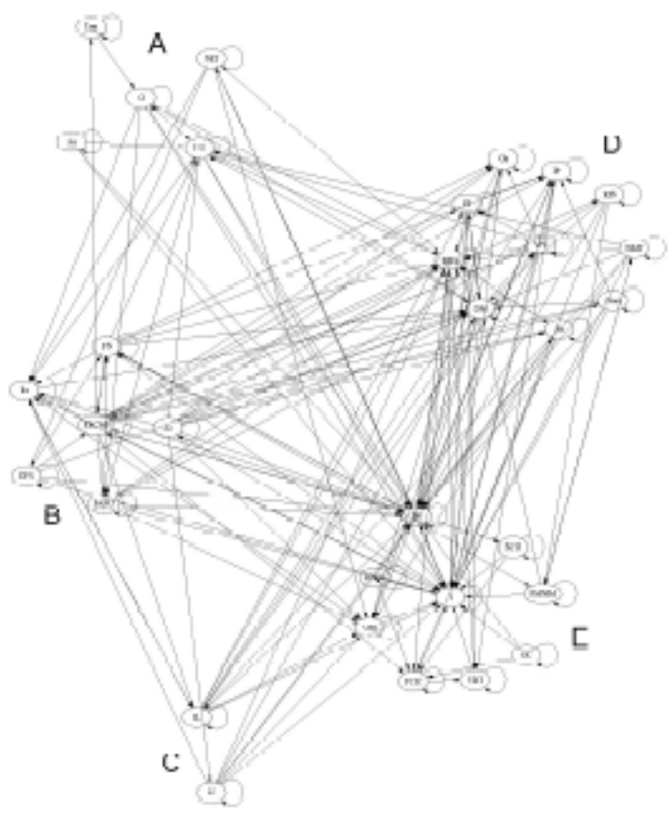
data: large software project

link matrix vs. node-link network

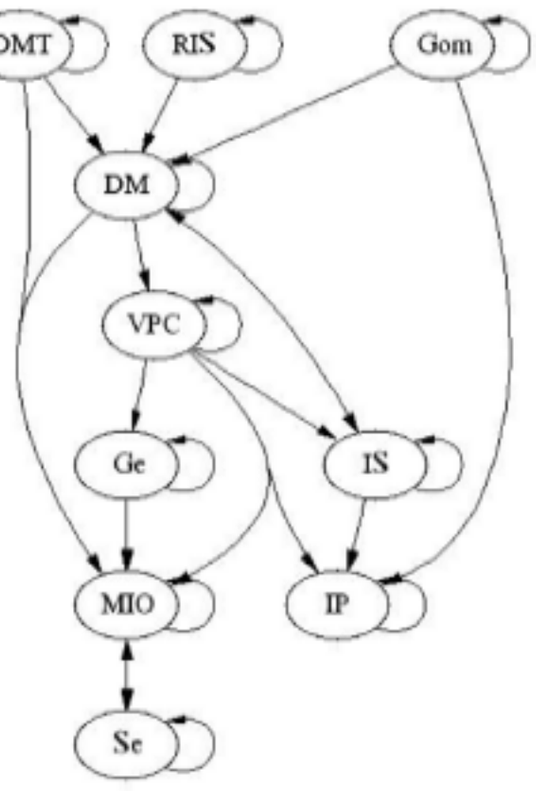
matrix



force-directed



layered subset (dot)



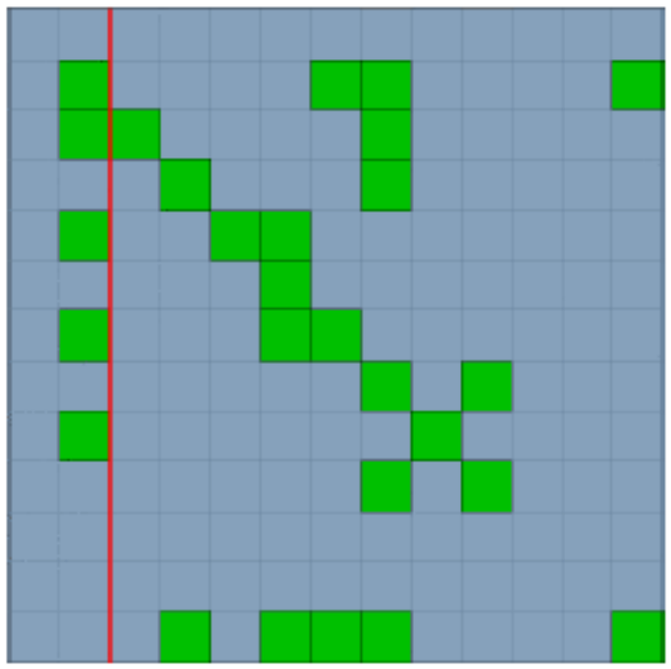
- position: box shows link between nodes in row/column
- color: calls not in specification in red

[van Ham. Using Multilevel Call Matrices in Large Software Projects. Proc. InfoVis 20[3]3]

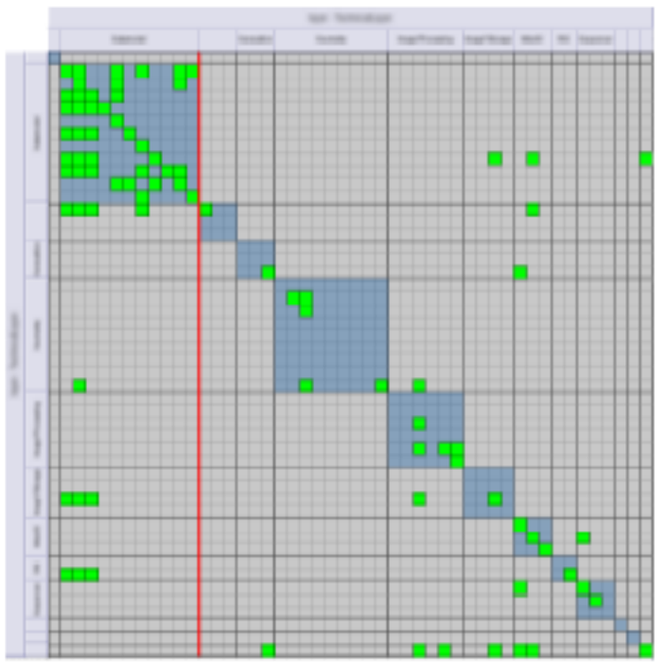
Abstraction Levels

matrices: uniform, recursive, stable

coarse



fine



[van Ham. Using Multilevel Call Matrices in Large Software Projects. Proc. InfoVis 2003]

Critique

strengths: tasks successfully supported

- spotting unwanted calls
  in implementation but not specification

- previous summary shown to be incomplete

weaknesses

- matrix views poor for some tasks

[Ghoniem, Fekete, and Castagliola. A Comparison of the Readability of Graphs Using Node-Link and Matrix-Based Representations. Proc. InfoVis 2004]

Outline

Visual Encoding

15 Views

- Traditional Graphs
- Nontraditional Representations
- Focus+Context Trees

Wrapup

Focus+Context

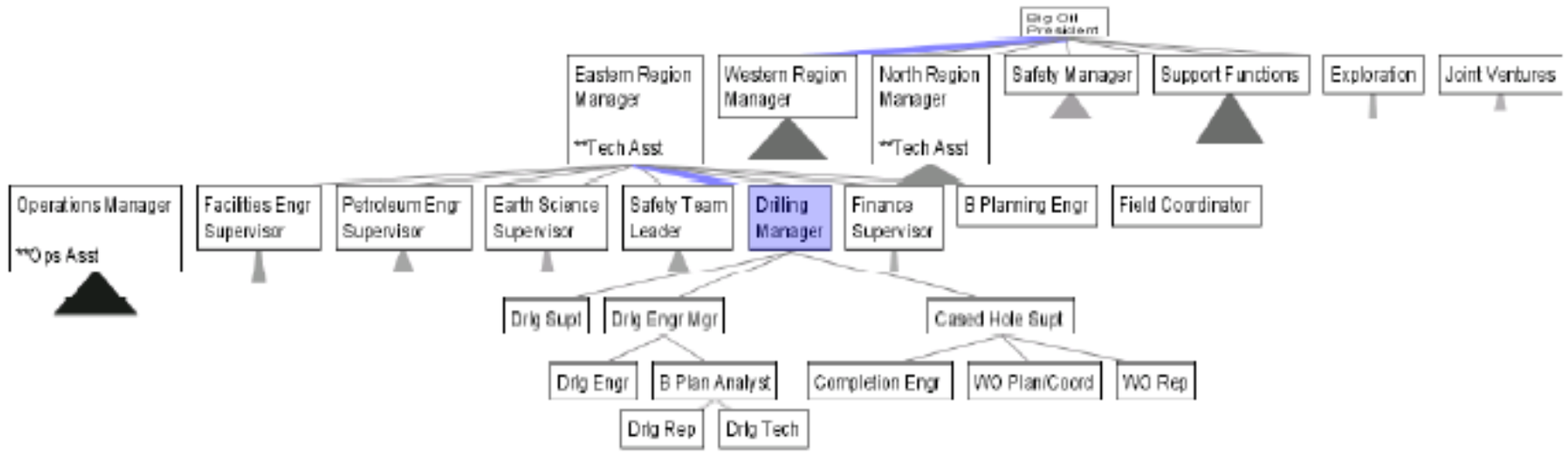
combine overview, details into integrated view

- vs. single detail view
- vs. multiple linked windows

12: SpaceTree

data: org charts, species relationships
interaction: expand/contract

- [demo: www.cs.umd.edu/hcil/spacetree]



strengths

- animated transitions easy to follow

weakness

- cannot have multiple areas of focus

[Plaisant, Grosjean, and Bederson. SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Proc. InfoVis 2002]

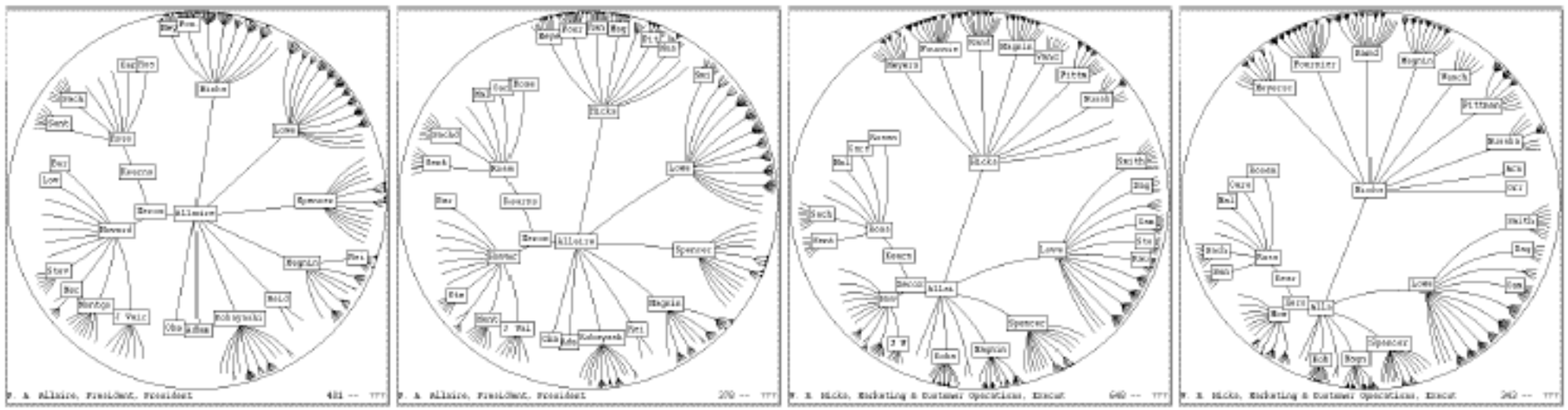
13: 2D Hyperbolic Trees

data: org charts, web sites

- node: document
- link: hyperlink between pages

carefully chosen distortion

- fisheye effect: single focus from hyperbolic geometry
- [demo: ucjeps.berkeley.edu/map2.html]



[The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies. Lamping and Rao, Proc SIGCHI '95. http://citeseer.nj.nec.com/lamping95focuscontext.h‡g‡l]

Critique

strengths

- scales to over 10,000 nodes

weaknesses

- distortion poor for distance judgement tasks
- still possible to get lost in large graphs

14: H3

data: web sites, species relationships
3D fisheye from hyperbolic geometry

- [demo: graphics.stanford.edu/~munzner/h3]

[Munzner. H3: Laying Out Large Directed Graphs in 3D Hyperbolic Space. Proc. InfoVis 1997. graphics.stanford.edu/papers/h3/]

Critique

strengths

- scales to over 100,000 nodes

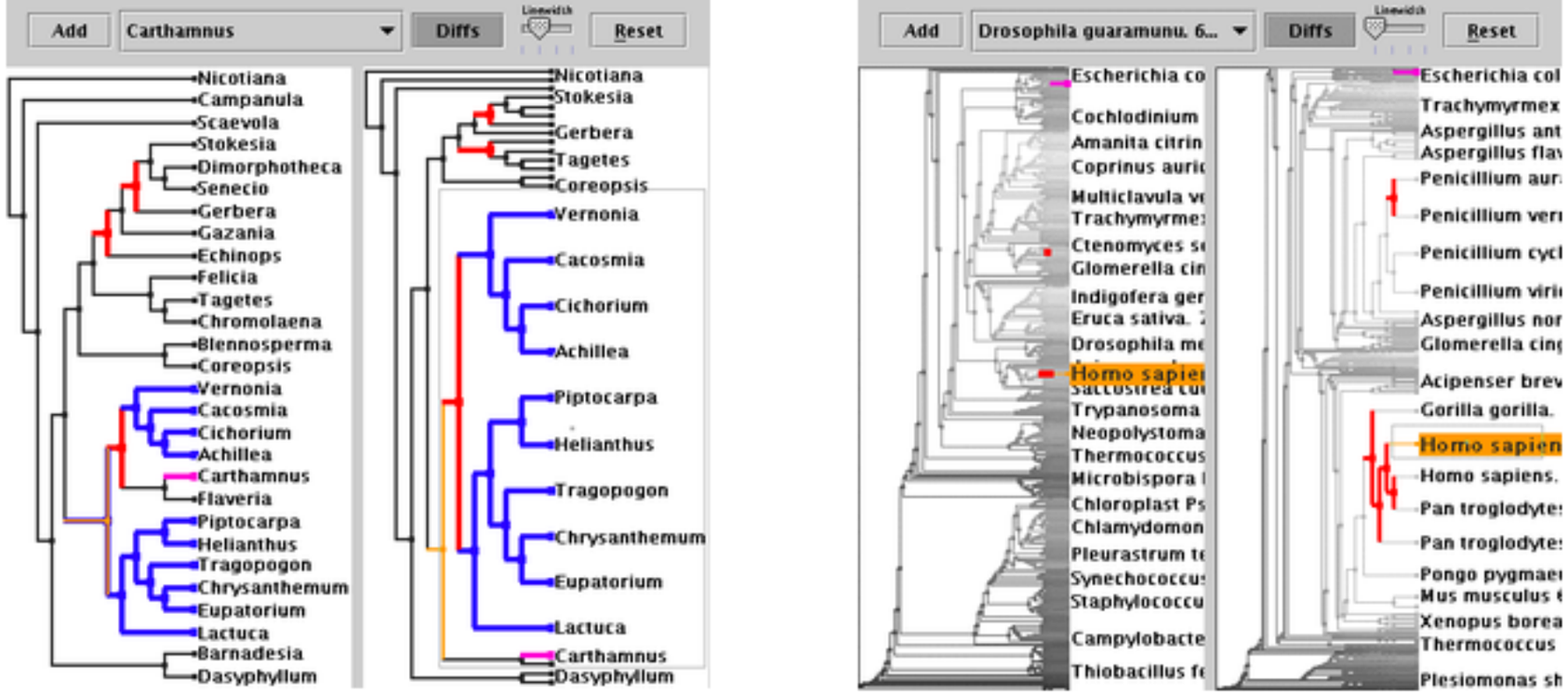
weaknesses

- distortion poor for distance judgement tasks
- still possible to get lost in large graphs

15: TreeJuxtaposer

data: species evolutionary relationships
task: side by side comparison
accordion drawing

- guaranteed visibility of landmarks
- stretch and squish navigation
- [demo: olduvai.sf.net/tj]



[Munzner et al. TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. SIGGRAPH 2003. www.cs.ubc.ca/~tmm/papers/tj]

Guaranteed Visibility

drawing colored marks

- easy with small datasets
- hard with big datasets

reasons a mark could be invisible

- outside the window
- underneath other marks
- smaller than a pixel

benefits of GV

- minimizes amount of navigation required
- guides necessary navigation choices
- provides visible landmarks

Critique

strengths

- scalability to millions of nodes
  guaranteed frame rate
- guaranteed visibility
- supports multiple focus areas

weaknesses

- stretch and squish navigation inappropriate for tasks requiring distance estimation
- computationally intensive

[Slack, Hildebrand, and Munzner. PRISAD: A Partitioned Rendering Infrastructure for Scalable Accordion Drawing. Proc. InfoVis 2005, to appear]

Outline

Introduction

15 Views

- Traditional Graphs
- Nontraditional Representations
- Focus+Context Trees

Wrapup

Hard Problems

designing within huge space of possibilities

scalability

- size of dataset
- number of pixels
- kinds of data

dynamic data

characterizing Focus+Context

- how and when does it help

Grand Challenge

"visual Google for nontextual data"

not search for images

web search made available text data useable

- for general and surprising uses beyond original intent

infovis browsing

- could make available nontext data useful/visible

More Information

this talk

- www.cs.ubc.ca/~tmm/talks.html#ie05

my grad course

- www.cs.ubc.ca/~tmm/courses/infovis

conferences

- InfoVis symposia: www.infovis.org/symposia.php
  IEEE Sympoxium on Information Visualization

- Graph Drawing conferences: www.gd2005.org