Information Visualization and Visual Analytics (M1522.000500)

Arrange Hierarchy and Trees

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The Big Picture

Arrange Networks and Trees

Node–Link Diagrams
Connection Marks
✔ NETWORKS ✔ TREES

Adjacency Matrix
Derived Table
✔ NETWORKS ✔ TREES

Enclosure
Containment Marks
✘ NETWORKS ✔ TREES

Hierarchy

- an arrangement of items in which
  - the items are represented as being "**above**," "**below**," or "**at the same level** as" one another and
- simply an ordered set or an acyclic graph

from *wikipedia*

- Data repository in which cases are related to subcases
- Can be thought of as imposing an ordering in which cases are parents or ancestors of other cases

Hierarchies are pervasive

- Family histories, ancestries
- File/directory systems on computers
- Organization charts
- Animal kingdom: phylum, class, family, genus, species, subspecies
- Object-oriented software classes
- ...

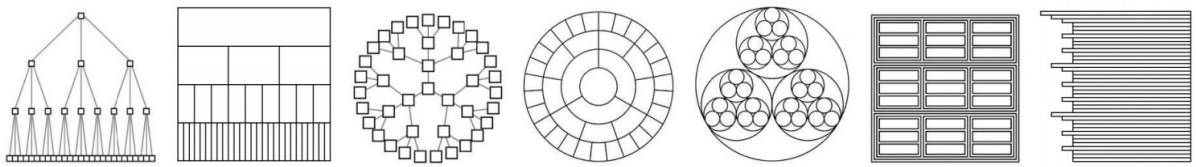
Trees

- any connected graph without cycles is a tree.

- Hierarchies often represented as trees
  - Directed, acyclic graph
  - Graph in which any two vertices are connected by exactly one simple path

- Two main representation schemes
  - Node-link
  - Space-filling

Visualization of Trees (Hierarchy)

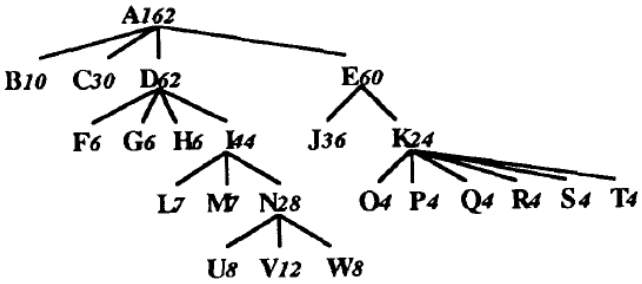


- Containment (Enclosure diagrams): (e) and (f)
- Connection (Node-Link diagrams): (a) and (c)
- Depth encoding with position :
  - (b) layering, (d) circular layering, (g) indentation

Node-Link Diagrams

- Nodes for Elements
  - Root node: a member that has no superior
- Links for Branches: lines connecting elements

- Root at top, leaves at bottom is very common



Johnson, B. and Shneiderman, B. 1991. Tree-Maps: a space-filling approach to the visualization of hierarchical information structures. In *Proceedings of the 2nd Conference on Visualization '91*

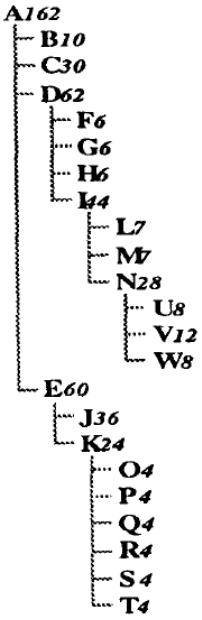


Figure 1. Outline

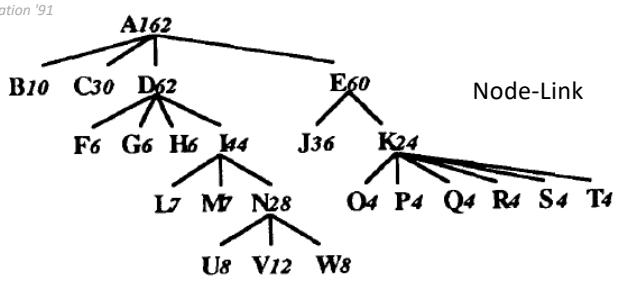


Figure 2. Tree Diagram

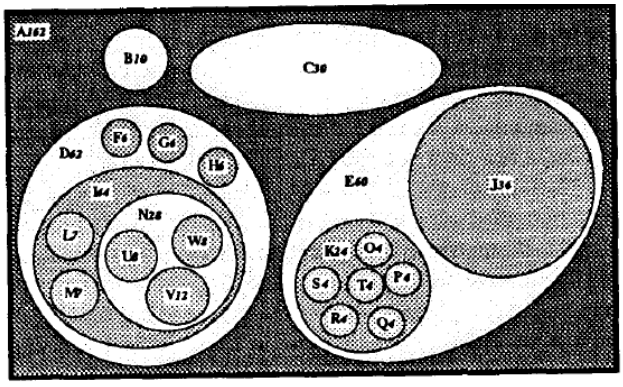


Figure 3. Venn Diagram

Johnson, B. and Shneiderman, B. 1991. Tree-Maps: a space-filling approach to the visualization of hierarchical information structures. In *Proceedings of the 2nd Conference on Visualization '91*

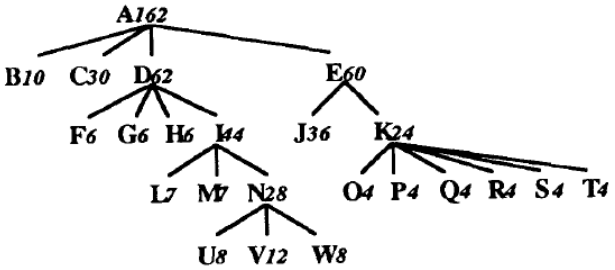


Figure 2. Tree Diagram

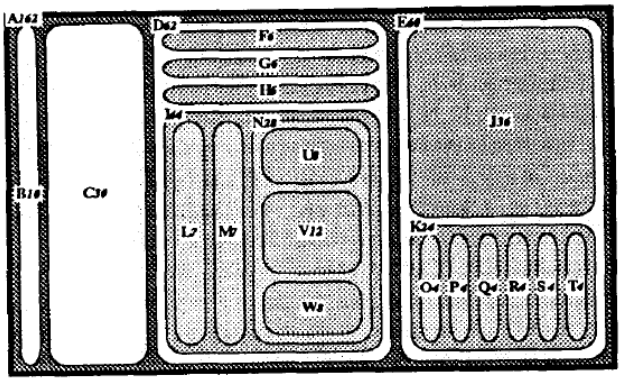


Figure 4. Nested Tree-Map

Johnson, B. and Shneiderman, B. 1991. Tree-Maps: a space-filling approach to the visualization of hierarchical information structures. In *Proceedings of the 2nd Conference on Visualization '91*

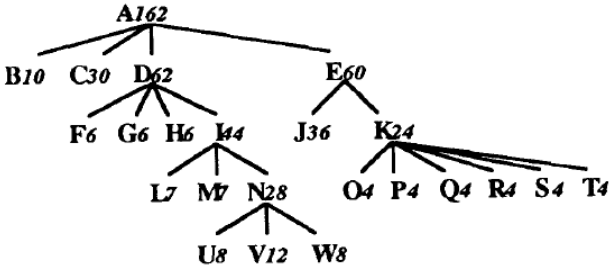


Figure 2. Tree Diagram

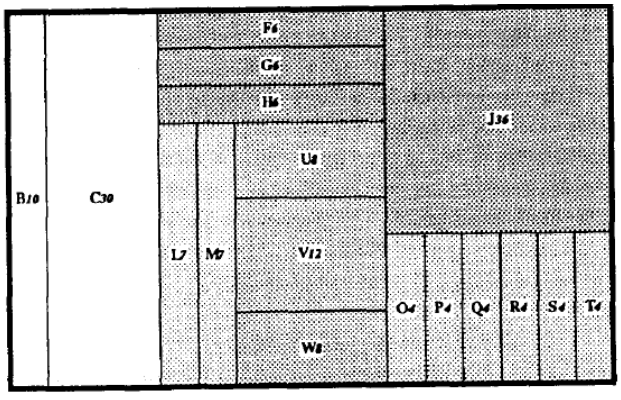
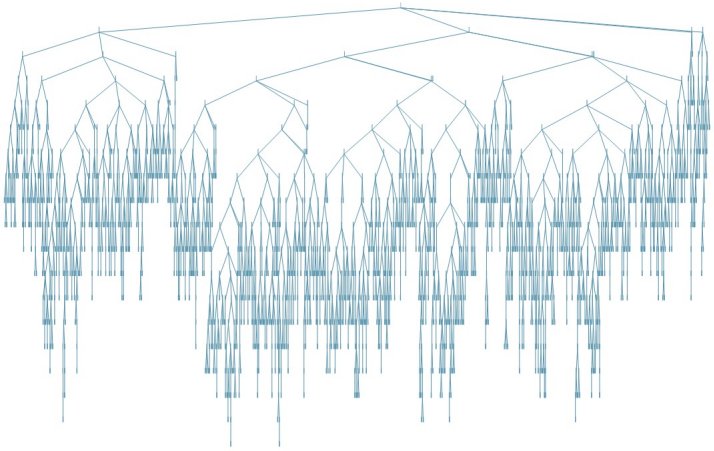


Figure 5. Tree-Map

Node-Link Diagram - Examples

- How does one draw this?
  - DFS
  - Percolate requirements upward



Jinwook Seo / John Stasko

Problems

- For top-down, width of **fan-out** uses up horizontal real estate very quickly
  - At level n, there are 2^n nodes
- What if tree is skewed?
  - Tree might grow a lot along one particular branch
  - Hard to draw it well in a view without knowing how it will branch

Solutions?

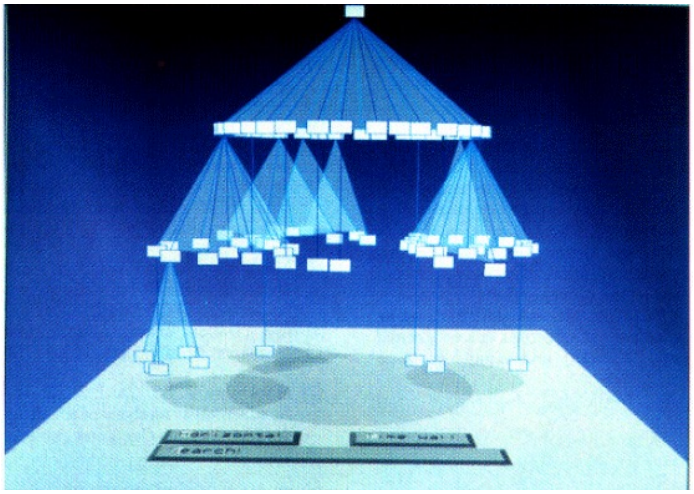
- Techniques developed in Information Visualization largely try to assist the problems identified in the last slide

- Alternatively, Information Visualization techniques attempt to show **more attributes** of data cases in hierarchy or focus on particular **applications** of trees

Cone Trees

- Xerox PARC
- Video

- Children of a node are laid out in a cylinder “below” the parent
  - Siblings live in one of the 2D planes
- pros and cons?

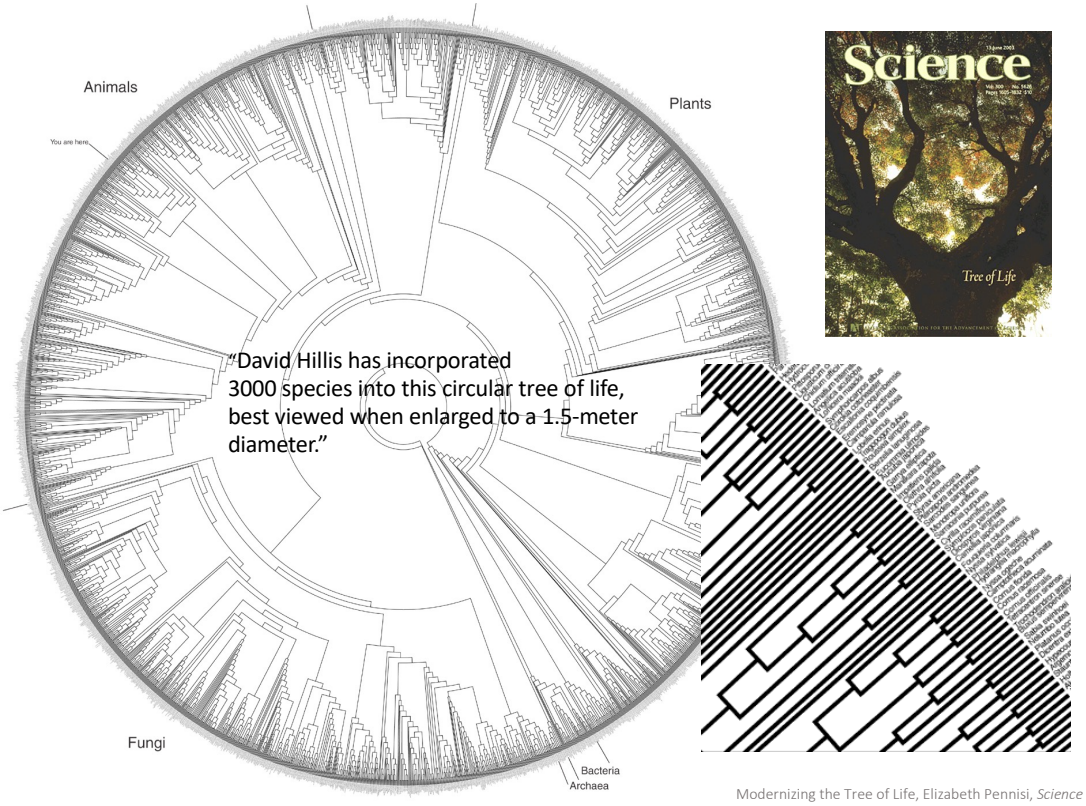


Cone Trees: Animated 3D Visualizations of Hierarchical Information
G. Robertson, J. Mackinlay, S. Card. CHI'91, p. 189-194

Radial Node-Link Tree

- data
  - tree
- encoding
  - link connection marks
  - point node marks
  - radial axis orientation
    - angular proximity: siblings
    - distance from center: depth in tree
- tasks
  - understanding topology, following paths
- scalability
  - 1K - 10K nodes

https://bl.ocks.org/mbostock/4063550



"David Hillis has incorporated 3000 species into this circular tree of life, best viewed when enlarged to a 1.5-meter diameter."

Jinwook Seo/Tamara Munzner

Modernizing the Tree of Life, Elizabeth Pennisi, *Science* 10 June 2003 300: 1692-1697)

Problems

- Number of nodes grows exponentially
  - but the circumference of a circle or the area of a sphere grows only polynomially
- To avoid collisions, we must allocate less room to nodes deeper in the tree

- Overview of the entire tree: see in detail only the nodes surrounding the root node.
- Zoom in deeper in the tree: lose all sense of surrounding context.

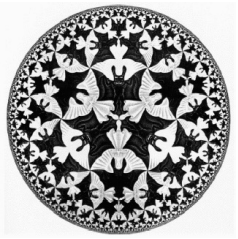
Change the Geometry

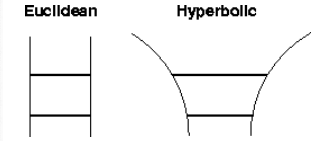
- Apply a *hyperbolic transformation* to the space
  - Perform tree layout in hyperbolic geometry,
  - and then project the result on to the Euclidean plane.
- Root is at center, subordinates around
  - Like tree breadth, the hyperbolic plane expands exponentially!

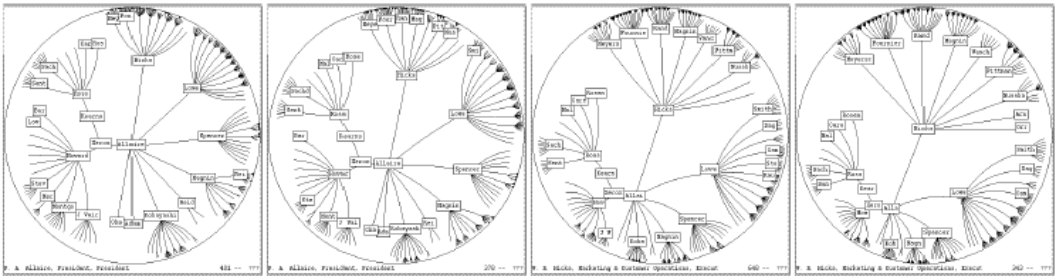
- Apply idea recursively, distance decreases between parent and child as you move farther from center, children go in wedge rather than circle

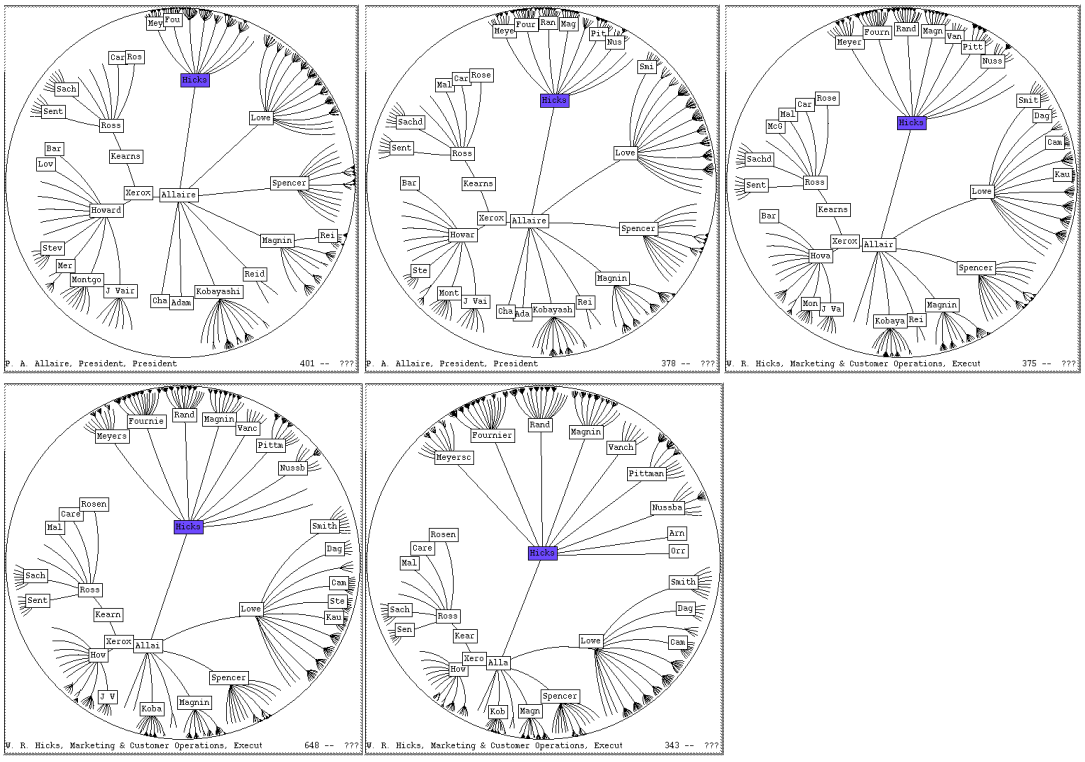
2D Hyperbolic Trees

- Fisheye effect from hyperbolic geometry
  - video: http://www.youtube.com/watch?v=pwpze3RF55o





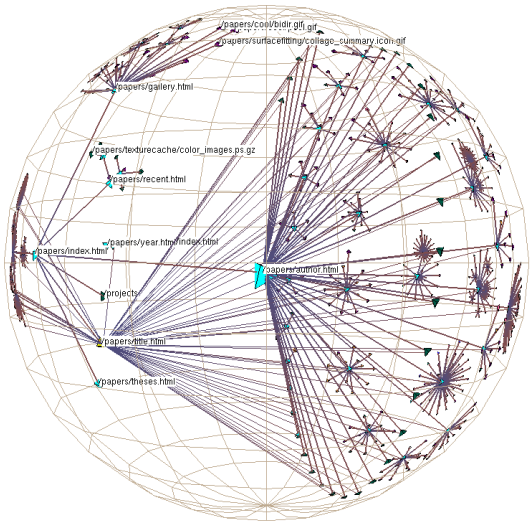




D3.js implementation (https://glouwa.github.io/d3-hypertree/)

Hyperbolic Browser

- Focus + Context Technique
  - Detailed view blended with a global view
- Characteristics
  - First lay out the hierarchy on the hyperbolic plane
  - Then map this plane to a disk
  - Start with the tree's root at the center
  - Use smooth animation to navigate along this representation of the plane
  - Also computable in 3D, projected into a sphere. (H3Viewer)

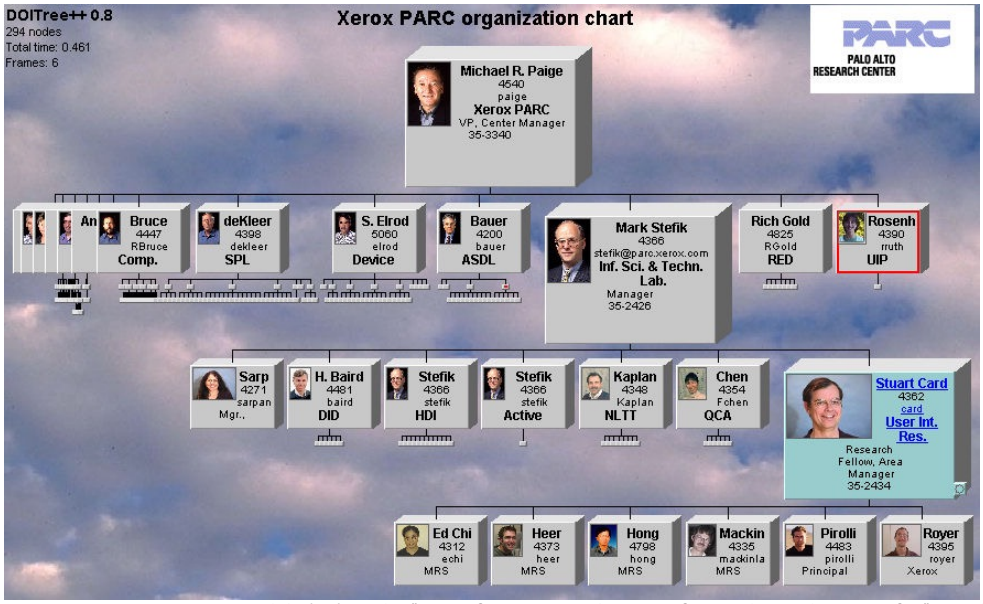


The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies John Lamping and Ramana Rao, Proc SIGCHI '95.

Problems

- Orientation
  - Watching the view can be disorienting
  - When a node is moved, its children don't keep their relative orientation to it as in Euclidean plane, they *rotate*
  - Not as **symmetric** and **regular** as Euclidean techniques, two important attributes in aesthetics

Degree-of-Interest Trees



S. Card and D. Nation, "Degree-of-Interest Trees: A Component of an Attention-Reactive User Interface", Proc. of AVI '02, May 2002, pp. 231-245.

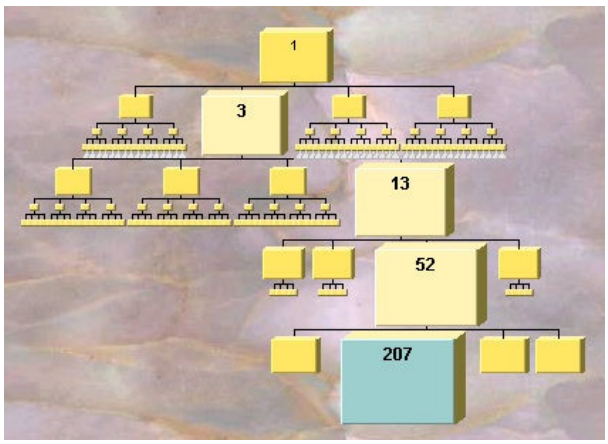
Ideas and Features

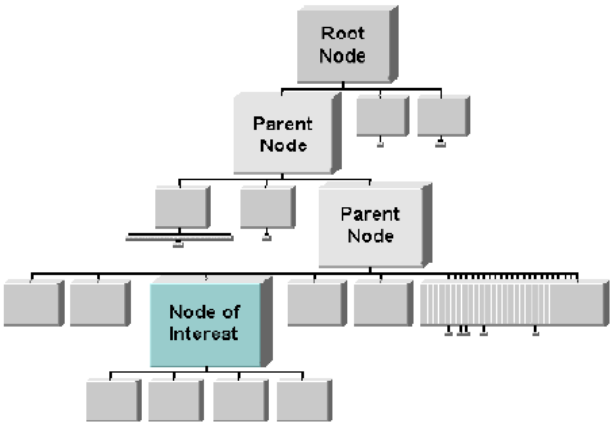
- Use fisheye-like focus + context ideas to control how a tree is drawn

- Features
  - Expanded DOI computation
  - Logical filtering to elide nodes
  - Geometric scaling & Semantic scaling
  - Clustered representation of large unexpanded branches
  - Animated transition

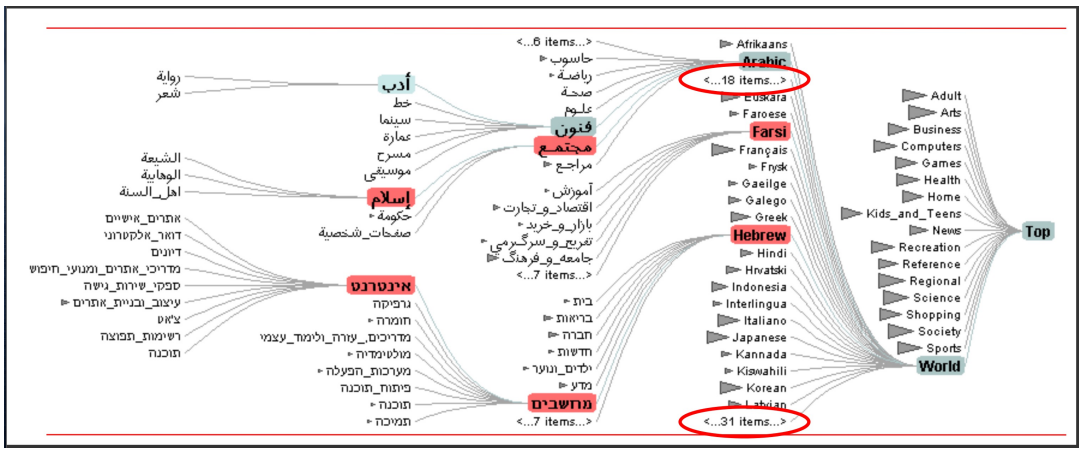
Degree-of-Interest Trees

- ~~http://prefuse.org/gallery/treeview/~~





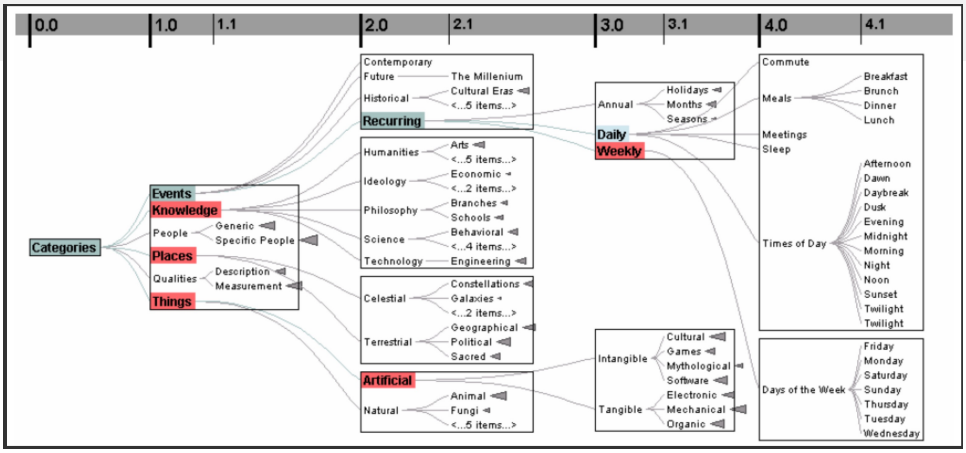
Degree-of-Interest Trees



- Scalable, Space-constrained Visualization
- Multi-focal tree layout

Heer, J. and Card, S. K. 2004. DOITrees revisited: scalable, space-constrained visualization of hierarchical data. AVI '04.

Degree-of-Interest Trees

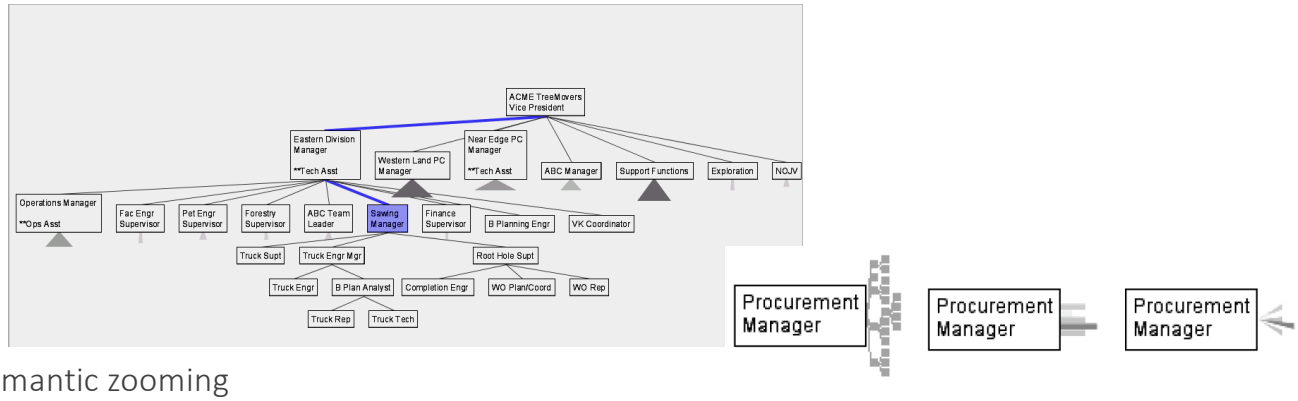


- Remove “low interest” nodes at a given depth level until all blocks on a level fit within bounds.
- Attempt to center child blocks beneath parents.

Heer, J. and Card, S. K. 2004. DOITrees revisited: scalable, space-constrained visualization of hierarchical data. AVI '04.

SpaceTree

- Focus+Context tree
  - filtering, not geometric distortion
  - animated transitions: break animated transitions into discrete stages



- semantic zooming

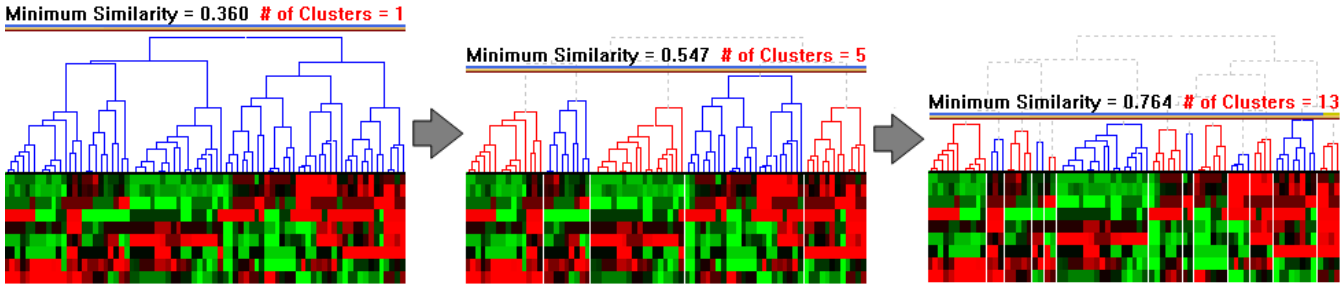
Design Considerations

- Vertical or horizontal arrangement
- Subtrees as triangles
  - Size indicates depth
  - Shading indicates number of nodes inside
- Navigate by clicking on nodes
  - Strongly restricted zooming

- Make labels readable
- Maximize number of levels opened
- Decompose tree animation
- Use landmarks
- Use overview and dynamic filtering

Minimum Similarity Bar

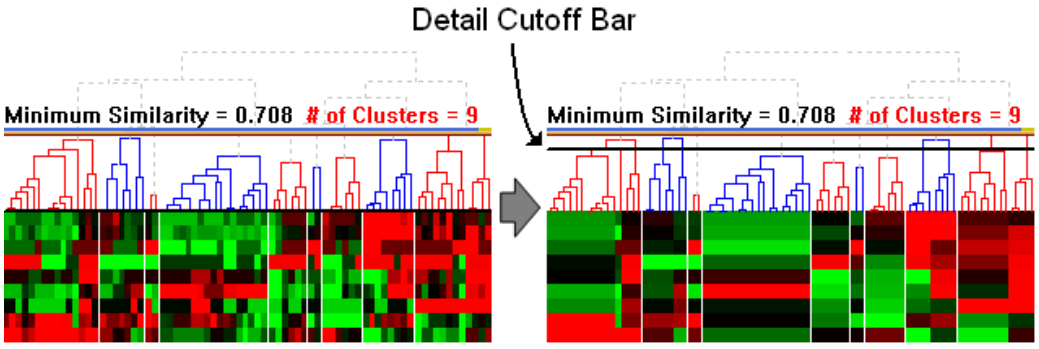
- Interactive Filtering (Dynamic Query) by Similarity of Braches



Jinwook Seo and Ben Shneiderman, Interactively Exploring Hierarchical Clustering Results, Computer, 35, 7: 80-86.

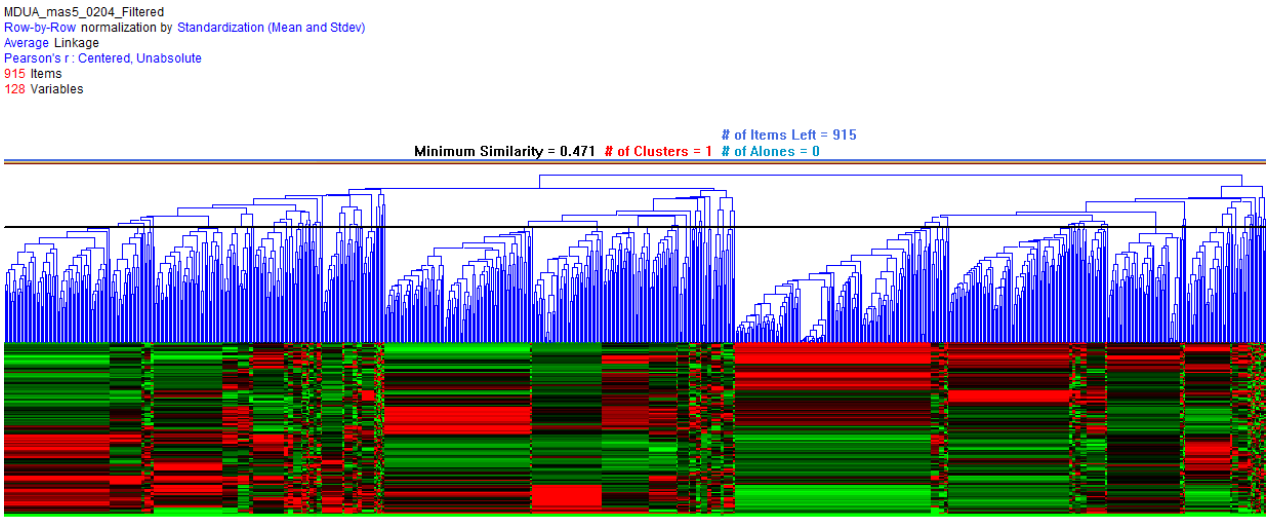
Detail Cutoff Bar

- Adjust the level of detail



Jinwook Seo and Ben Shneiderman, Interactively Exploring Hierarchical Clustering Results, Computer, 35, 7: 80-86.

Scalability



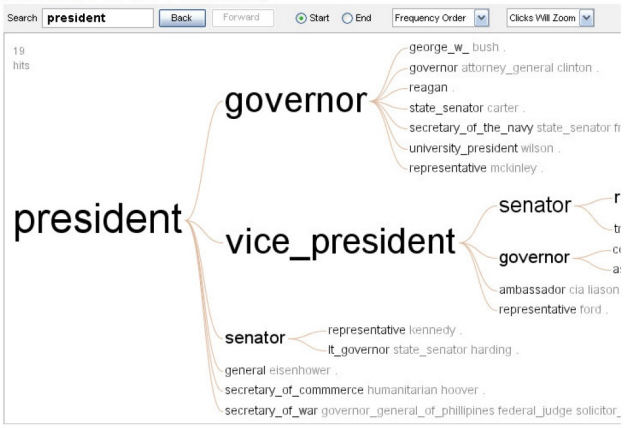
Word Tree

- Interactive Visual Concordance in Text

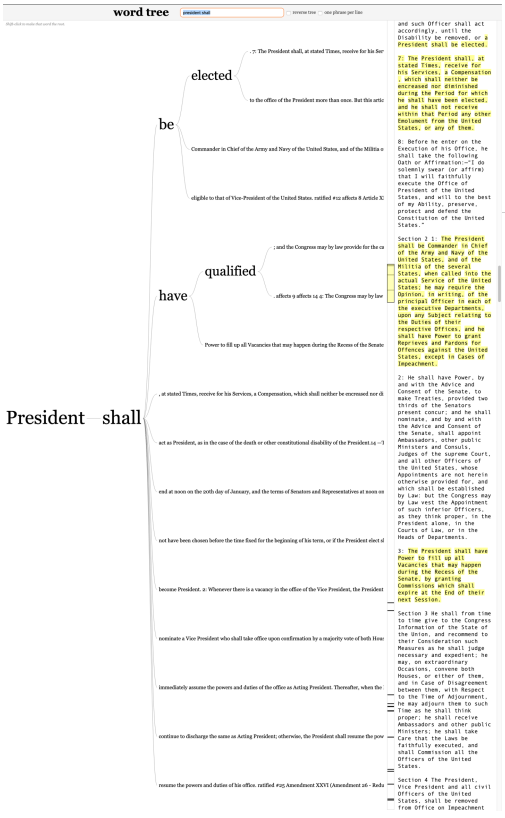
Data set Structure

```
President  Governor  George_W_  Bush
President  Governor  Governor  Attorney_General  Clinton
President  Vice_President  Ambassador  CIA  Liason  Representative  George_HW_Bush
President  Governor  Reagan
President  Governor  State_Senator  Carter
President  Vice_President  Representative  Ford
President  Vice_President  Senator  Representative  Nixon
President  Vice_President  Senator  Representative  Johnson
President  Senator  Representative  Kennedy
President  General  Eisenhower
President  Vice_President  Senator  Truman
President  Governor  Secretary_of_the_Navy  State_Senator  Franklin_Roosevelt
President  Secretary_of_Commmerce  Humanitarian  Hoover
President  Vice_President  Governor  Coolidge
President  Senator  Lt_Governor  State_Senator  Harding
President  Governor  University_President  Wilson
President  Secretary_of_War  Governor_General_of_Phillipines  Federal_Judge
```

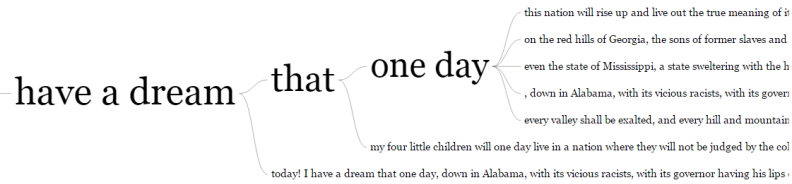
Pathways to the Presidency

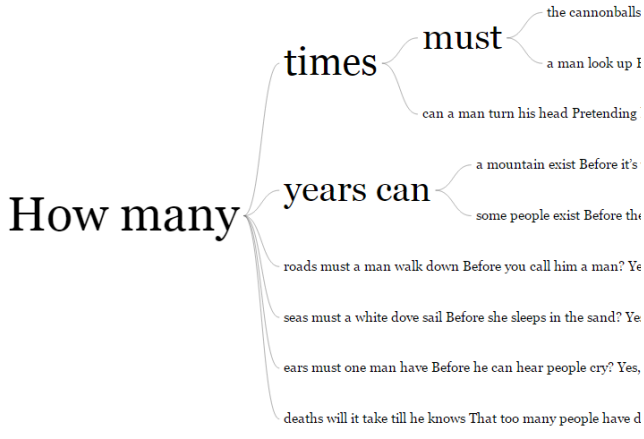


Martin Wattenberg, Fernanda B. Viégas, "The Word Tree, an Interactive Visual Concordance", *IEEE Transactions on Visualization & Computer Graphics*, vol.14, no. 6, pp. 1221-1228, November/December 2008, doi:10.1109/TVCG.2008.172



http://www.jasondavies.com/wordtree/





Node-link Shortcoming

- Inefficient use of screen space

- Difficult to encode more variables of data cases (nodes)
  - Shape
  - Color
  - Size
  - …but all quickly clash with basic node-link structure

http://tashian.com/carl/archives/2004/06/

Motivations

- a filled hard disk
- 80 MB shared by 14 users
- determine how and where space was used
- node-link diagrams grew too large to be useful

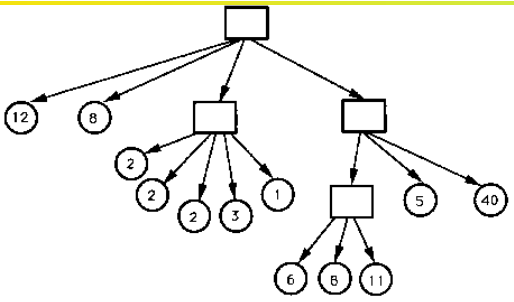


Figure 1: Typical 3-level tree structure with numbers indicating size of each leaf node

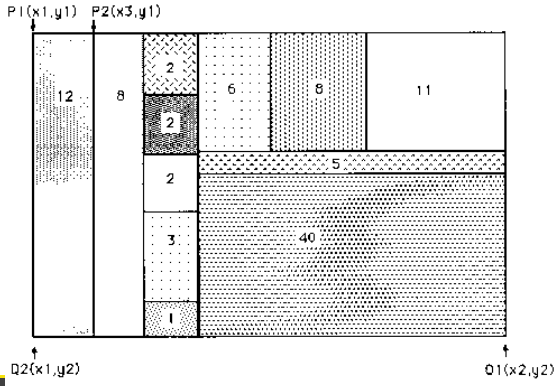


Figure 2: Tree-map of figure 1

Brian Johnson and Ben Shneiderman. 1991. Tree-Maps: a space-filling approach to the visualization of hierarchical information structures. In *Proceedings of the 2nd conference on Visualization '91* (VIS '91), Gregory M. Nielson and Larry Rosenblum (Eds.). IEEE Computer Society Press, Los Alamitos, CA, USA, 284-291

hci lab
SEOUL NATIONAL UNIVERSITY

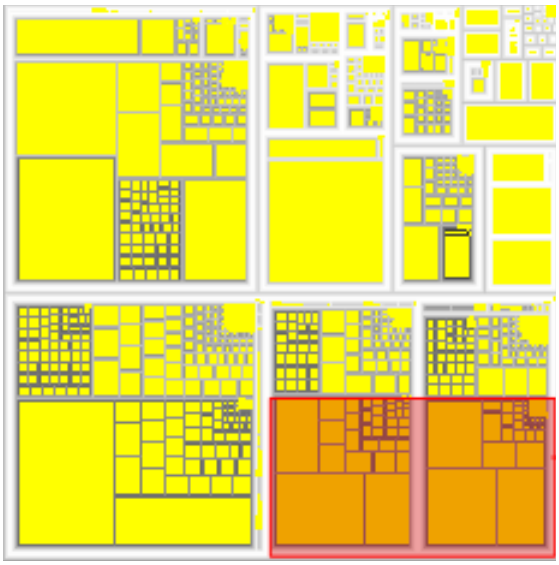
Idea

- Space-filling representation developed by Shneiderman and Johnson, Vis ’91
- Children are drawn inside their parent
- Alternate horizontal and vertical slicing at each successive level
- Use area to encode other variable of data items

Brian Johnson and Ben Shneiderman. 1991. Tree-Maps: a space-filling approach to the visualization of hierarchical information structures. In *Proceedings of the 2nd conference on Visualization '91* (VIS '91), Gregory M. Nielson and Larry Rosenblum (Eds.). IEEE Computer Society Press, Los Alamitos, CA, USA, 284-291

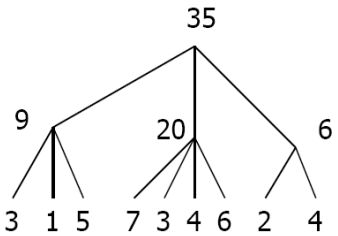
Treemap

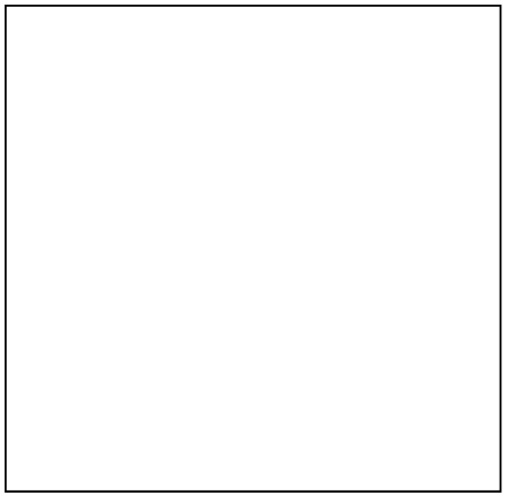
- data
  - tree
  - 1 quant attrib at leaf nodes
- encoding
  - area containment marks for hierarchical structure
  - rectilinear orientation
  - size encodes quant attrib
- tasks
  - query attribute at leaf nodes
- scalability
  - 1M leaf nodes



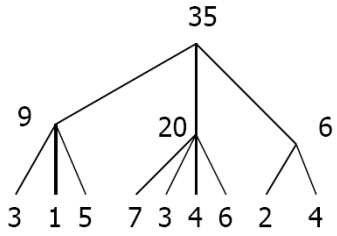
https://bl.ocks.org/mbostock/4063582
http://tulip.labri.fr/Documentation/3_7/userHandbook/html/ch06.html

Slice-and-Dice (Basic Idea)

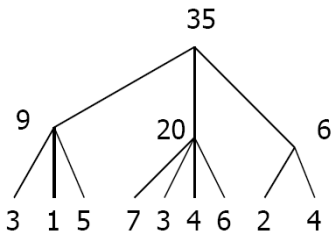


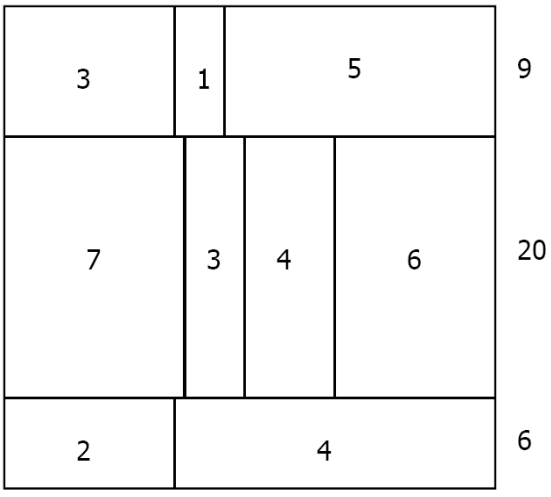


Slice-and-Dice (Basic Idea)



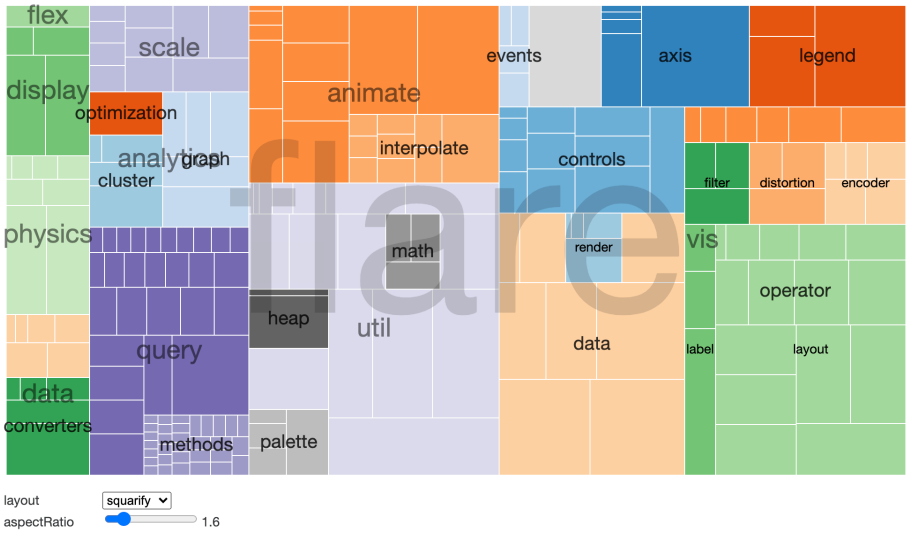
Slice-and-Dice (Basic Idea)





Interactive Example – using Vega

- https://vega.github.io/vega/examples/treemap/



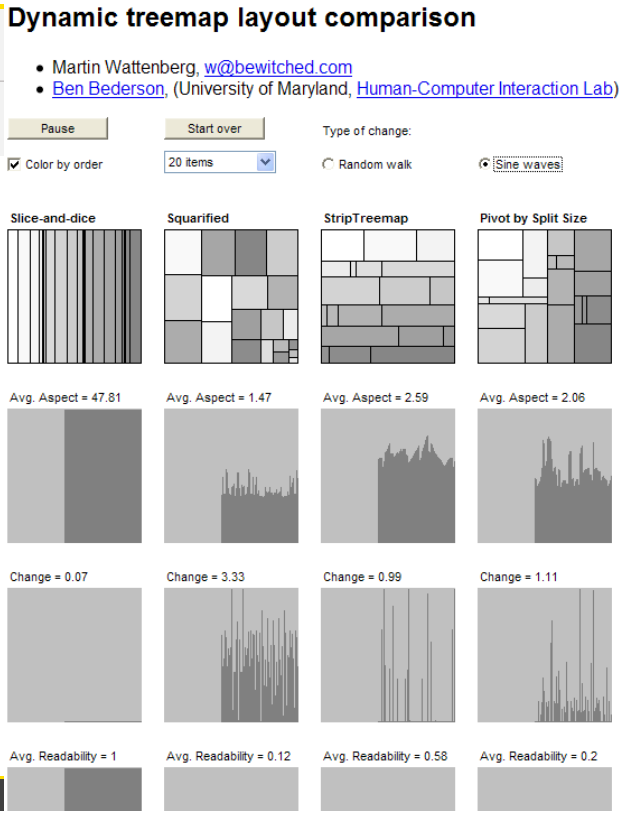
Analysis

Compare

- slice and dice
- squarified
- strip
- pivot

techniques by

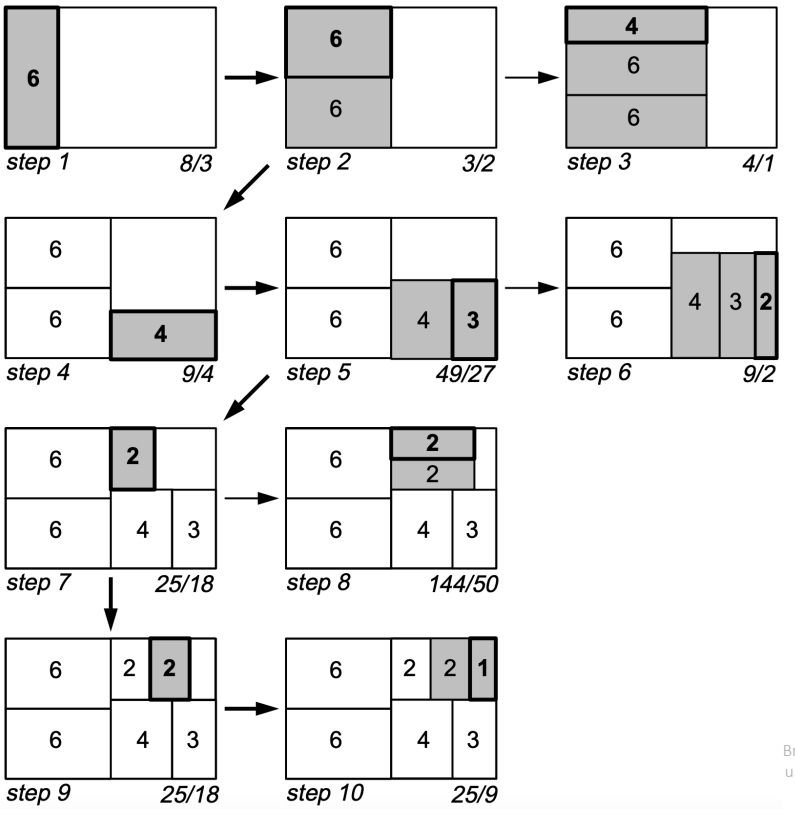
- aspect ratio
- structural change
- readability



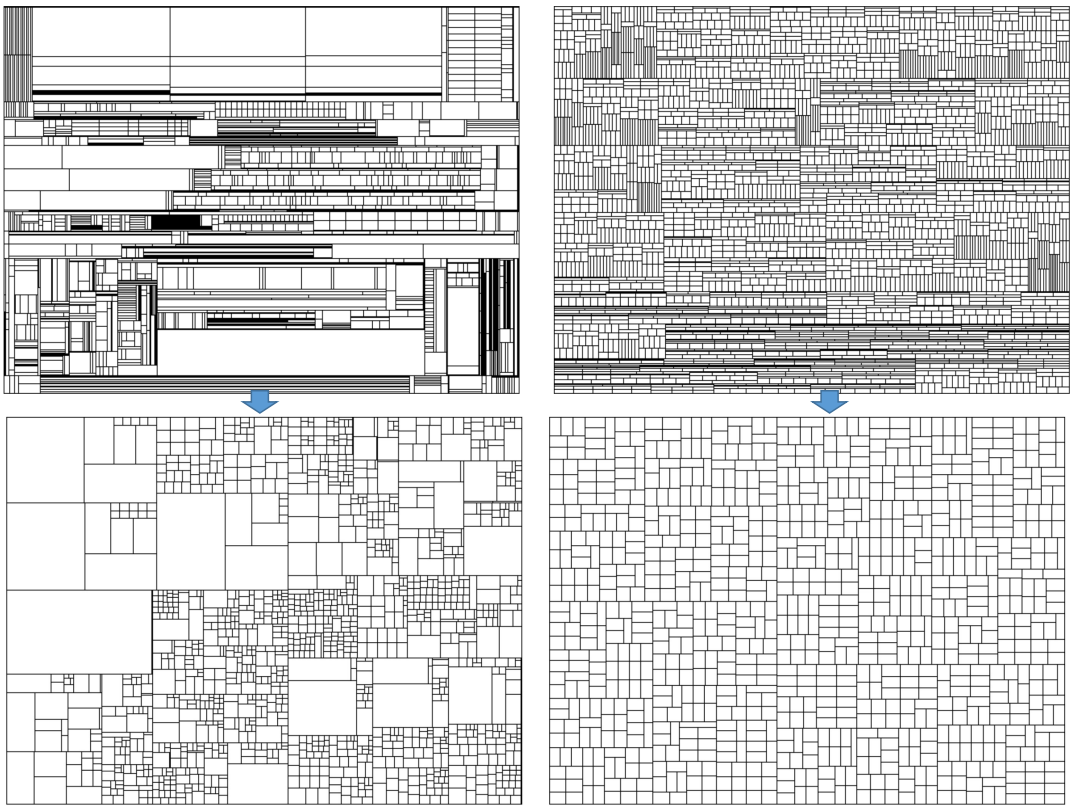
Squarified Treemaps

- Slice-and-Dice layout suffers from extreme aspect ratios.
- How might we do better?

- Squarified layout:
  - greedy optimization for making rectangles square as much as possible
  - Slice/dice only within siblings; alternate whenever ratio worsens.



Bruls, M., Huizing, K., & Van Wijk, J. J. (2000). Squarified treemaps. In *Data visualization 2000* (pp. 33-42). Springer, Vienna.



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Why Squares?

- Posited Benefits of 1:1 Aspect Ratios

1. Minimize perimeter, reducing border ink.
   - *Mathematically true!*
2. Easier to select with a mouse cursor.
   - *Validated by empirical research & Fitts' Law!*
3. Similar aspect ratios are easier to compare.
   - *Seems intuitive, but is this true?*
   - Extreme ratios & squares-only more inaccurate.
   - Balanced ratios better? Target golden ratio?

Bruls, M., Huizing, K., & Van Wijk, J. J. (2000). Squarified treemaps. In *Data visualization 2000* (pp. 33-42). Springer, Vienna.
From Jeff Heer's Lecture Note.

Aspect Ratio Matters

- significant effect of aspect ratio on judgment accuracy

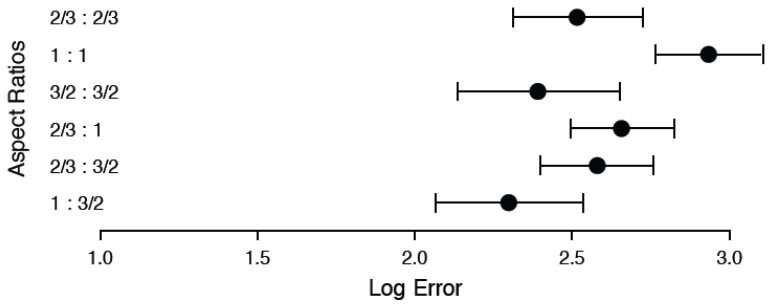
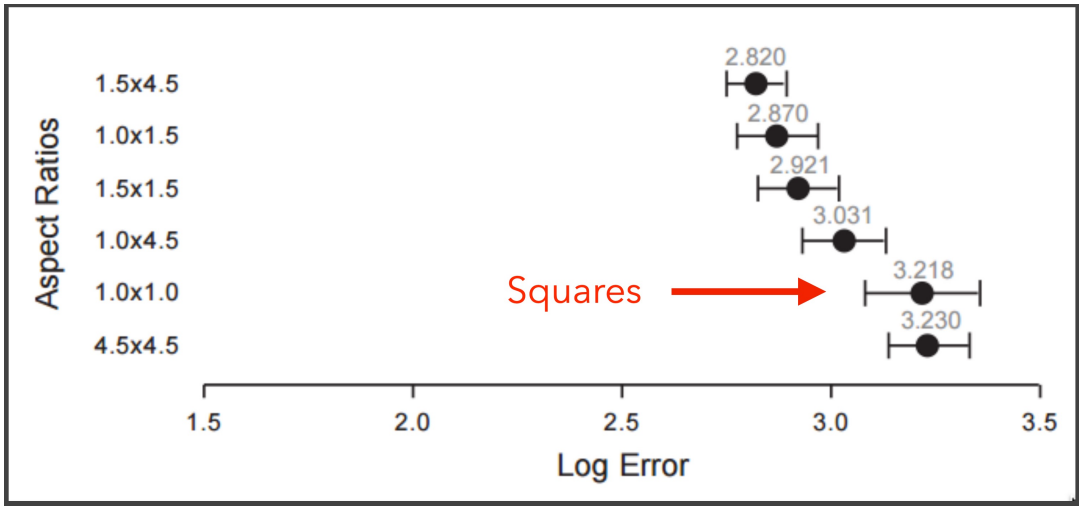


Figure 5: Rectangular area judgments by aspect ratios (1B). Error bars indicate 95% confidence intervals.

- viewers use 1D length comparisons to help estimate area

Jeffrey Heer and Michael Bostock. 2010. Crowdsourcing graphical perception: using mechanical turk to assess visualization design. In *Proceedings of the 28th international conference on Human factors in computing systems* (CHI '10). ACM, New York, NY, USA, 203-212. DOI=10.1145/1753326.1753357 http://doi.acm.org/10.1145/1753326.1753357

Comparison Error vs. Aspect Ratio



Kong, Heer & Agrawala, InfoVis '10.

Cushion Treemap

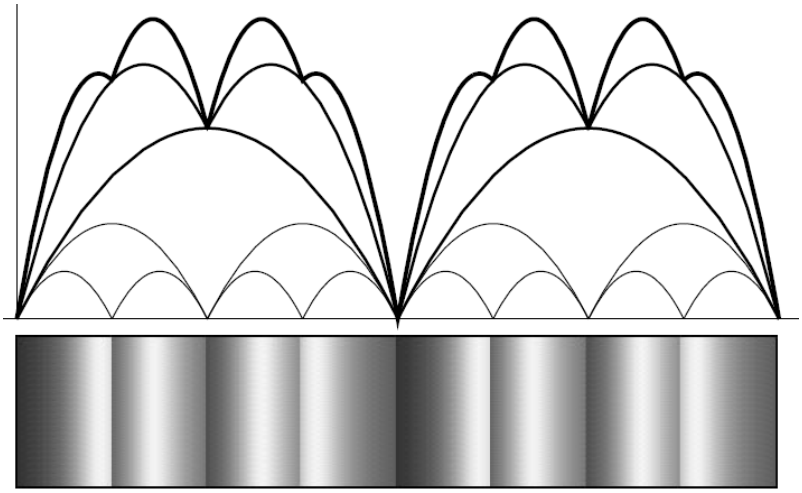


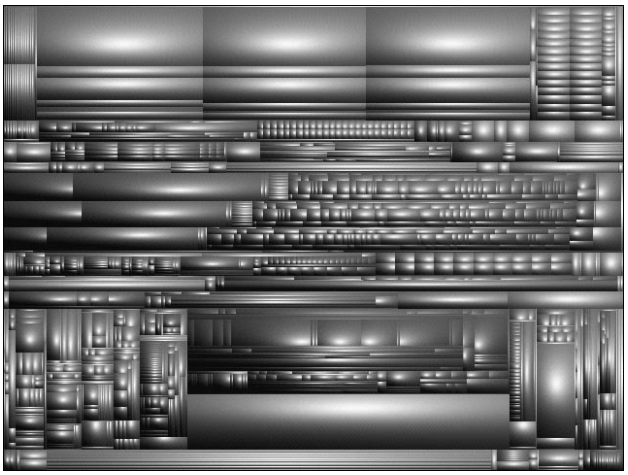
Figure 4. Binary subdivision of interval

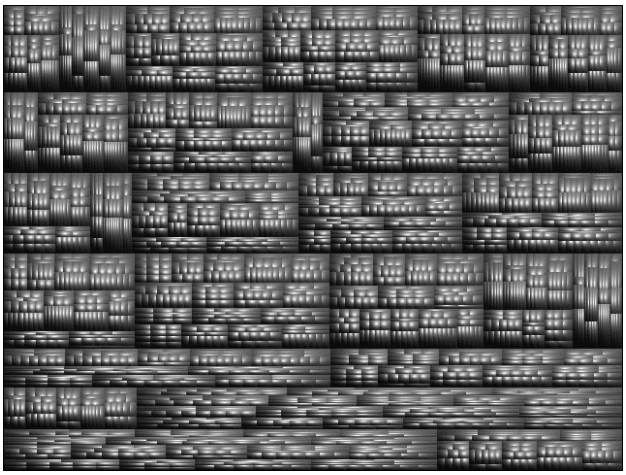
Van Wijk, J.J.; Van de Wetering, H., "Cushion treemaps: visualization of hierarchical information," *Information Visualization, 1999. (Info Vis '99) Proceedings. 1999 IEEE Symposium on* , vol., no., pp.73-78, 147, 1999

Make the Hierarchy Clear

Cushion Treemap

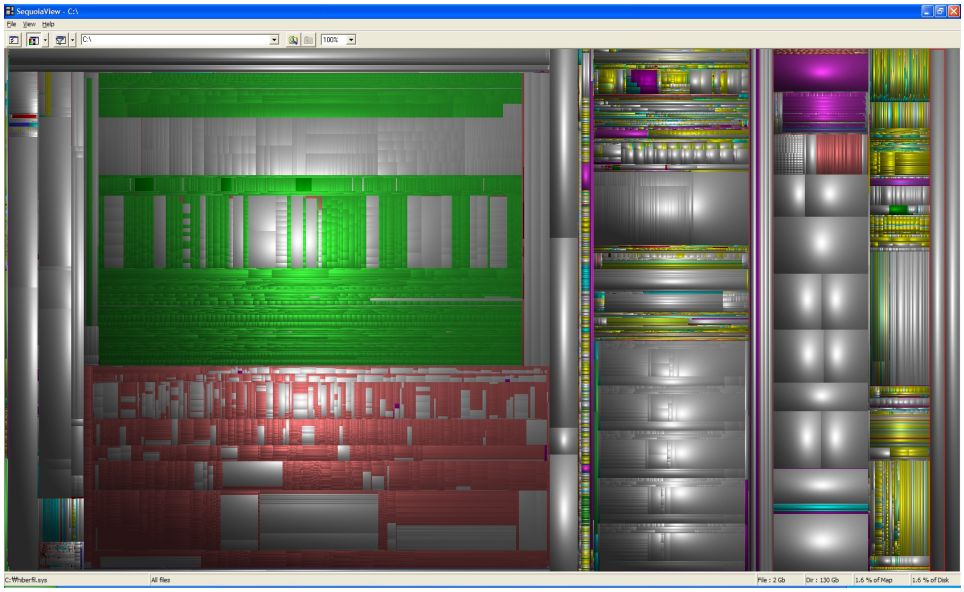
- Add shading and texture to help convey structure of hierarchy





Van Wijk, J.J.; Van de Wetering, H., "Cushion treemaps: visualization of hierarchical information," *Information Visualization, 1999. (Info Vis '99) Proceedings. 1999 IEEE Symposium on* , vol., no., pp.73-78, 147, 1999

SequoiaView



Pros and Cons

- shine when users care mostly about **leaf** nodes and their **attributes** (e.g. outlier stocks)
- good when they do not need to focus on the **topology** of the tree, or the topology of the tree is trivial (2 or 3 fixed levels)
- good for **monitoring** changes
- require **training** because of the unfamiliar layout

Pros and Cons

- Revealing topology
- Familiar layout
- inefficient use of screen space
  - empty top or left, overcrowding the opposite
  - overview + detail views with pan and zoom
  - fisheye (DOI tree)
  - 3D node link diagrams
  - hyperbolic space
  - overlapping, pruning, preview(semantic zoom)

Credits

- Many slides from Tamara Munzner’s slide deck
- Many slides from John Stasko’s slide deck
- Many figures from Main Textbook by Tamara Munzner

- Questions?