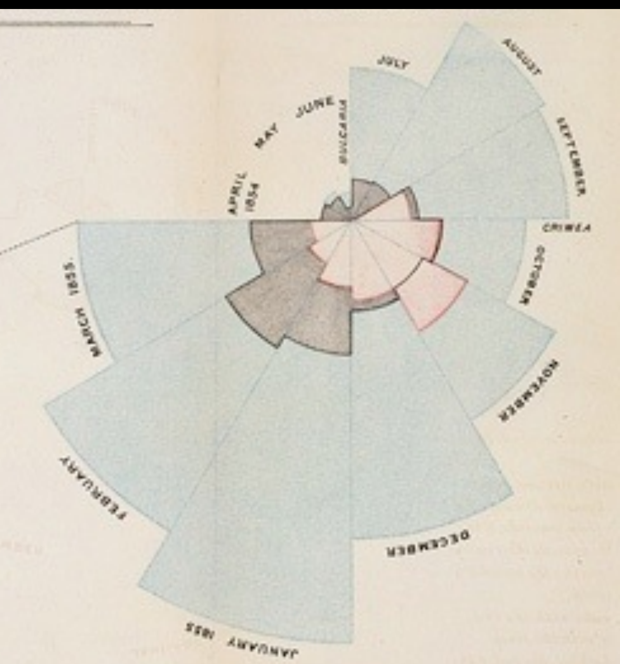
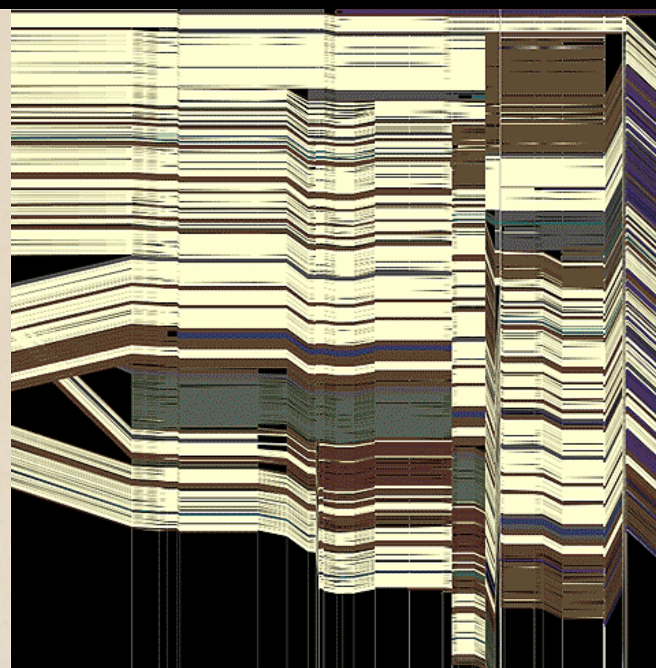
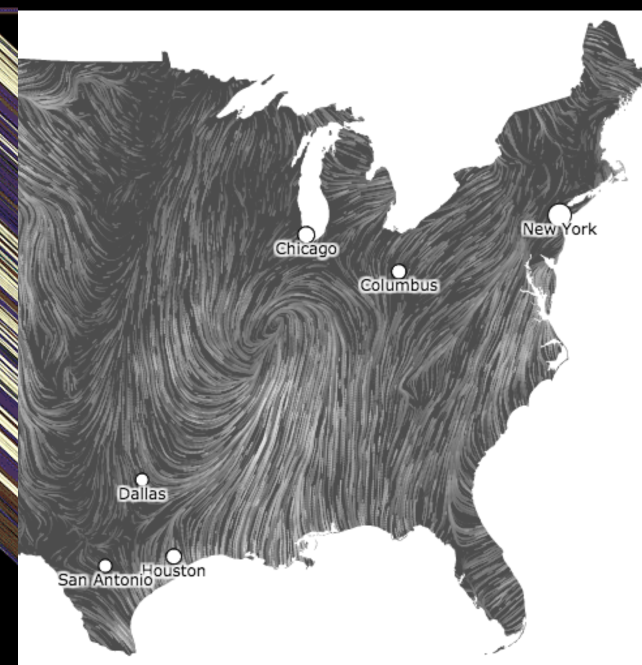
CSE 412 - Intro to Data Visualization

Hierarchies



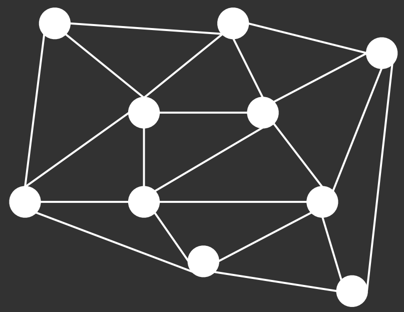
Jane Hoffswell University of Washington

Graphs and Trees

Graphs

Model relations among data

Nodes and *edges*

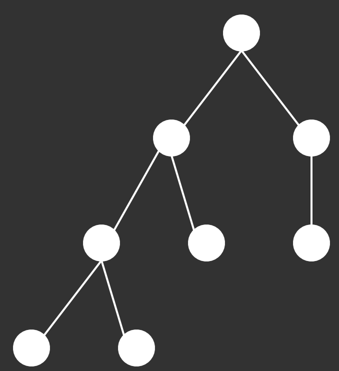


Trees

Graphs with hierarchical structure

Connected graph with N-1 edges

Nodes as *parents* and *children*



Spatial Layout

A primary concern of tree/graph drawing is the spatial arrangement of nodes and edges.

Often (but not always) the goal is to effectively depict the graph structure:

- Connectivity, path-following
- Topological distance
- Clustering / grouping
- Ordering (e.g., hierarchy level)

Applications

Tournaments
Organization Charts
Genealogy
Diagramming (e.g., Visio)
Biological Interactions (Genes, Proteins)
Computer Networks
Social Networks
Simulation and Modeling
Integrated Circuit Design

Network Analysis Tasks [Pretorius '13]

Structure-based: relationships and connectivity

Attribute-based: specific node/link attributes

Browsing: understand paths in the data

Estimation: summarization and temporal changes

Network Analysis Tasks [Pretorius '13]

Structure-based: relationships and connectivity

Find all of the friends of friends for Taylor.

Find all of the people who are friends with Jordan and Alex.

Six degrees of separation: shortest path between two individuals.

Attribute-based: specific node/link attributes

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Find all "students" attending CSE412.

Find all the "friends" and "family" of Alex.

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Browsing: understand paths in the data

Find Alex's friend Taylor, and then Taylor's friend Jordan.

Estimation: summarization and temporal changes

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Find all the "friends" and "family" of Alex.

Browsing: understand paths in the data

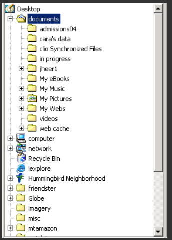
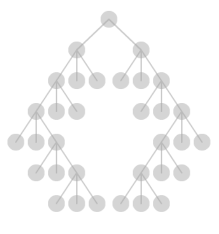
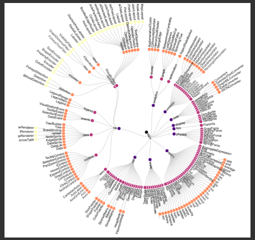
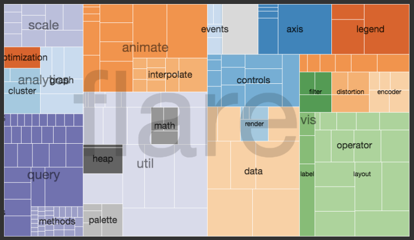
Find Alex's friend Taylor, and then Taylor's friend Jordan.

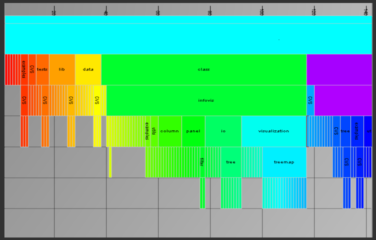
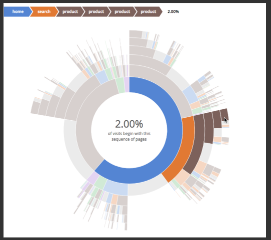
Estimation: summarization and temporal changes

How does Jordan's friend group change over the course of the year?

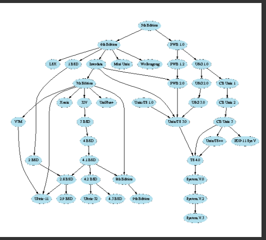
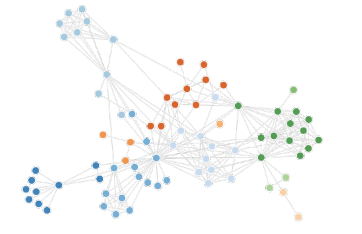
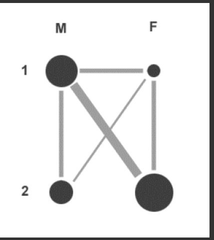
Topics

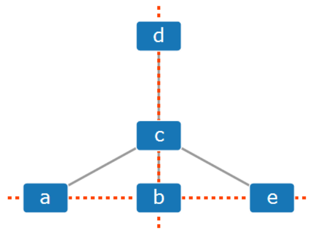
TODAY - Tree Visualization

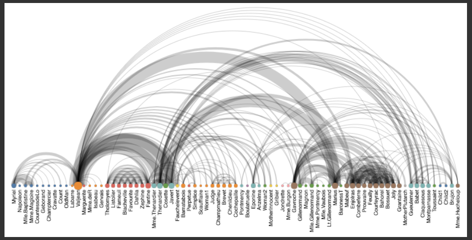





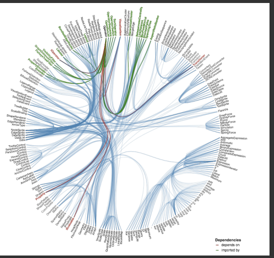
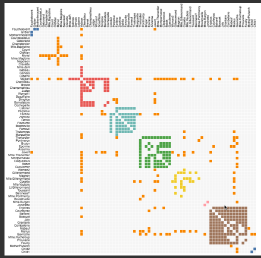
Wed - Graph Layout: Node-Link Diagrams





Wed - Alternative Visualizations and Techniques

Select an image to jump to those slides.

Tree Visualization

Tree Visualization

Indentation

Linear list, indentation encodes depth

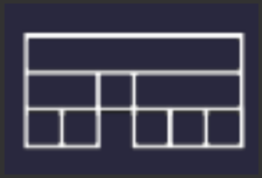
Node-Link diagrams

Nodes connected by lines/curves

Enclosure diagrams

Represent hierarchy by enclosure

Layering

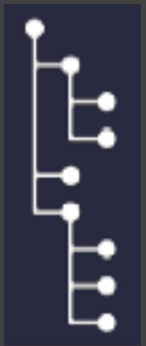


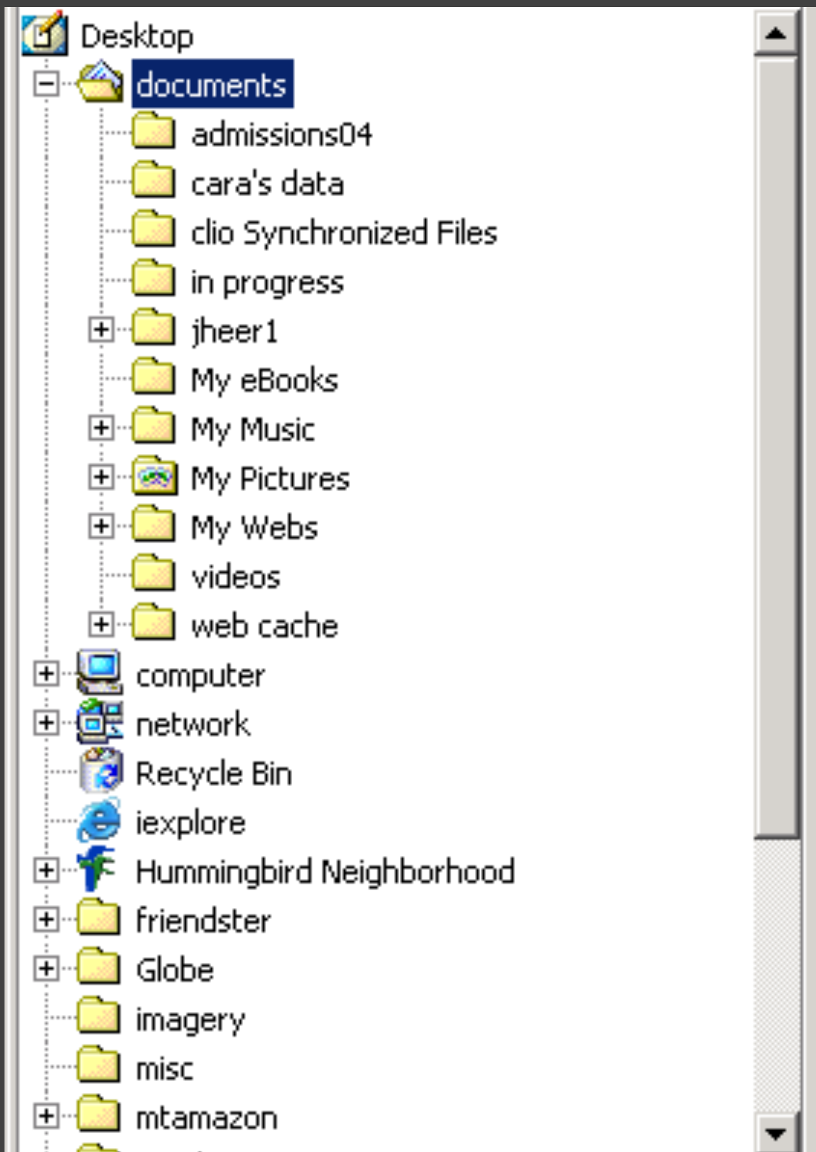
Relative position and alignment

Typically fast: O(n) or O(n log n), interactive layout

Indentation

Indentation





Places all items along vertically spaced rows

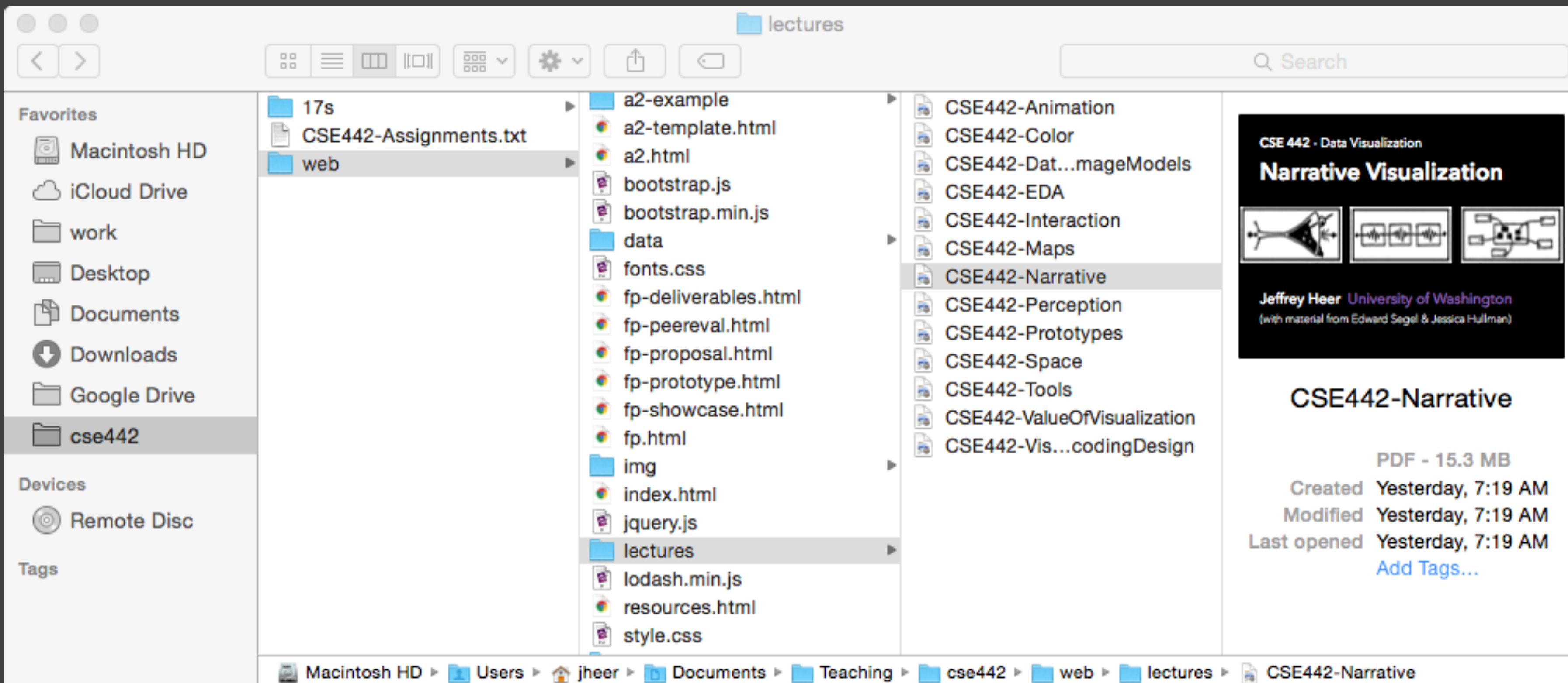
Indentation used to show parent/child relationships

Commonly used as a component in an interface

Breadth and depth contend for space

Often requires a great deal of scrolling

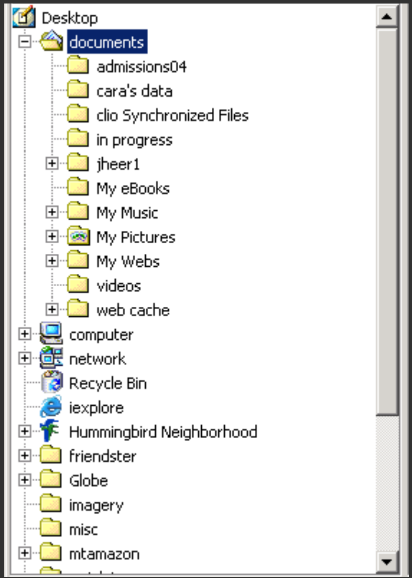
Single-Focus (Accordion) List

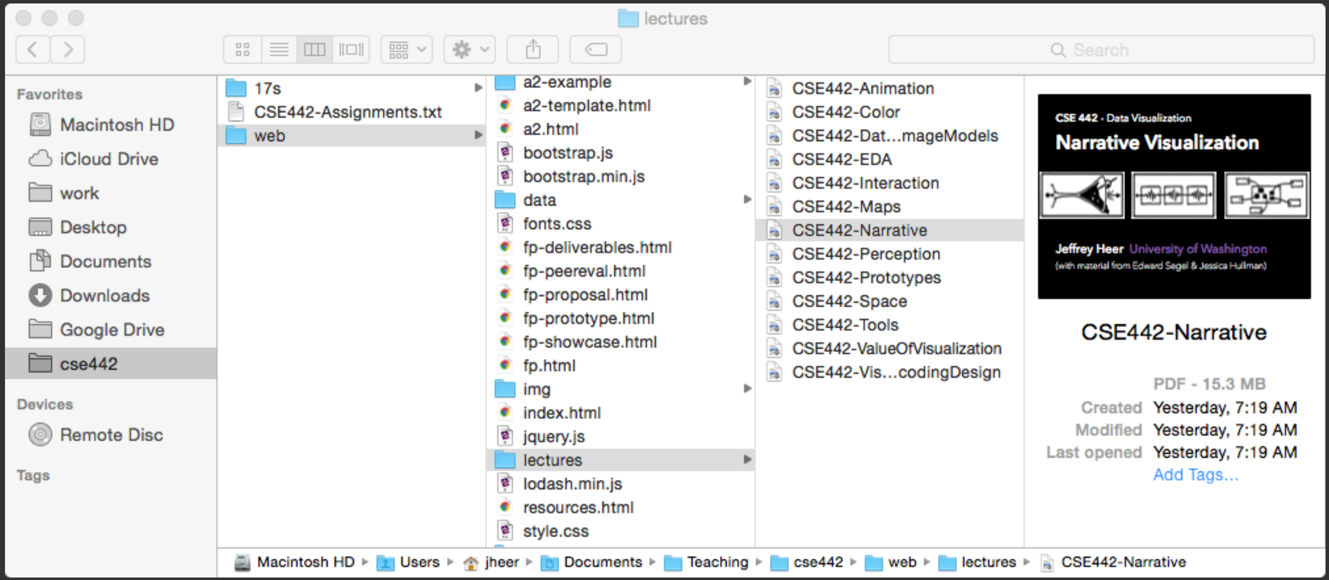


Separate breadth & depth along 2D.

Focus on a single path at a time.

What tasks are these good for?





Benefits:

Navigation + Browsing, Parent-Child Relationships

Disadvantages:

Estimation, Comparison, Network Overview

Node-Link Diagrams

Node-Link Diagrams

Nodes are distributed in space, connected by straight or curved lines

Typical approach is to use 2D space to break apart breadth and depth

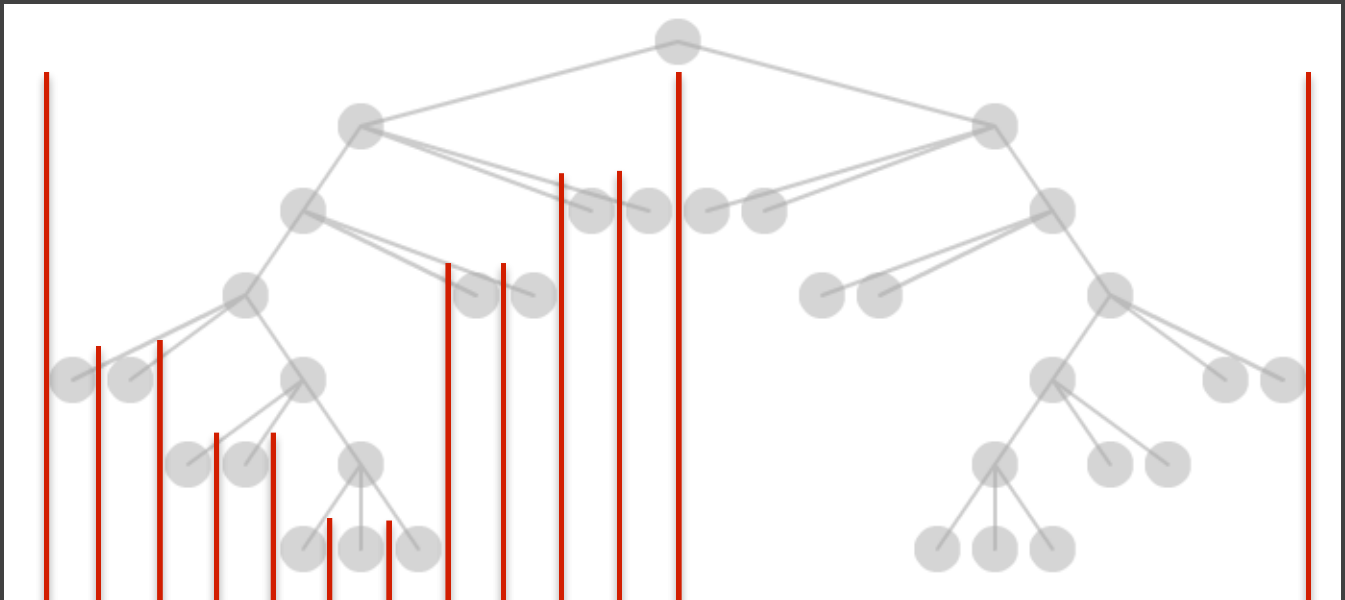
Often space is used to communicate hierarchical orientation (e.g., towards authority or generality)

Naïve Recursive Layout

Repeatedly divide space for subtrees by leaf count

Breadth of tree along one dimension

Depth along the other dimension



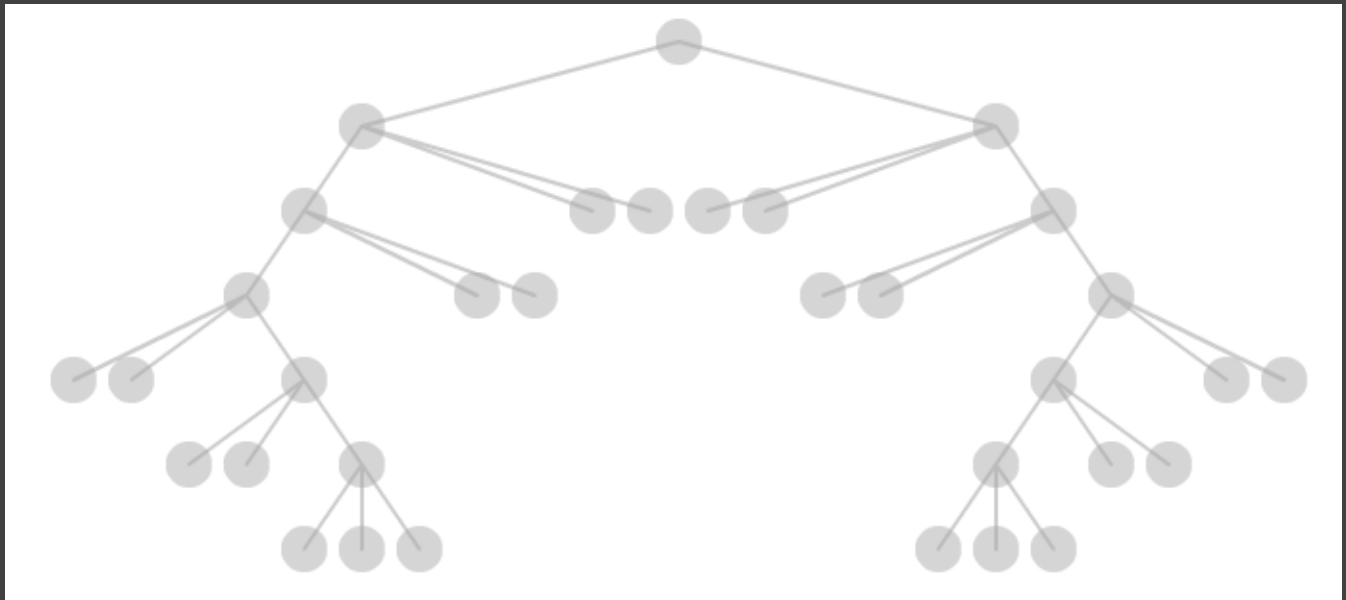
Naïve Recursive Layout

Repeatedly divide space for subtrees by leaf count

Breadth of tree along one dimension

Depth along the other dimension

Problems?



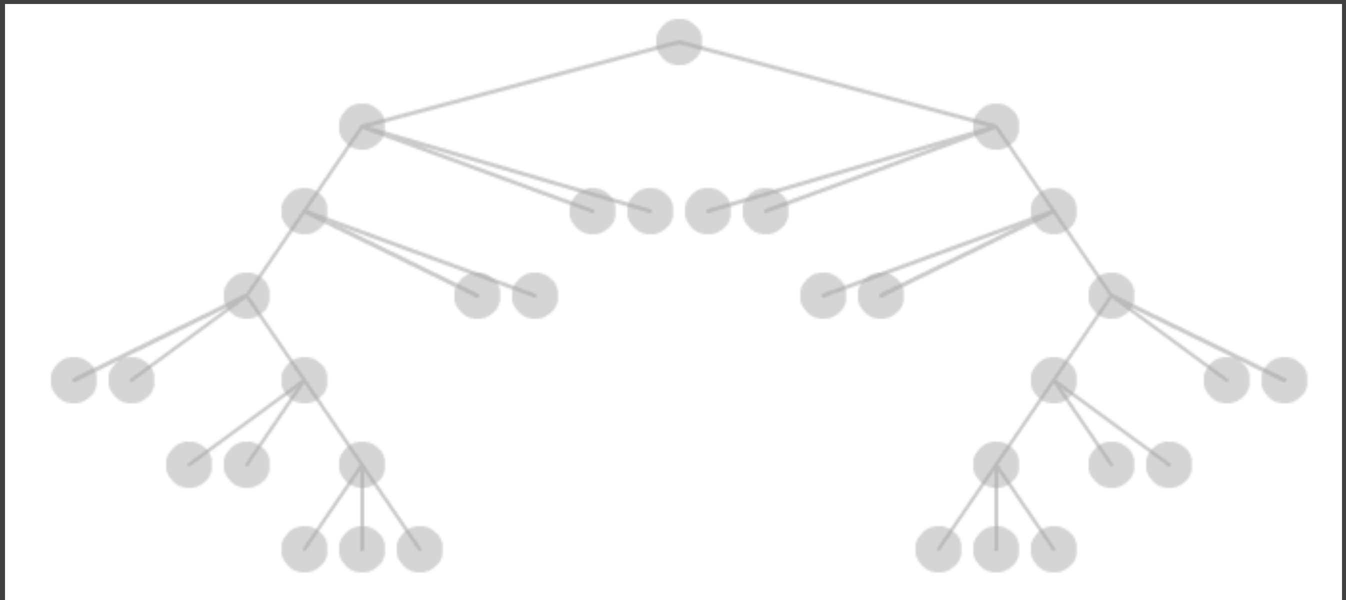
Naïve Recursive Layout

Repeatedly divide space for subtrees by leaf count

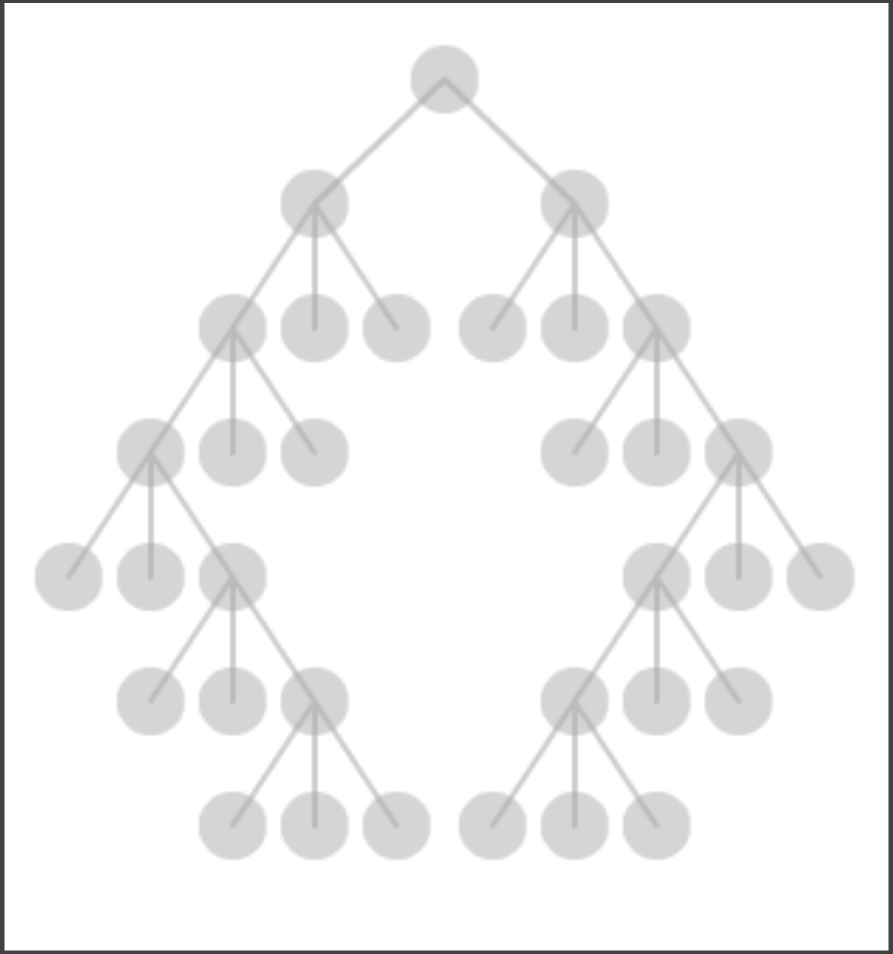
Breadth of tree along one dimension

Depth along the other dimension

Problem: exponential growth of breadth



Reingold & Tilford's "Tidy" Layout

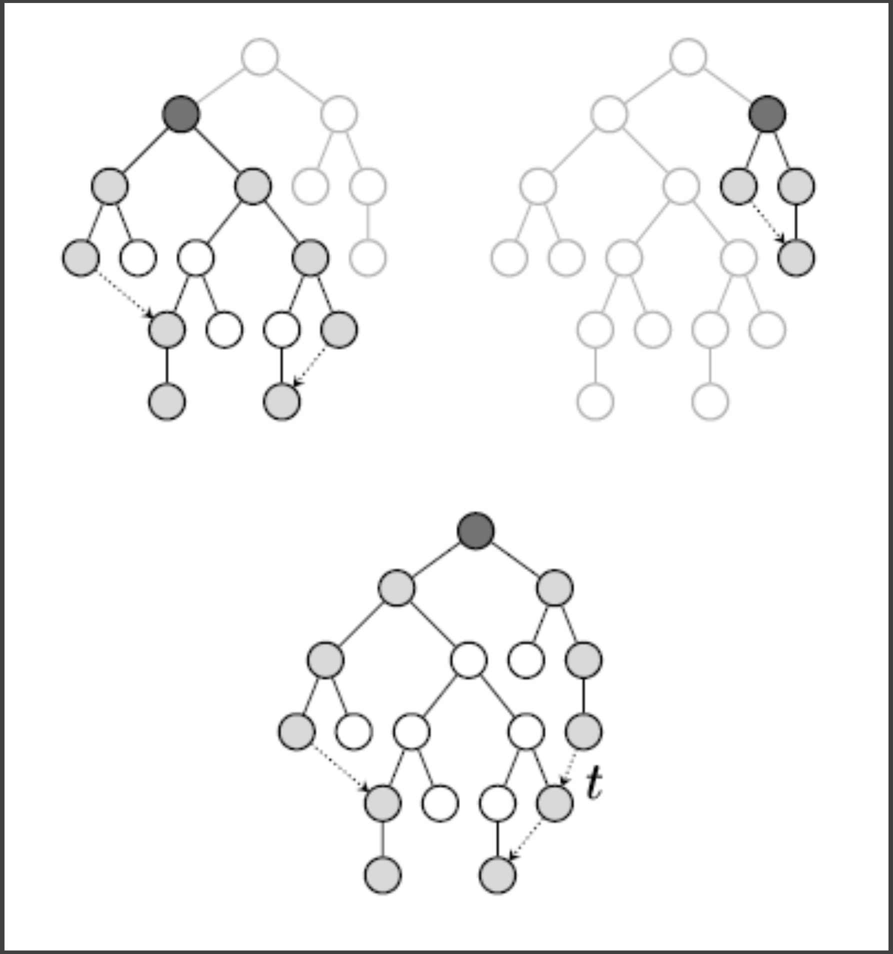


Goal: make smarter use of space, maximize density and symmetry.

Originally binary trees, extended by Walker to cover general case.

Corrected by Buchheim et al. to achieve a linear time algorithm.

Reingold-Tilford Layout



Design Considerations

Clearly encode depth

No edge crossings

Draw isomorphic subtrees identically (same shape)

Preserve layout ordering and symmetry

Compact, space-saving layout (don't waste space)

Reingold-Tilford Layout

Initial bottom-up (post-order) traversal of the tree

- Y-coordinates based on tree depth
- X-coordinates initialized to zero

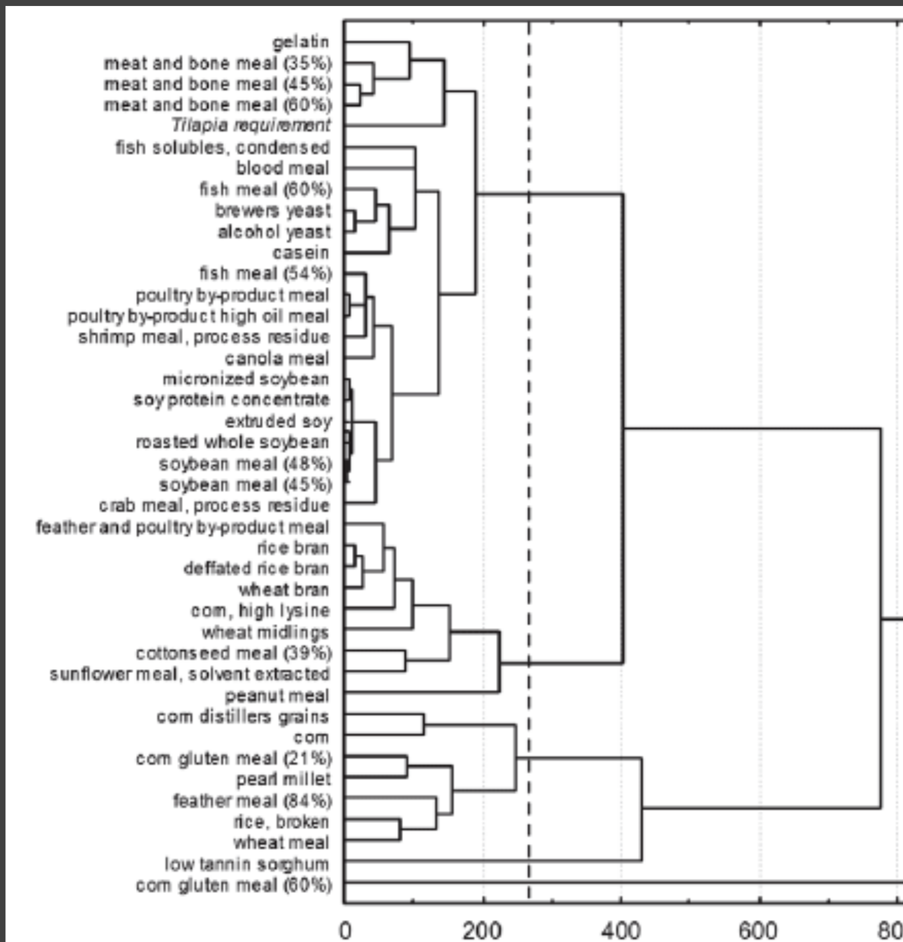
At each parent node: merge left and right subtrees

- Shift right subtree as close as possible to the left
- Compute efficiently by maintaining subtree boundaries
- Center the parent node above its children
- Record "shift" position offset for right subtree

Final top-down (pre-order) traversal to set X-coordinates

- Sum the aggregated shifts

Cluster Dendrograms

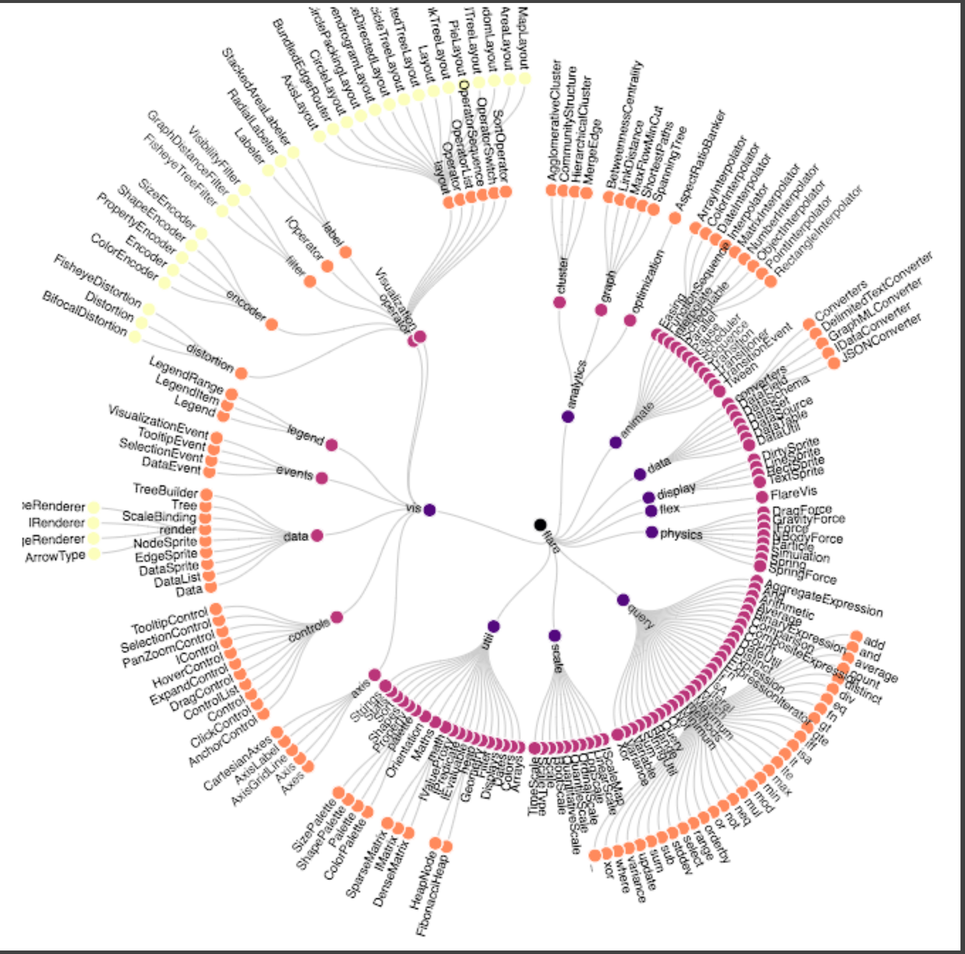


Depicts cluster trees produced by hierarchical clustering algorithms.

Leaf nodes arranged in a line, internal node depth indicates order/value at which clusters merge.

Naïve recursive layout with orthogonal two-segment edges.

Radial Tree Layout



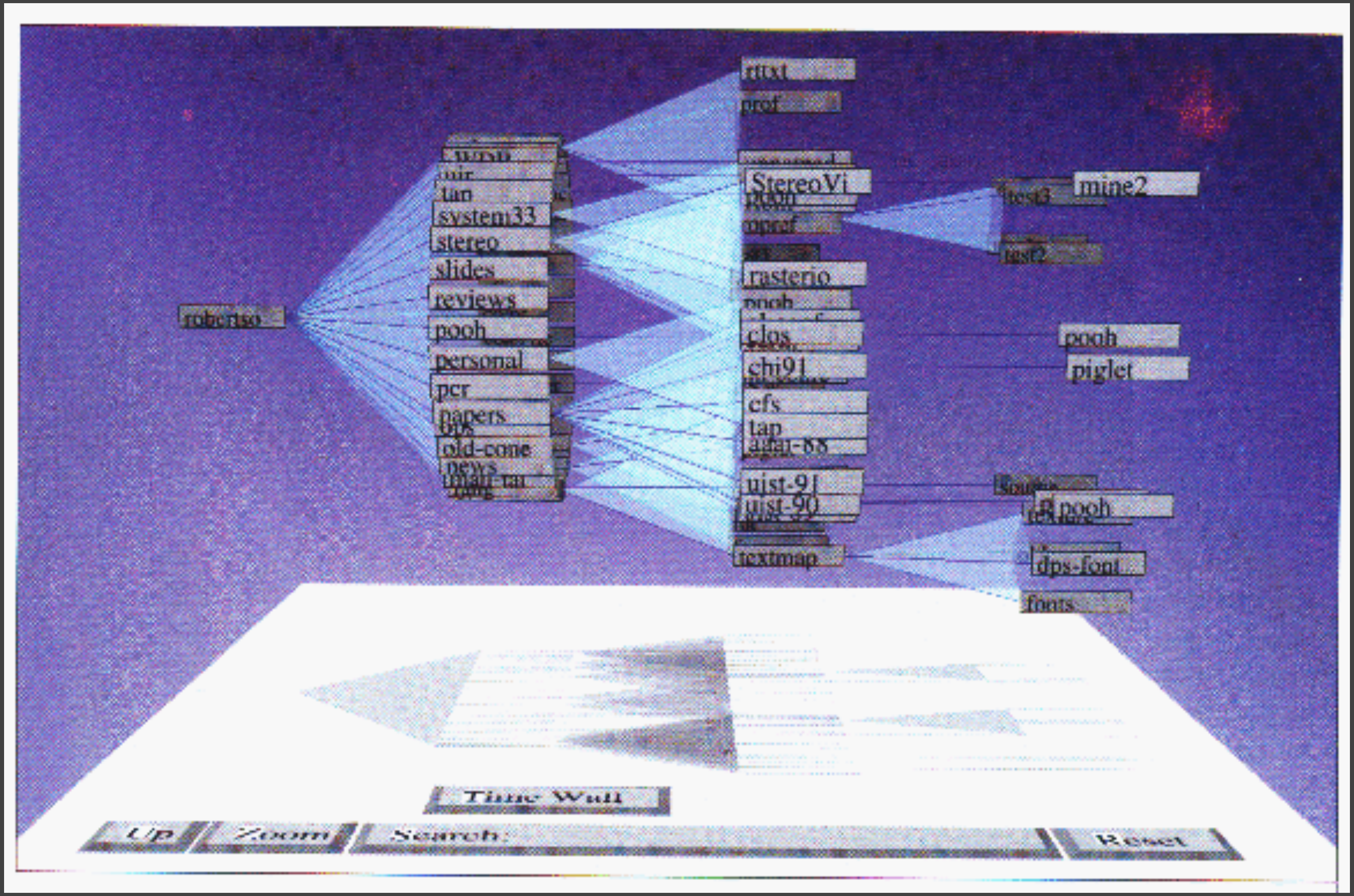
Node-link diagram in polar co-ordinates.

Radius encodes depth, with root in the center.

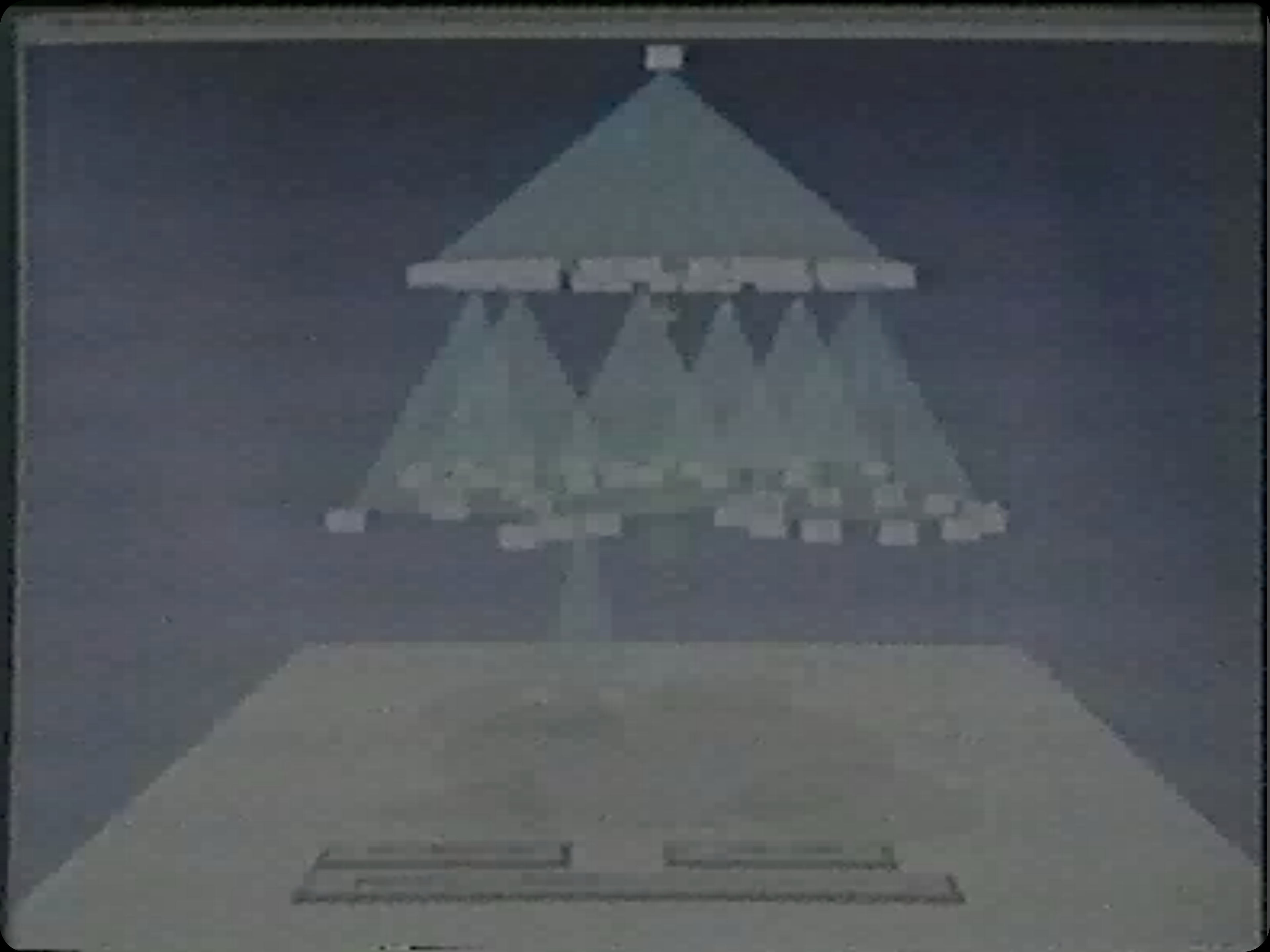
Angular sectors assigned to subtrees (often with naïve recursive layout).

Reingold-Tilford method can also be applied here.

Cone Trees [Robertson 91]



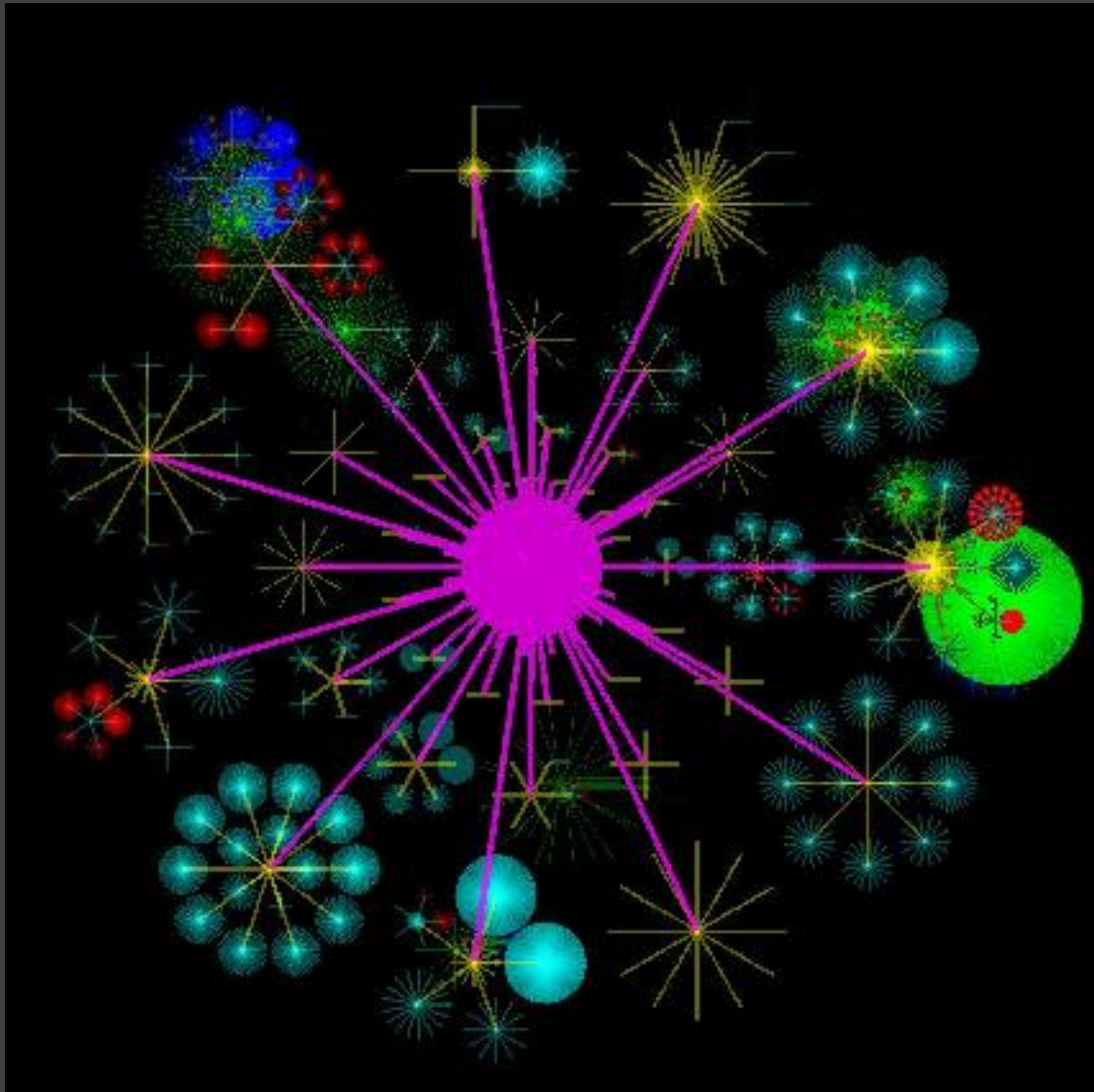
Video



Balloon Trees

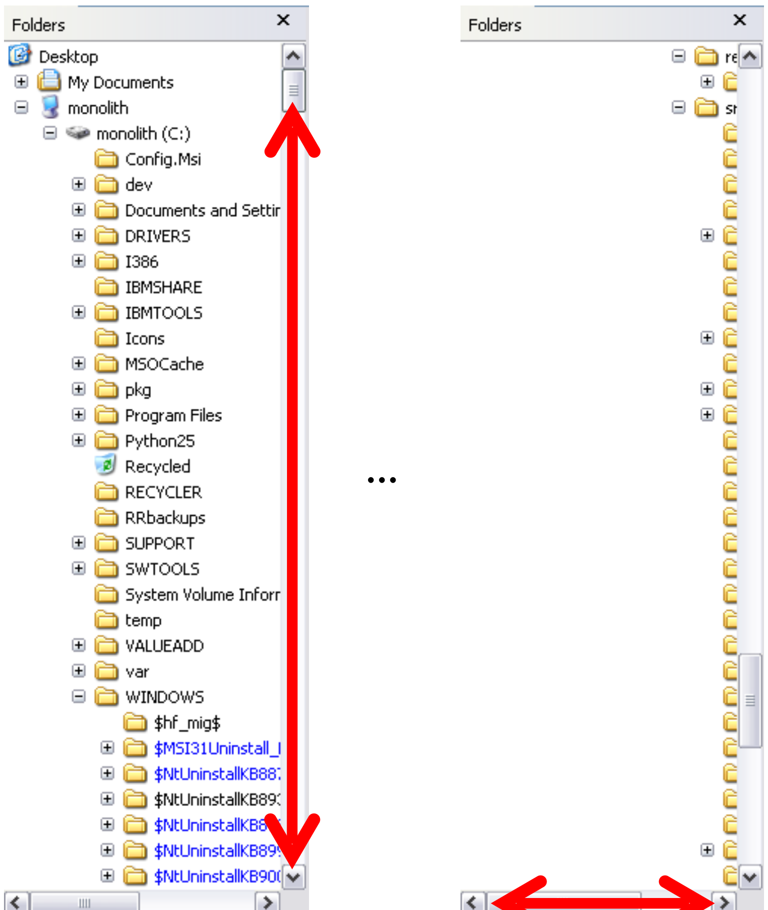
Described as a 2D variant of a Cone Tree.

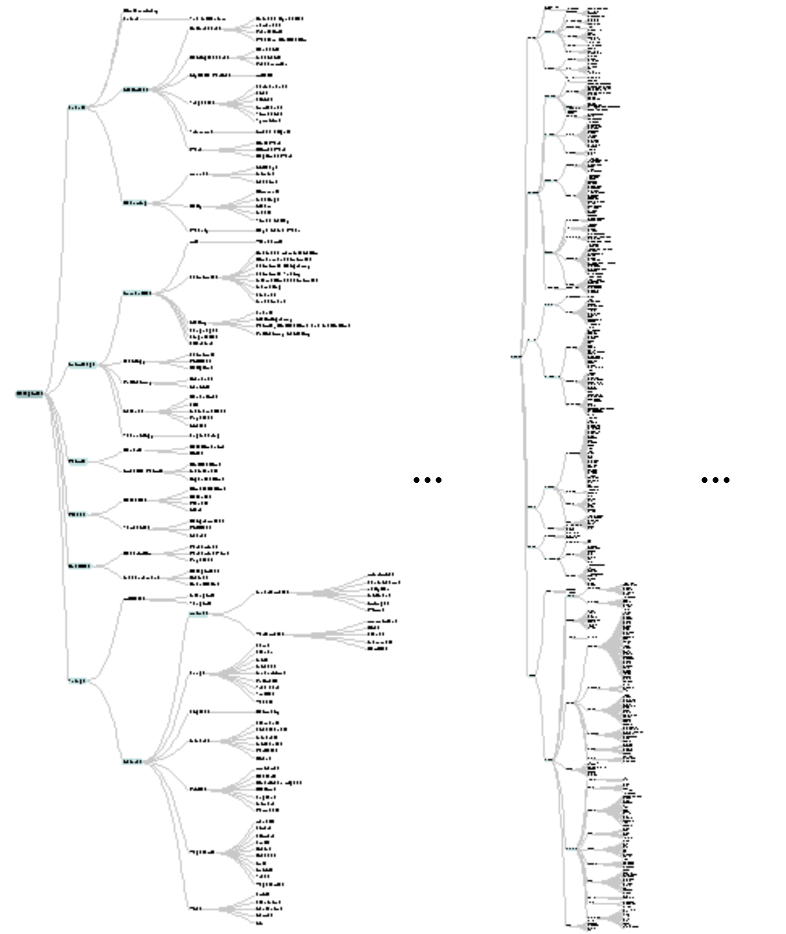
Not just a flattening process: circles must not overlap.



Analysis Tasks: Focus+Context

Visualizing Large Hierarchies





Indented Layout

Reingold-Tilford Layout

More Nodes, More Problems…

Scale

Tree breadth often grows exponentially

Even with tidy layout, quickly run out of space

Possible Solutions

Filtering

Focus+Context

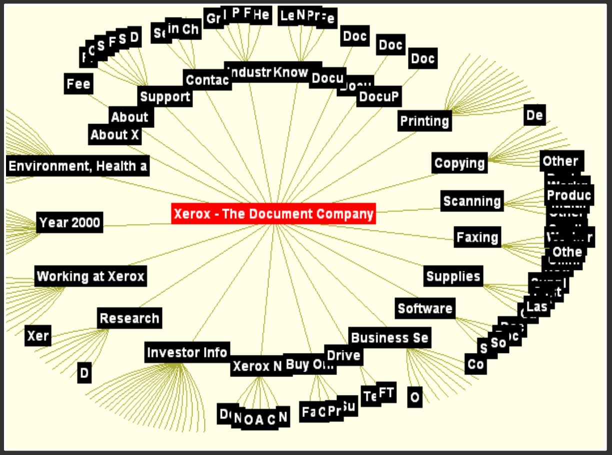
Scrolling or Panning

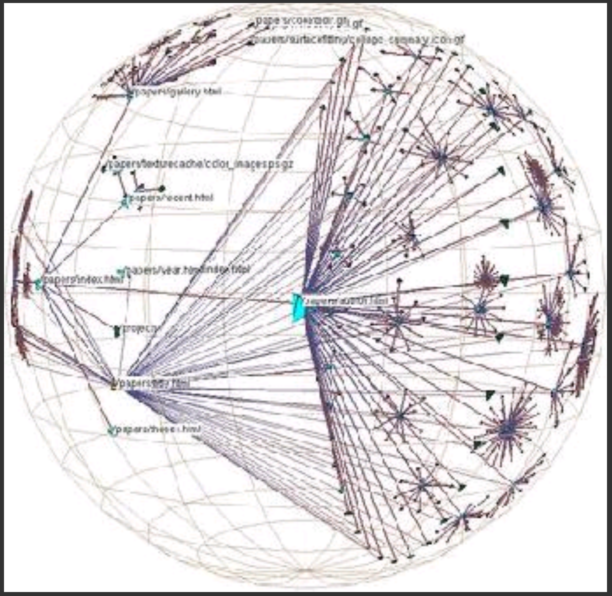
Zooming

Aggregation

MC Escher, *Circle Limit IV*

Hyperbolic Layout



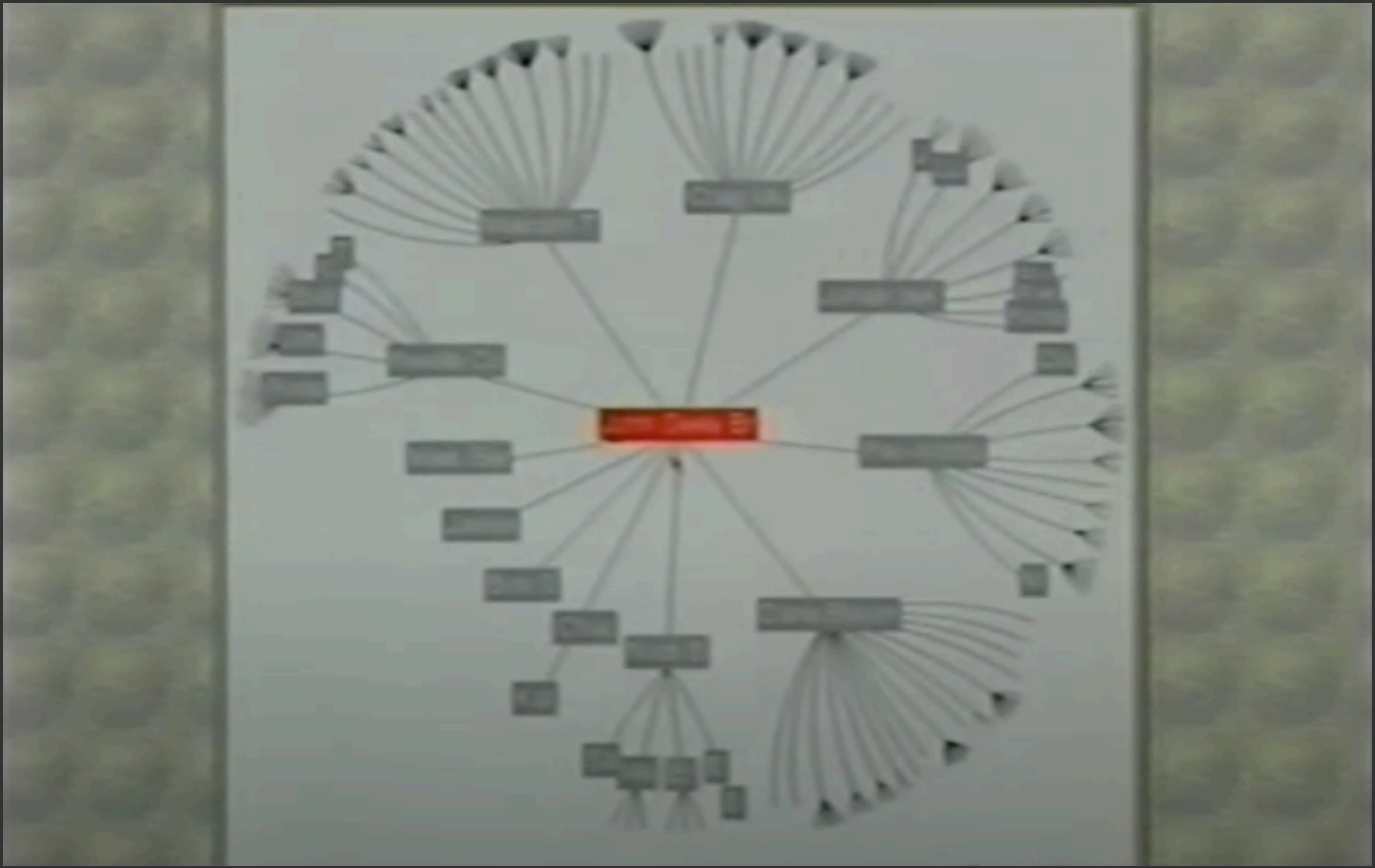


Perform tree layout in hyperbolic geometry, project the result on to the Euclidean plane.

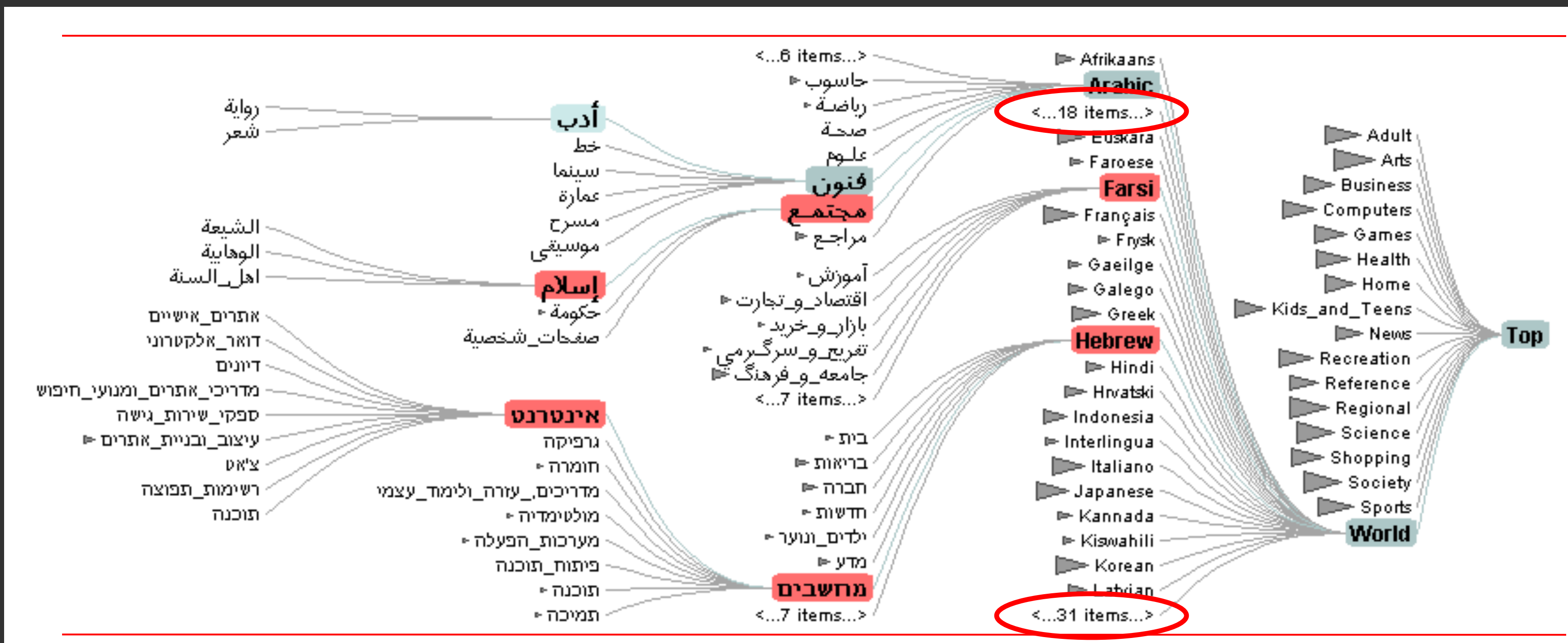
Why? Like tree breadth, the hyperbolic plane expands exponentially!

Also computable in 3D, projected into a sphere.

Hyperbolic Layout

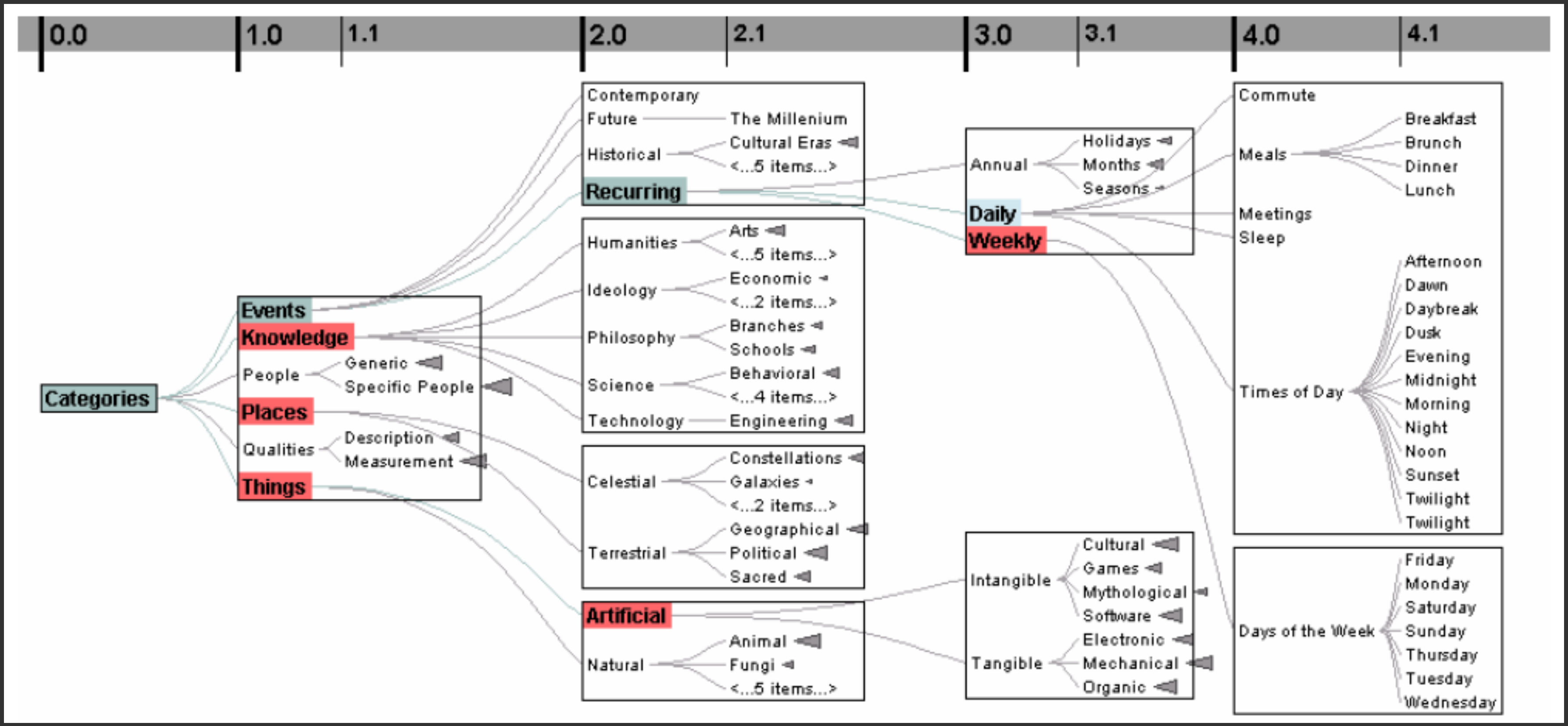


Degree-of-Interest Trees



Space-constrained, multi-focal tree layout

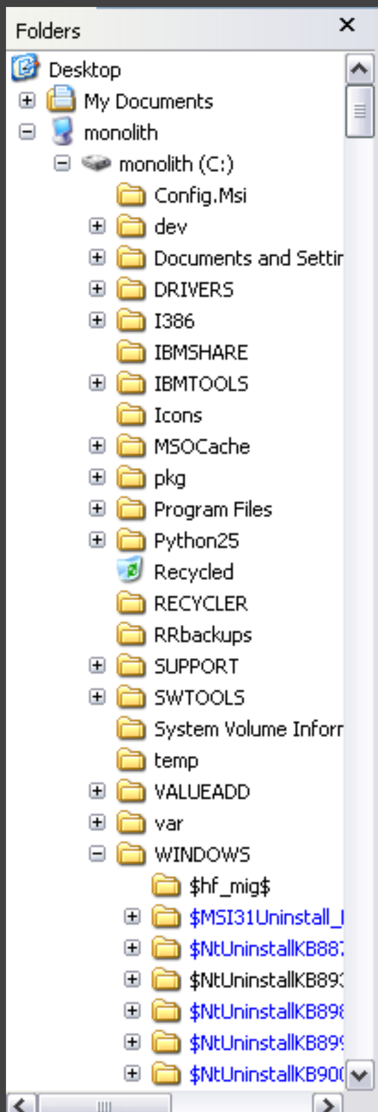
Degree-of-Interest Trees

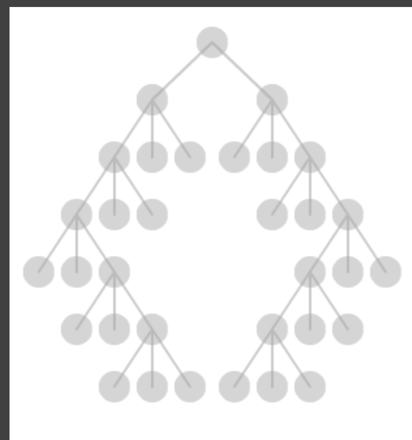


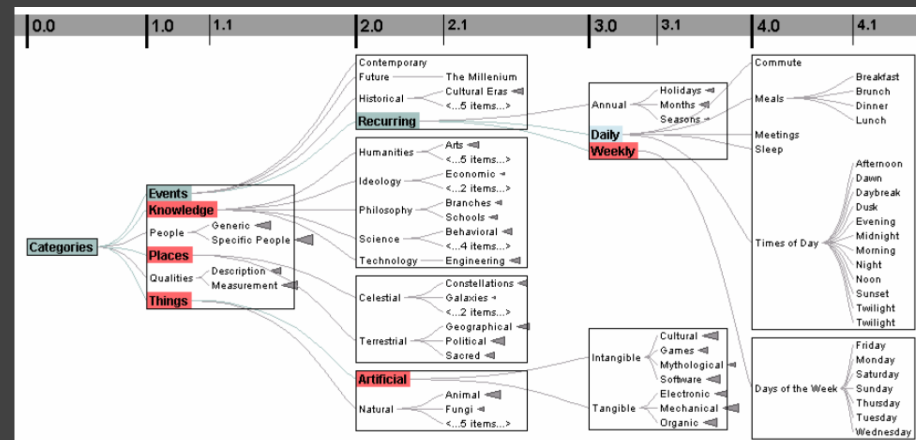
Remove “low interest” nodes at a given depth level until all blocks on a level fit within bounds.

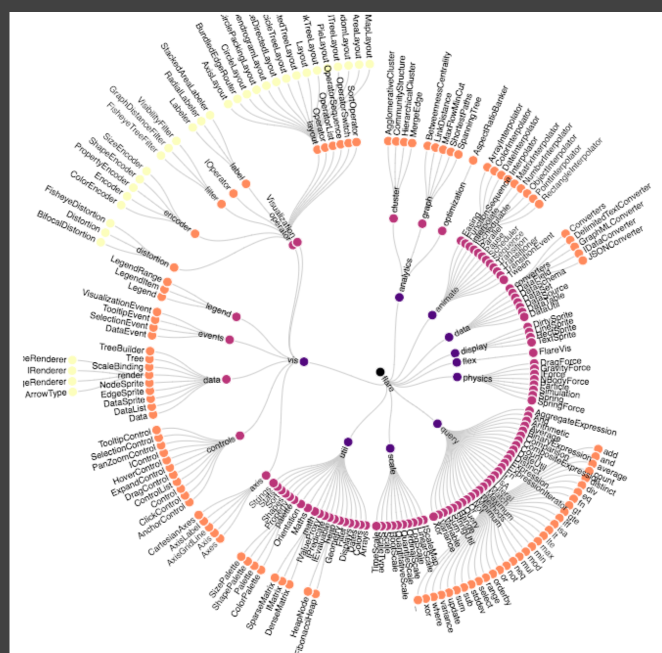
Attempt to center child blocks beneath parents.

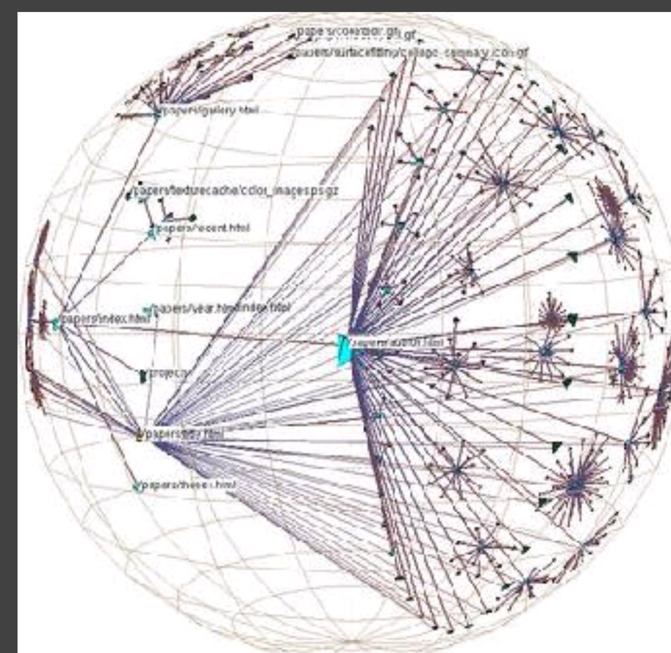
What tasks are supported/missing?











Indentation & Node-Link Diagrams

Encode structure in **2D space** (breadth/depth)

Benefits
Clearly depicts node relationships / structure
Structure-based or browsing tasks

Problems
Even with tidy layout, quickly run out of space

Missing
Attribute-based encodings

Enclosure

Enclosure Diagrams

Encode structure using **spatial enclosure**
Popularly known as **treemaps**

Benefits
Provides a single view of an entire tree
Easier to spot large/small nodes

Problems
Difficult to accurately read structure / depth

Circle Packing Layout

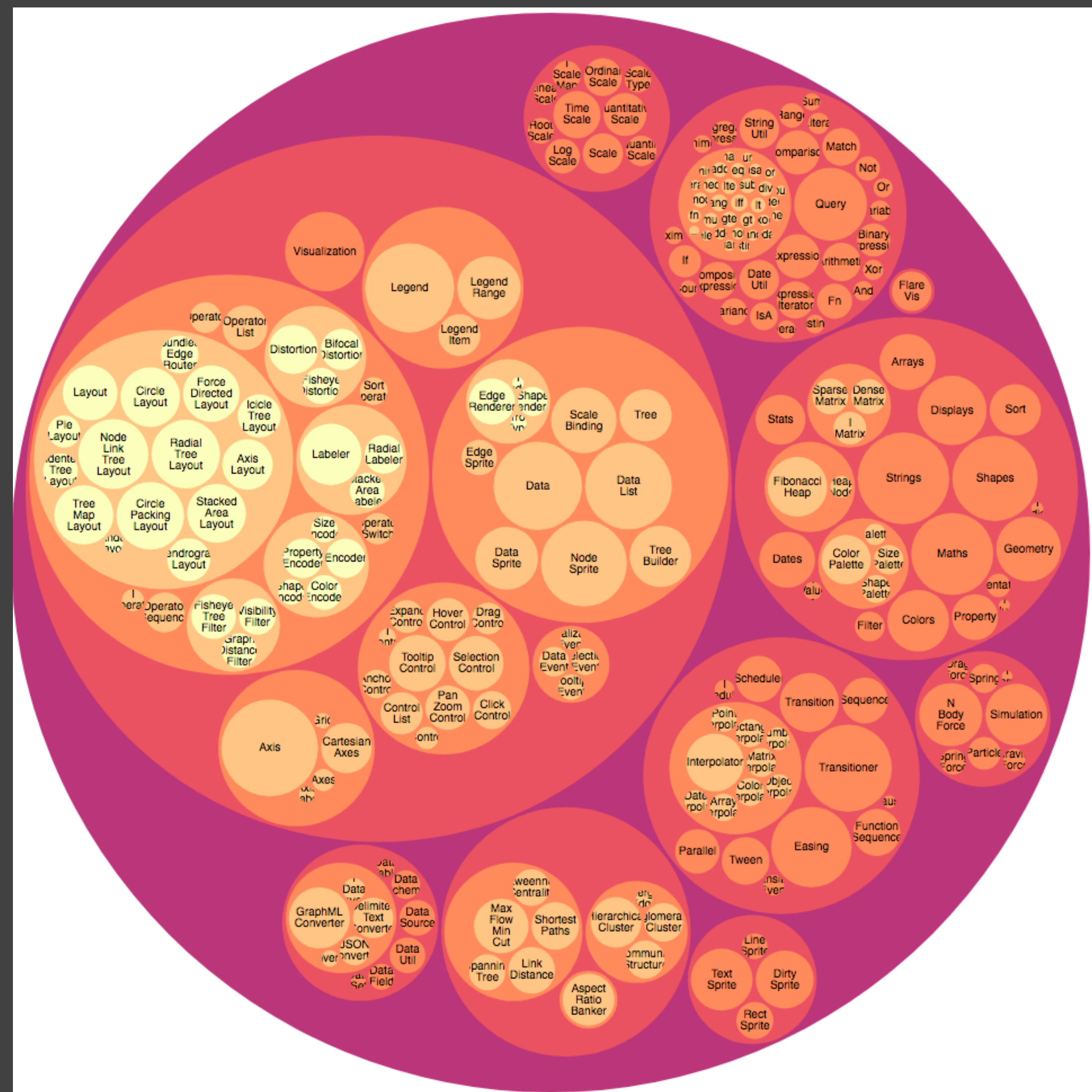
Nodes are represented as sized circles.

Nesting shows parent-child relationships.

Issues?

Inefficient use of space.

Parent size misleading?

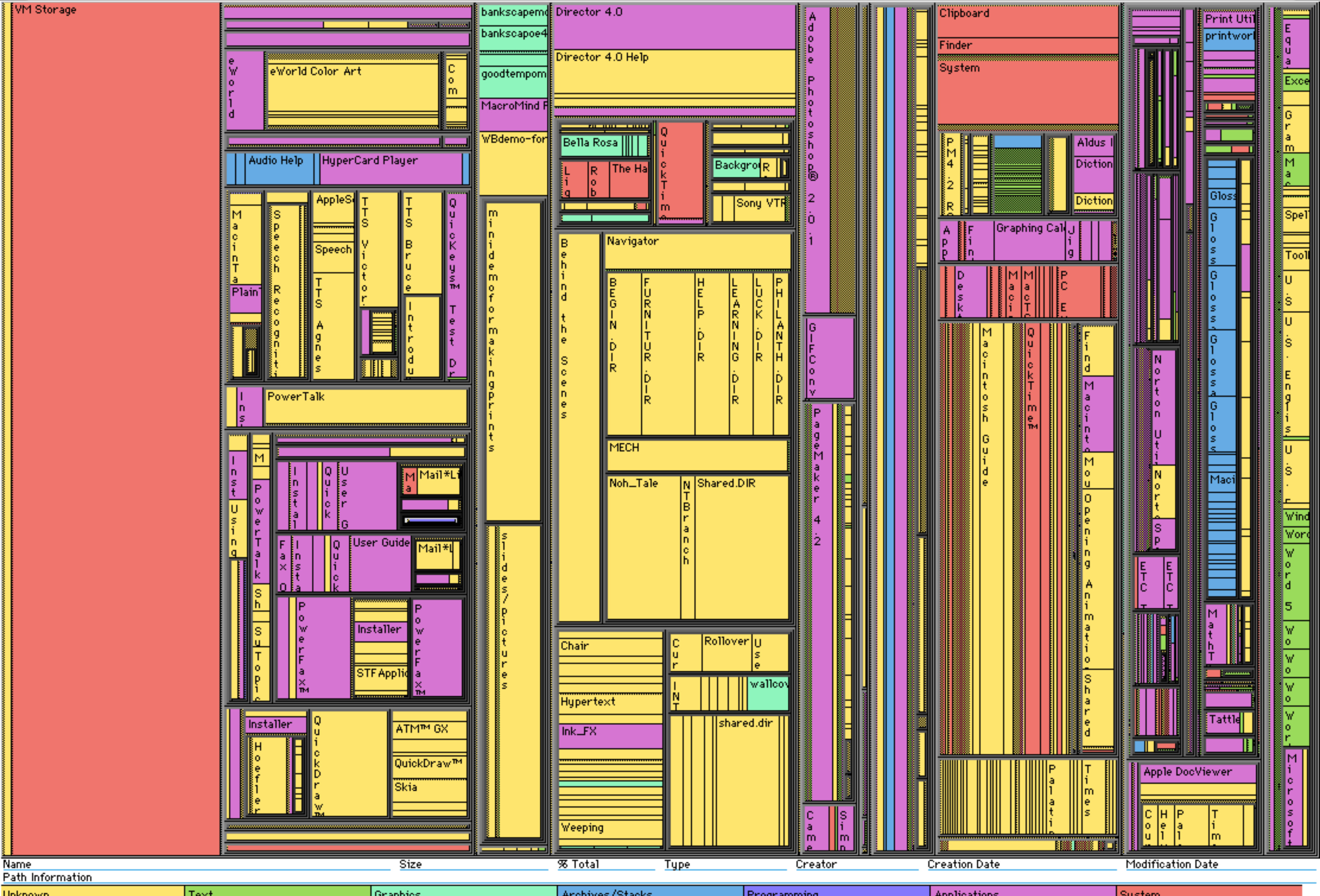


Treemaps

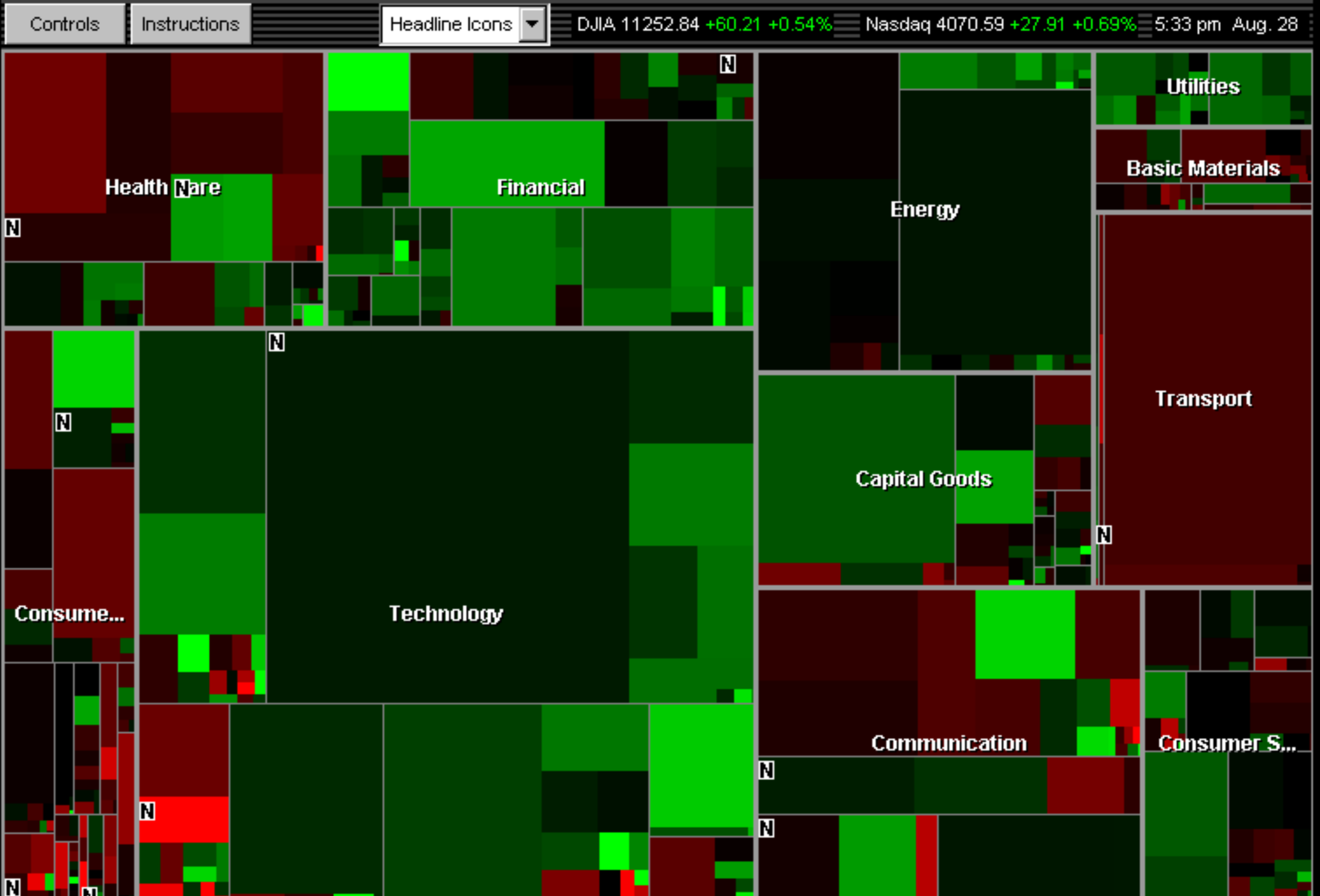
Hierarchy visualization that emphasizes values of nodes via area encoding.

Partition 2D space such that leaf nodes have sizes proportional to data values.

First layout algorithms proposed by Shneiderman et al. in 1990, with focus on showing file sizes on a hard drive.



Slice & Dice layout: Alternate horizontal / vertical partitions.

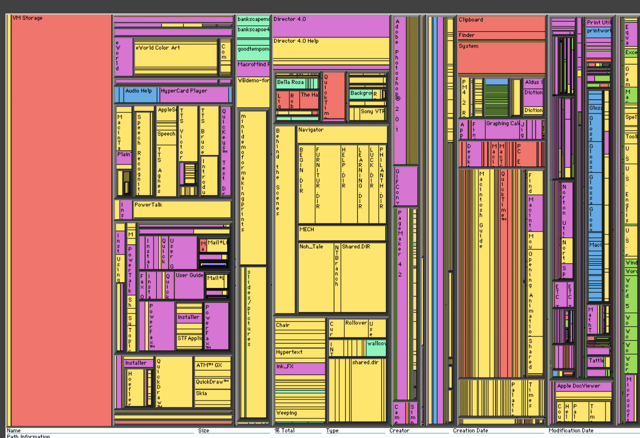


Squarifed layout: Try to produce square (1:1) aspect ratios

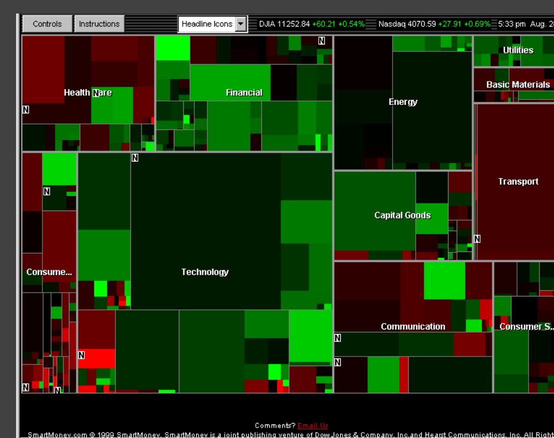
Squarified Treemaps [Bruls et al. '00]

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

Squarified layout: greedy optimization for objective of square rectangles. Slice/dice within siblings; alternate whenever ratio worsens.



vs.



Why Squares? [Bruls et al. '00]

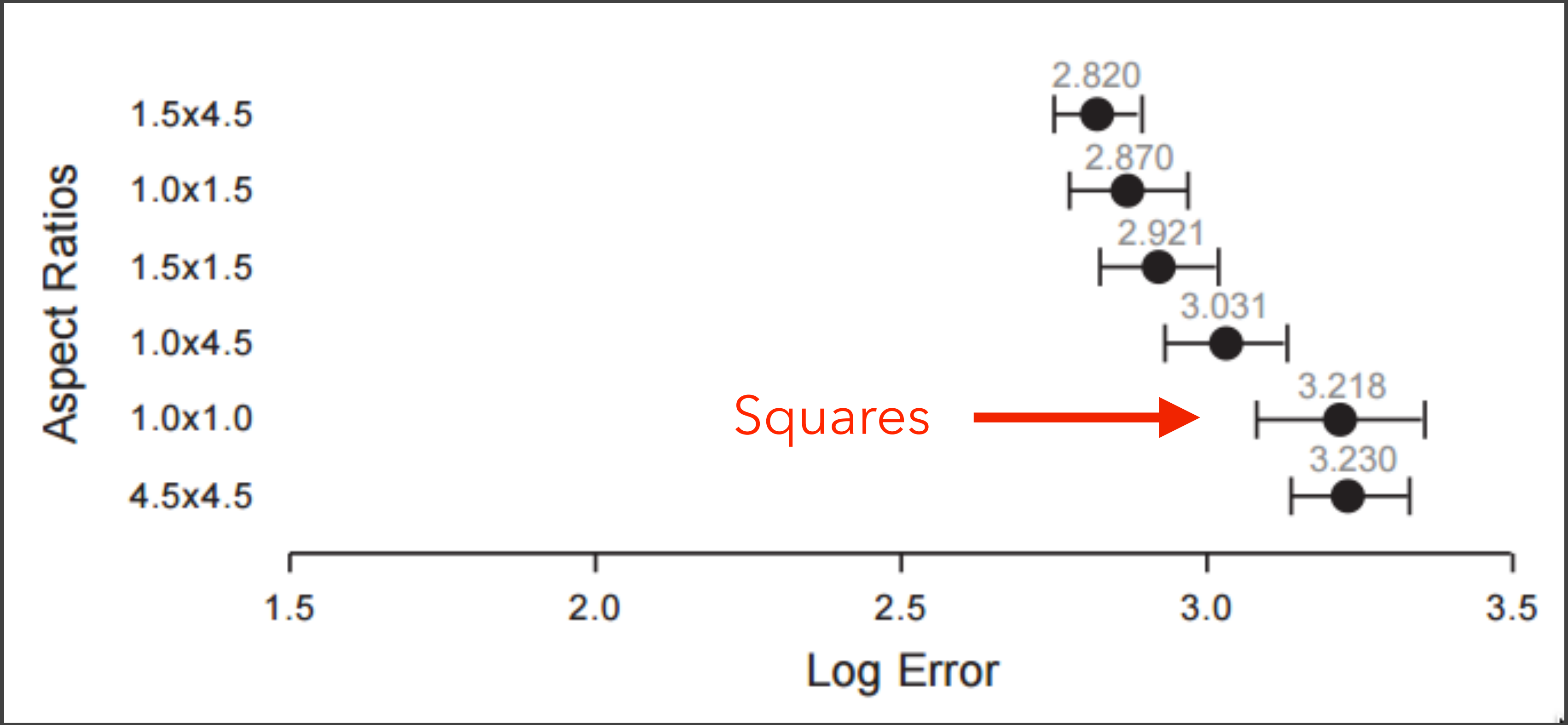
Posited Benefits of 1:1 Aspect Ratios

1. Minimize perimeter, reducing border ink.
   Mathematically true!

2. Easier to select with a mouse cursor.
   Validated by empirical research & Fitt's Law!

3. Similar aspect ratios are easier to compare.
   Seems intuitive, but is this true?

Comparison Error vs. Aspect Ratio



Study by Kong, Heer & Agrawala, InfoVis '10.
Comparison of squares has higher error!
"Squarify" works because it fails to meet its objective?

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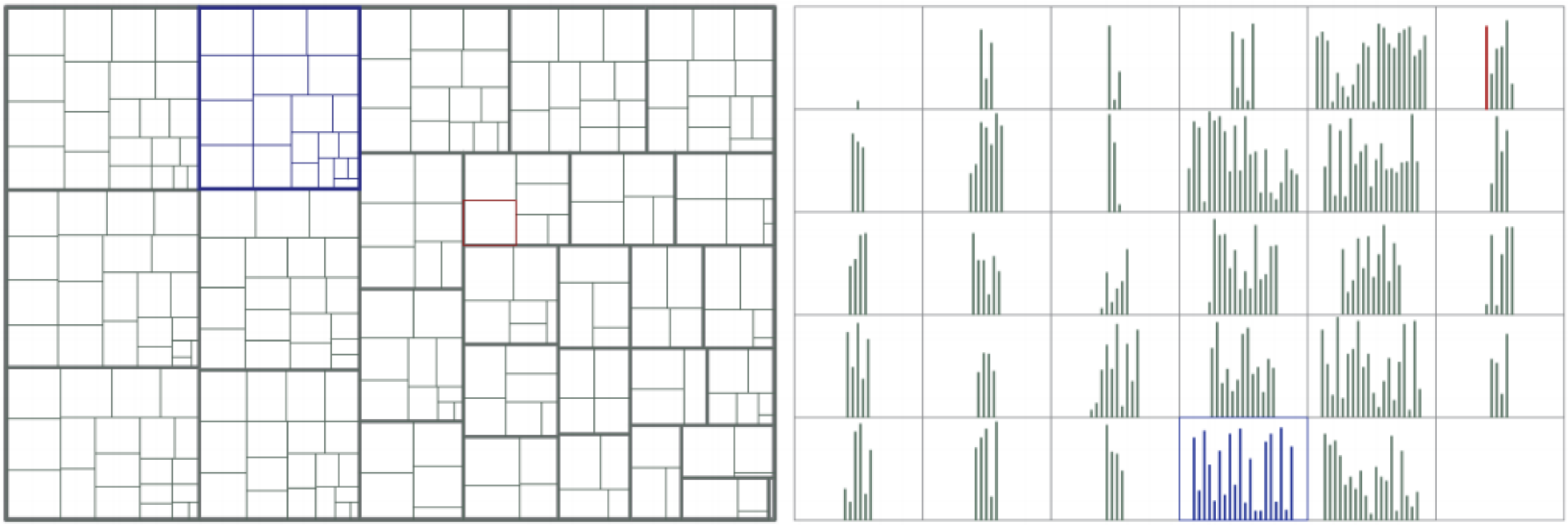
3. ~~Similar aspect ratios are easier to compare.~~
   Extreme ratios & squares-only more inaccurate.
   Balanced ratios better? Target golden ratio?

Treemaps vs. Bar Charts [Kong et al. '10]

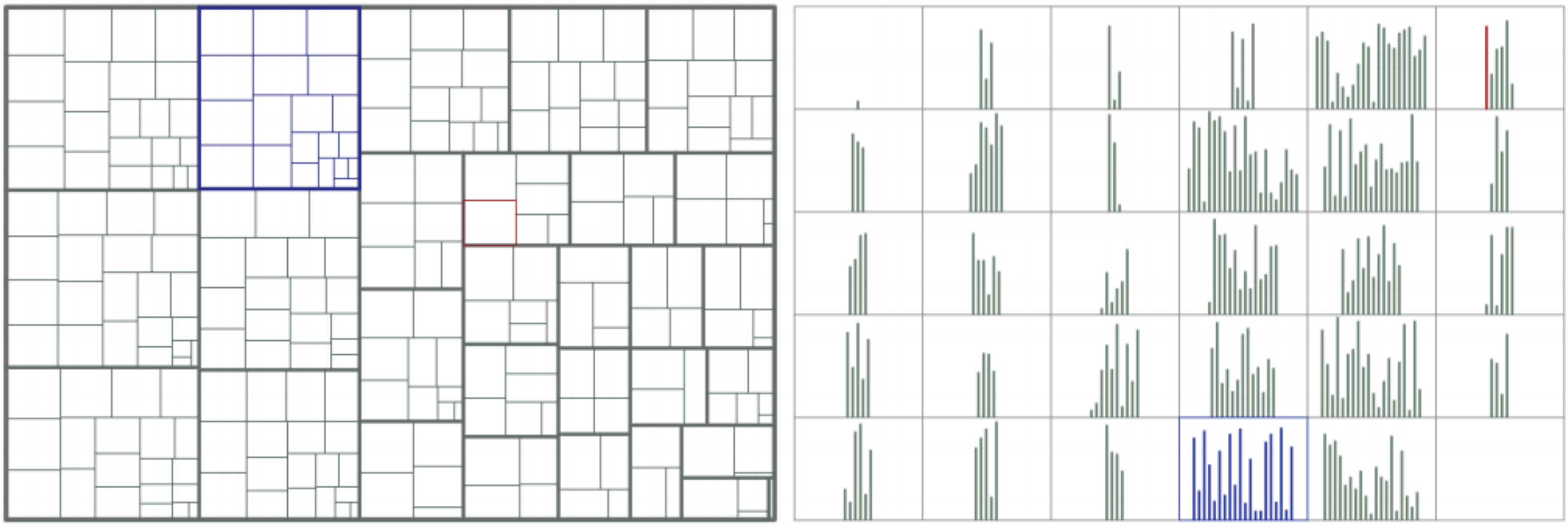


Position is generally more effective than area, but…

What happens when the element count gets high?

What happens when comparing groups of elements, such as leaf values vs. internal node values?

Treemaps vs. Bar Charts [Kong et al. '10]

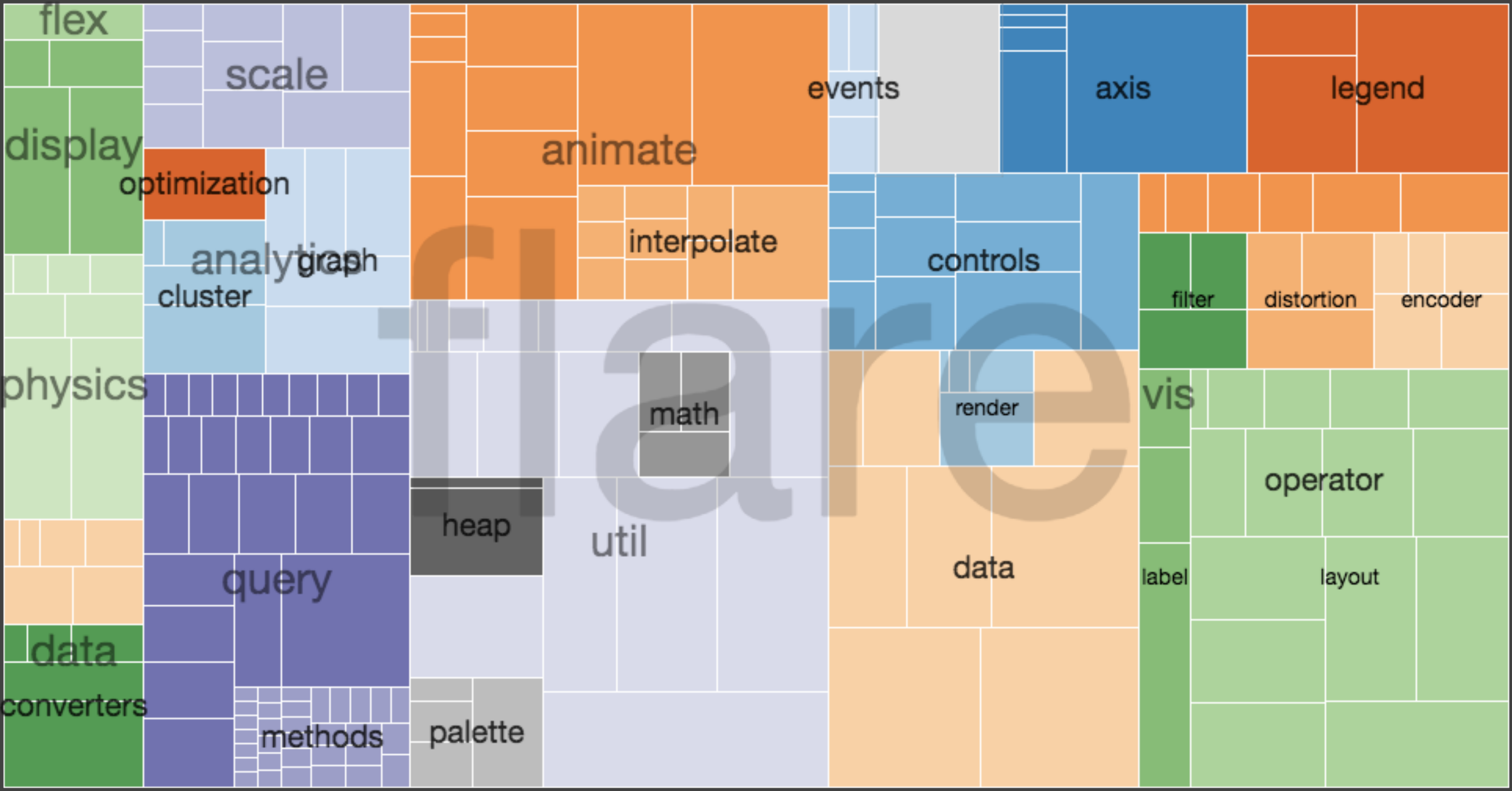


At low densities (< 4k elements), bar charts more accurate than treemaps for leaf-node comparisons.

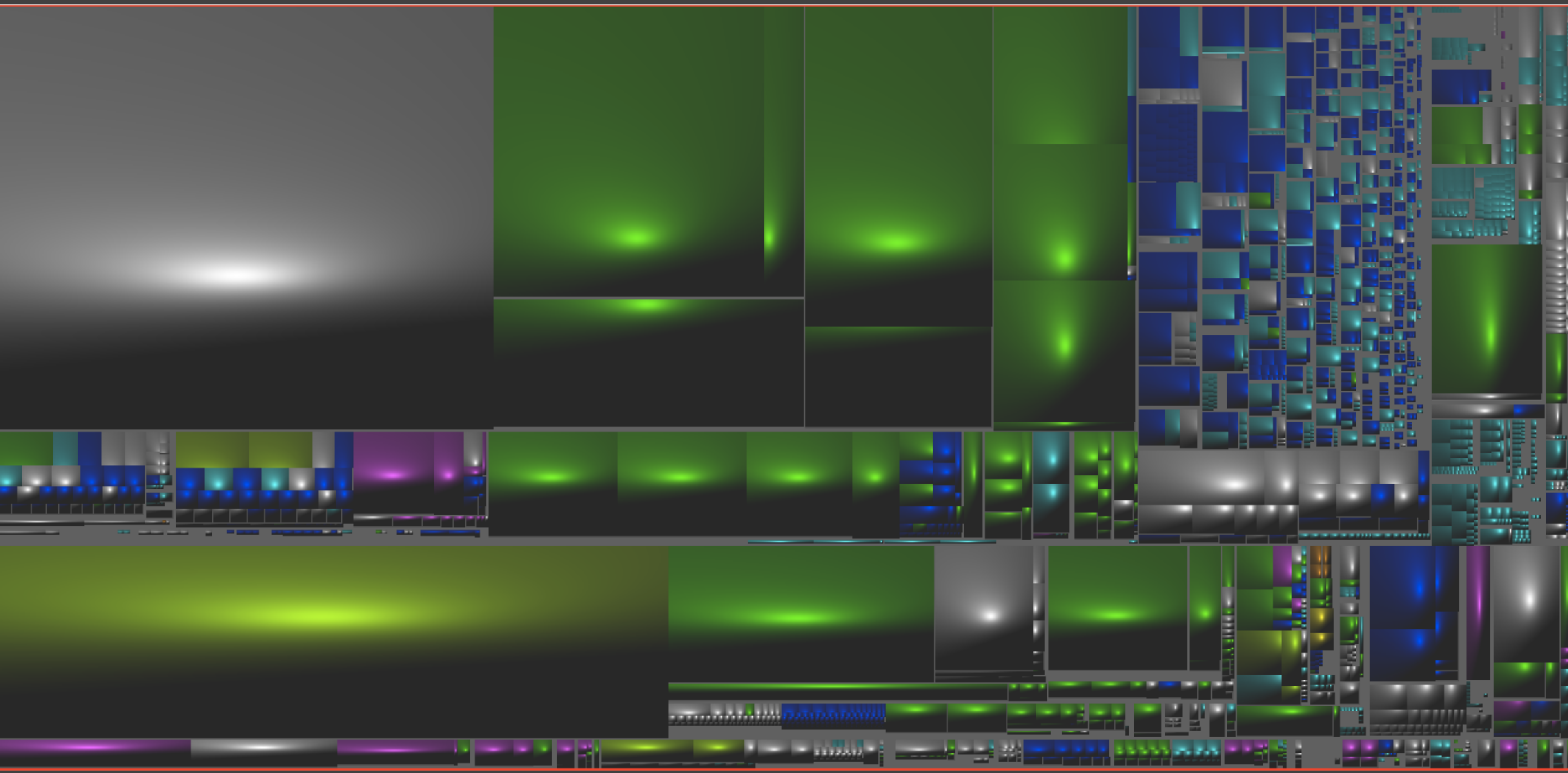
At higher density, treemaps led to faster judgments.

Treemaps better for group-level comparisons.

Interactive Example...

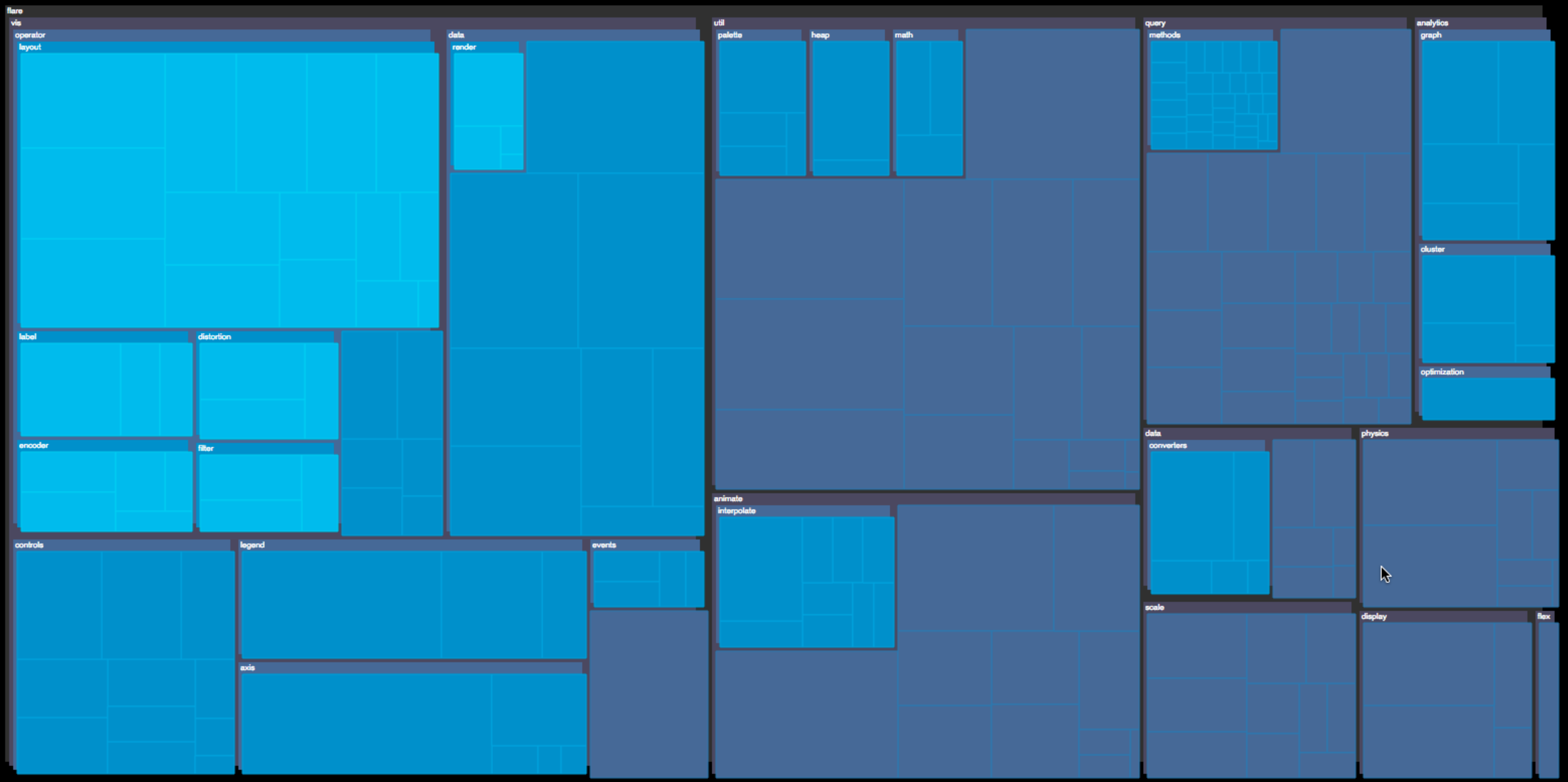


Cushion Treemaps [van Wijk & Wetering '99]



Uses shading to emphasize hierarchal structure.

Cascaded Treemaps [Lü & Fogarty '08]

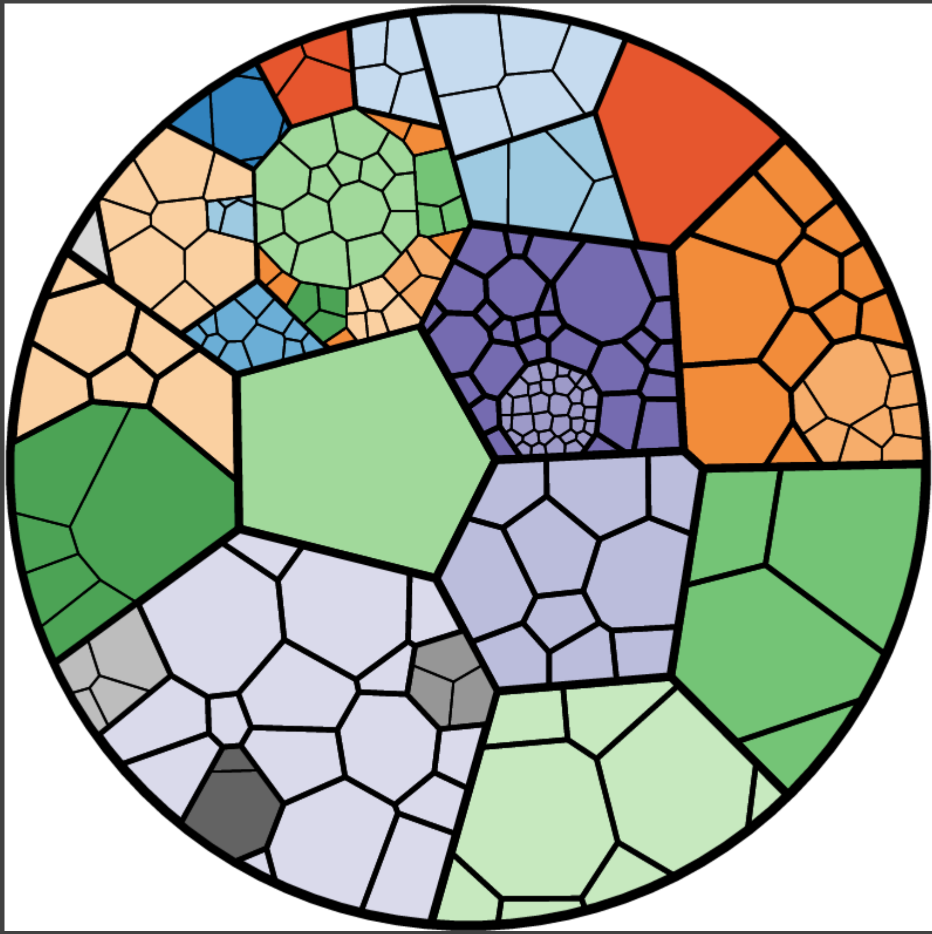


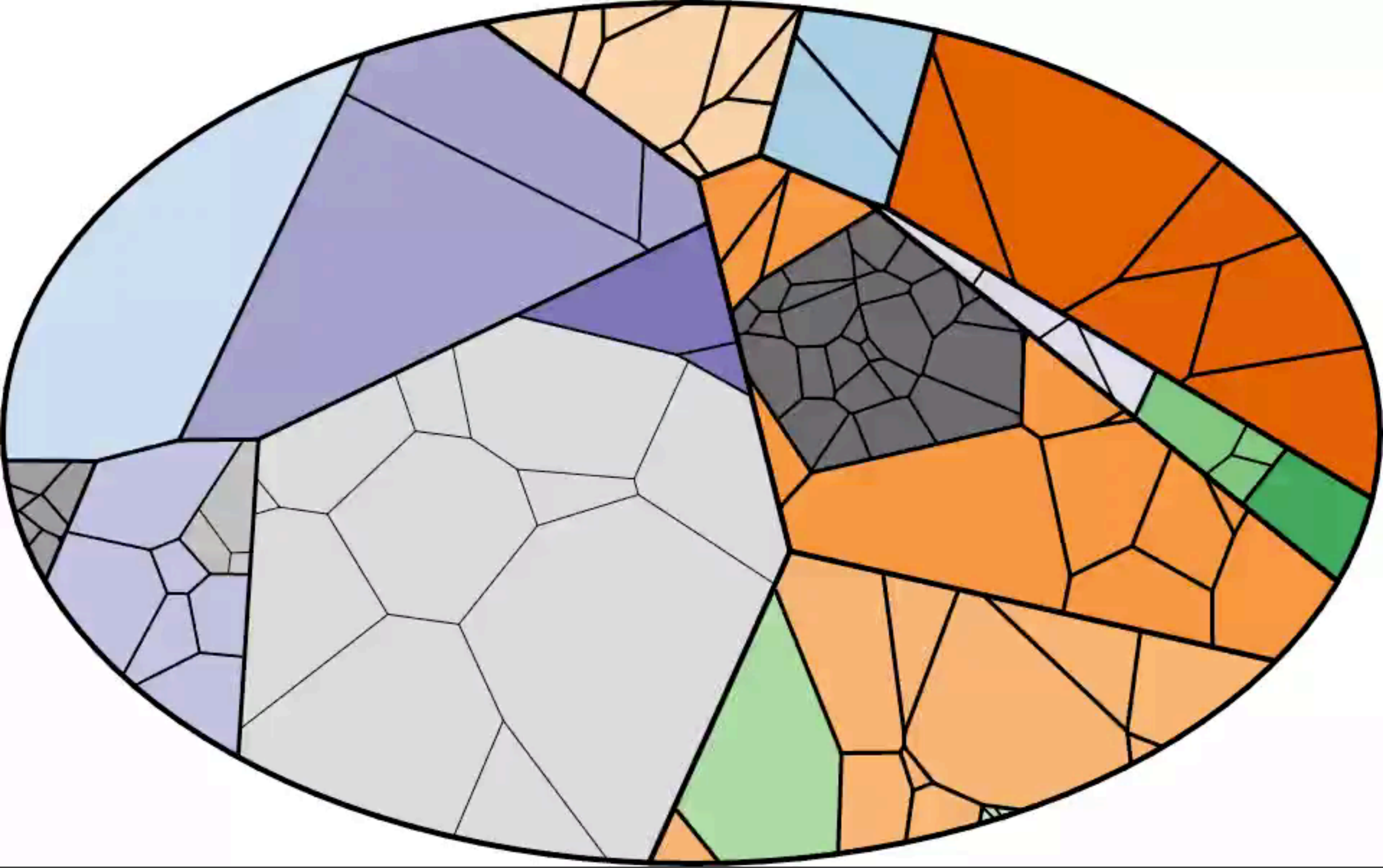
Uses 2.5D effect to emphasize hierarchy relations.

Voronoi Treemaps [Balzer et al. '05]

Instead of rectangles, create treemaps with arbitrary polygonal shapes and boundary.

Use iterative, weighted Voronoi tessellations to achieve cells with value-proportional areas.

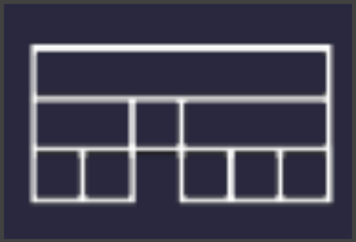




Iterative Voronoi Tesselations [Jason Davies]

Layering

Layered Diagrams

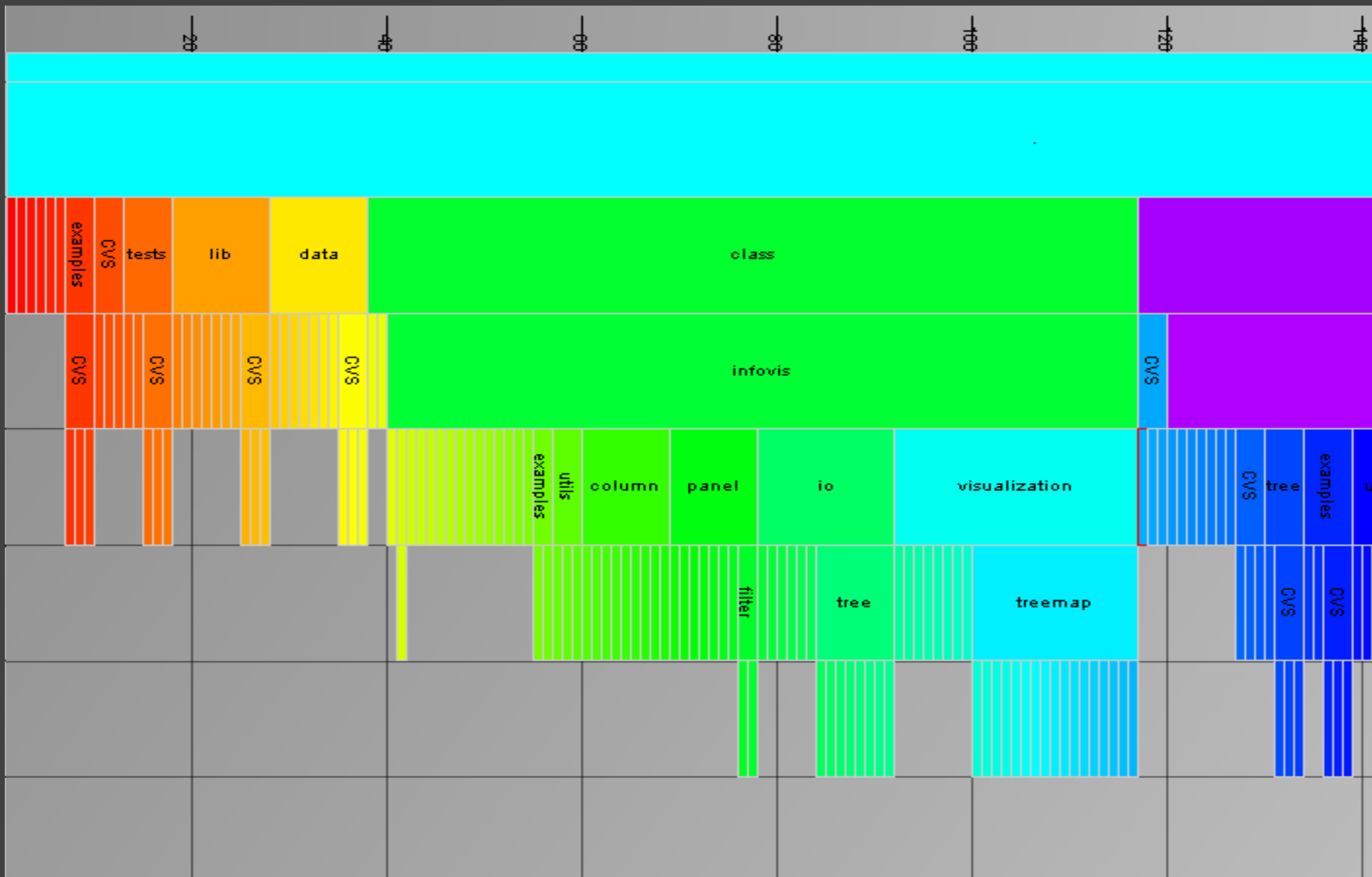


Signify tree structure using:
- Layering
- Adjacency
- Alignment

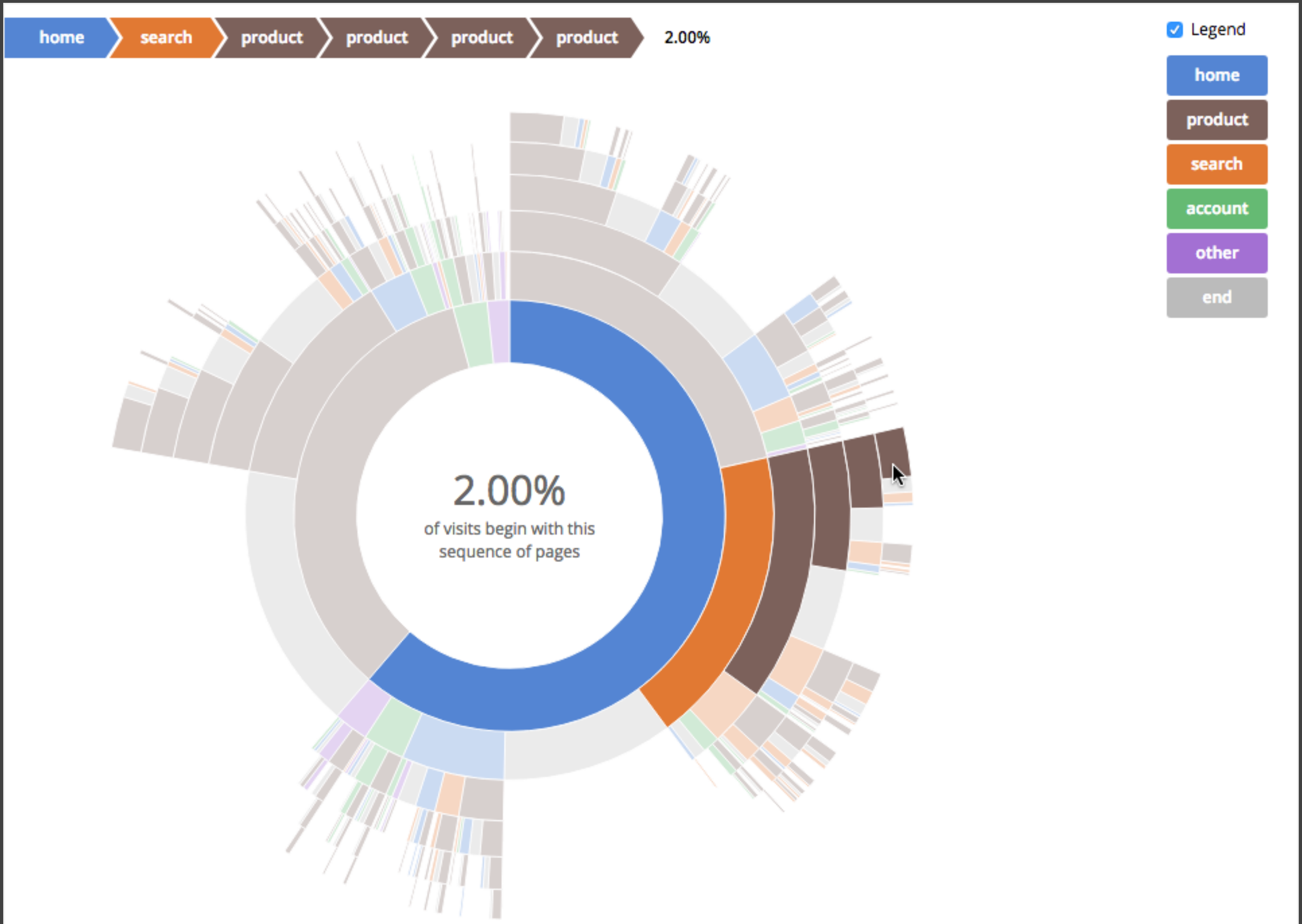
Involves recursive sub-division of space.

Leaf nodes may be sized by value, parent size visualizes sum of descendant leaf values.

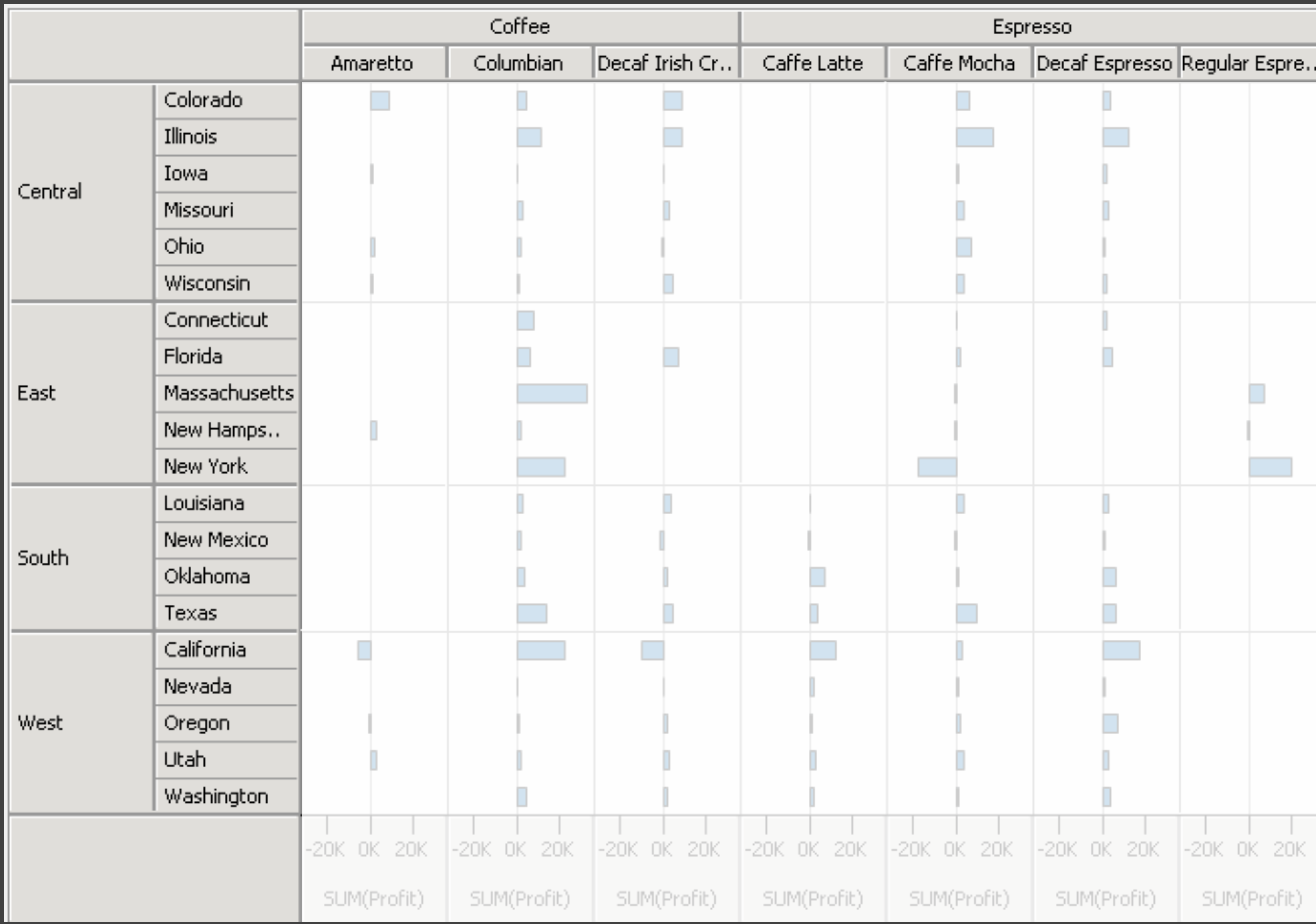
Icicle Trees: Cartesian Partition



"Sunburst" Trees: Polar Partition

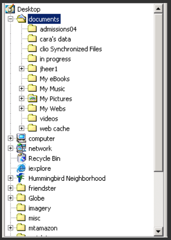
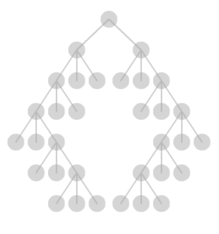
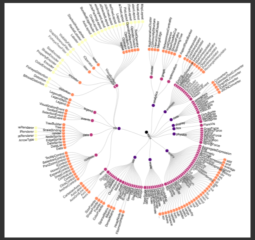
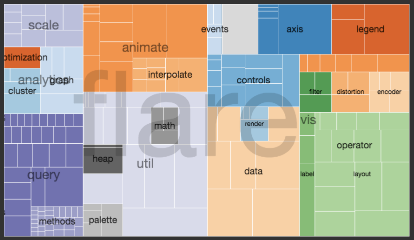


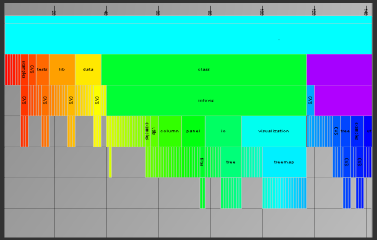
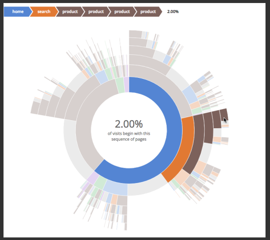
Layered Trees Useful Elsewhere…



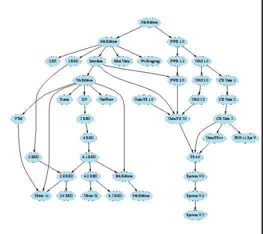
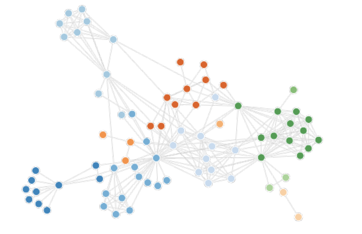
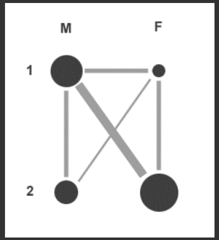
Topics

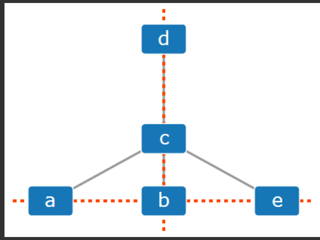
TODAY - Tree Visualization

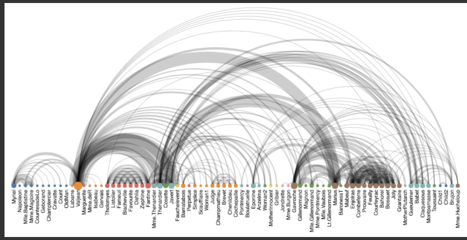





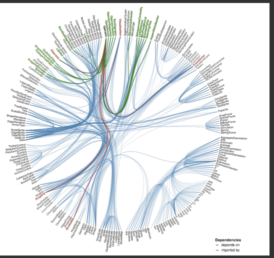
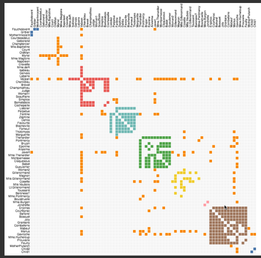
Wed - Graph Layout: Node-Link Diagrams





Wed - Alternative Visualizations and Techniques

Select an image to jump to those slides.