15 Views of a Node-Link Graph: An Information Visualization Portfolio

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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

information visualization (infovis):
- visual representation of abstract data
  computer-based: interactivity possible
- help human perform some task more effectively

Visual Channels

visual attribute of geometric mark
- position, color, size, shape, orientation, ...

separable vs. integral

color position | color motion | color shape | size orientation | x-size y-size | red-green 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
[...]

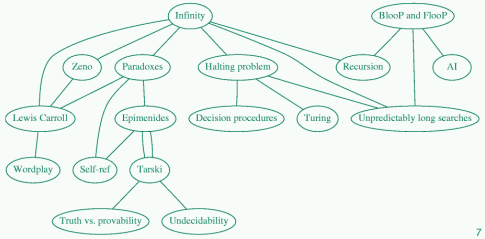
Critique

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

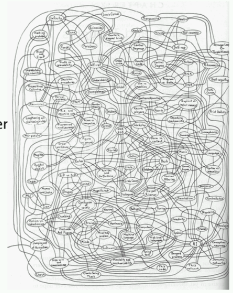


2: Hand-Drawn

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

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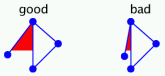
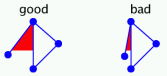
- crossings, area, bends/curves



maximize
- angular resolution, symmetry

Graph Layout Criteria

minimize
- crossings, area, bends/curves

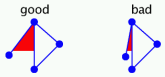


maximize
- angular resolution, symmetry

most criteria individually NP-hard
- cannot just compute optimal answer
- heuristics: try to find something reasonable

Graph Layout Criteria

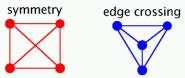
minimize
- crossings, area, bends/curves



maximize
- angular resolution, symmetry

most criteria individually NP-hard
- cannot just compute optimal answer
- heuristics: try to find something reasonable

criteria mutually incompatible

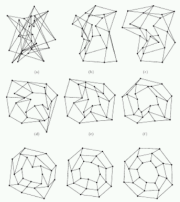


[Ware, Purchase, Colpys, and McGill. Cognitive Measures of Graph Aesthetics. Information Visualization 1(2):103-110, Palgrave 2002]
[Brandenburg. Nice Drawings of Graphs are Computationally Hard. Visualization in Human-Computer Interaction, Springer Verlag 1988]

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]

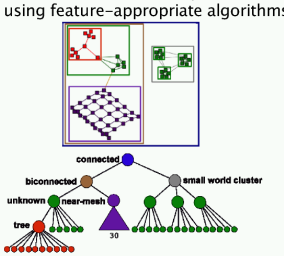
Critique

strengths
- intuitive model
- many mathematical approaches

weaknesses
- does not scale to large datasets

5: TopoLayout

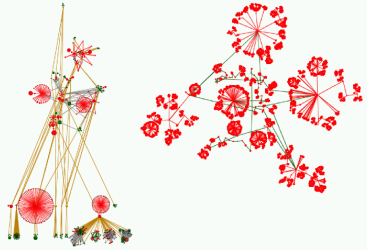
multilevel decomposition and layout
- automatic detection of topological features
  chop into hierarchy of manageable pieces
- lay out using feature-appropriate algorithms



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

Multilevel Hierarchies

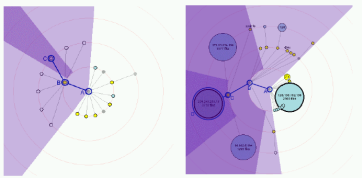
data: web sites, network backbones
- strengths: handles large class of graphs
- weaknesses: poor if no detectable features



[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]

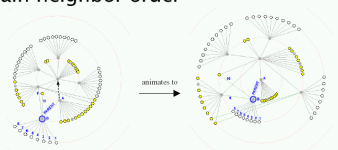


[Yee, Fisher, Dhamija, and Hearst. Animated Exploration of Graphs with Radial Layout. Proc. InfoVis 2001. bailando.sims.berkeley.edu/papers/infovis01.htm]

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

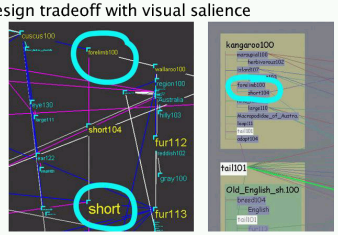
strengths
- smoother transtions

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

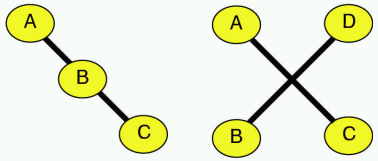


[Munzner, Guimbretiere and Robertson. Constellation: A Visualization Tool For Linguistic Queries from MindNet. Proc. InfoVis 1999. graphics.stanford.edu/papers/const]
[graphics.stanford.edu/papers/munzner_thesis/html/node11.html#noncanonfig]

Traditional Layout

avoid crossings
- considered "aesthetic criterion"

reason: avoid false attachments



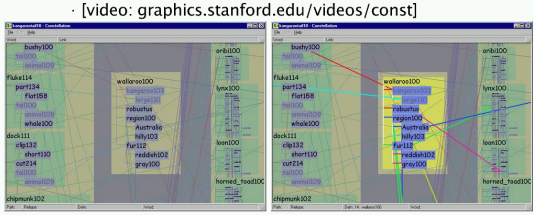
ambiguity artifact salience

[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

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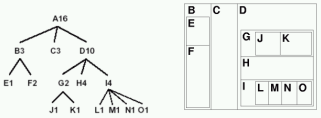
Wrapup

8: Treemaps

data: filesystems, stock performance

show structure with containment not connection

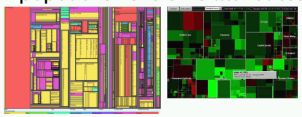
- size according to node attribute



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

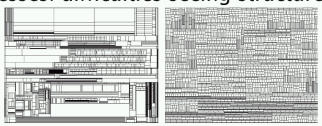
Critique

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

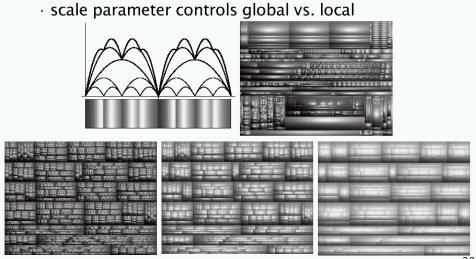


[van Wijk and van de Wetering. Cushion Treemaps. Proc. InfoVis 1999]

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

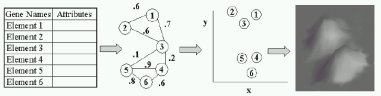
weaknesses

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

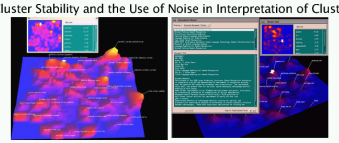
10: Themescapes

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

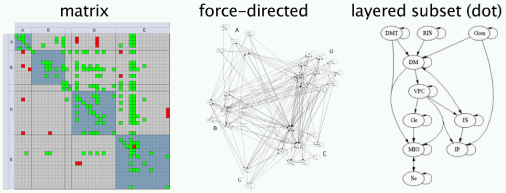
weaknesses
- possibly misleading implication of continuous data
  typically made from discrete samples

11: Multilevel Call Matrices

data: large software project

link matrix vs. node-link network

matrix | force-directed | layered subset (dot)



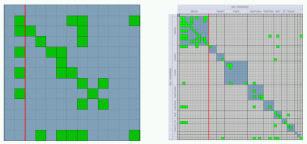
- position: box shows link between nodes in row/column
- color: calls not in specification in red

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

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

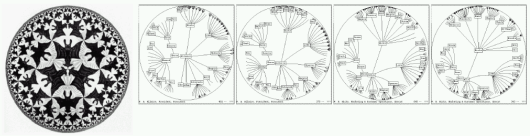
weakness
- see only small fraction of information in detail view

[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



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

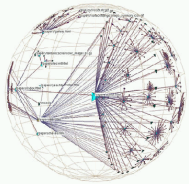
Critique

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
- [video/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/]

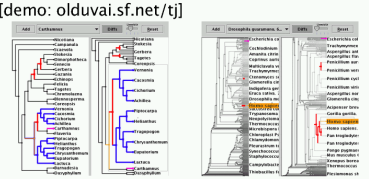
Critique

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

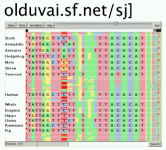
strengths
- scalability to millions of nodes
  guaranteed frame rate
- guaranteed visibility
- supports multiple focus areas

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]

SequenceJuxtaposer

data: genomic sequences
task: side by side comparison
accordion drawing
- [video/demo: olduvai.sf.net/sj]



[Slack et al. SequenceJuxtaposer: Fluid Navigation For Large-Scale Sequence Comparison In Context. Proc German Conf. on Bioinformatics. www.cs.ubc.ca/~tmm/papers/sj]

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Wrapup

Hard Problems

design within huge space of possibilities
evaluate whether and how systems help real users

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

dynamic data

More Information

this talk
- www.cs.ubc.ca/~tmm/talks.html#nih06

my grad course
- www.cs.ubc.ca/~tmm/courses/infovis

conferences
- IEEE InfoVis symposia: www.infovis.org/symposia.php
- Graph Drawing conferences: www.gd2005.org

NIH/NSF Visualization Research Challenges Report
- tab.computer.org/vgtc/vrc