Large Scale Information Visualization

Jing Yang

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Hierarchy and Tree Visualization

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Hierarchies

- Definition
  - An ordering of groups in which larger groups encompass sets of smaller groups.
  - Data repository in which cases are related to subcases

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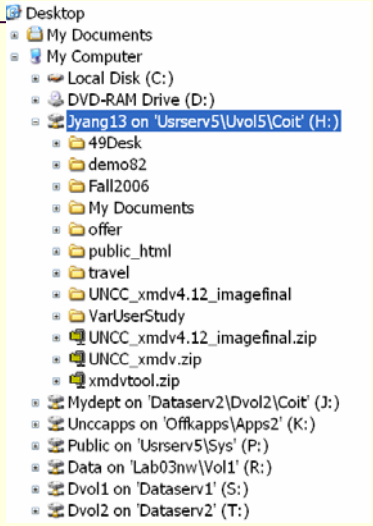
Hierarchies in the World

- Family histories, ancestries
- File/directory systems on computers
- Organization charts
- Object-oriented software classes



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Good Hierarchy Visualization

- Allow adequate space within nodes to display information
- Allow users to understand relationship between a node and its context
- Allow to find elements quickly
- Fit into a bounded region
- Much more

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Trees

- Hierarchies are often represented as trees
  - Directed, acyclic graph
- Two major categories of tree visualization techniques:
  - Node-link diagram
    - Visible graphical edge from parents to their children
  - Space-filling

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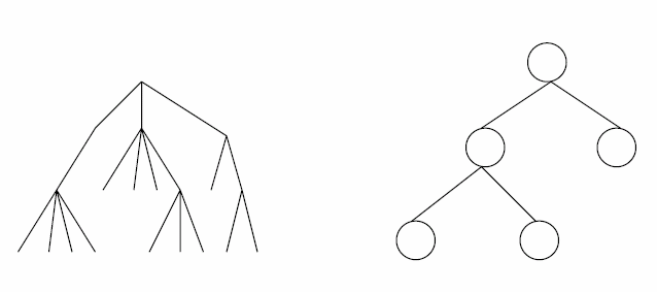
Node-Link Diagrams

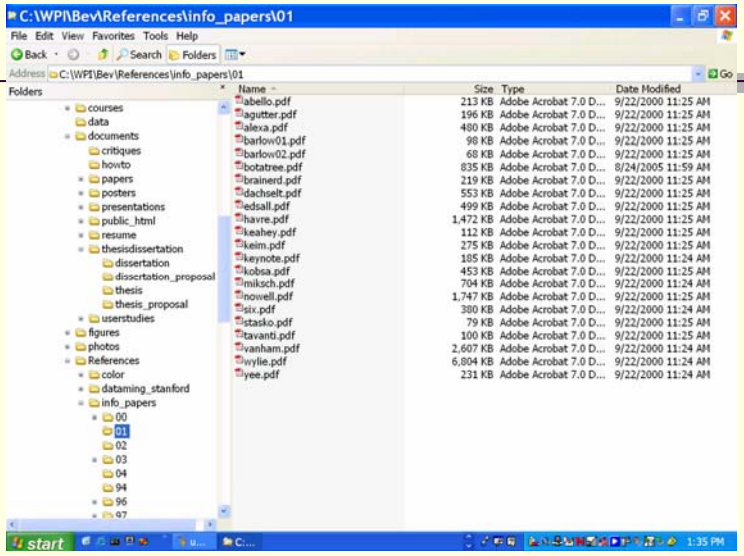
Node-Link Diagrams

- Root at top, leaves at bottom is very common



J. Stasko's InfoVis class slides

Microsoft Explorer



What do you like and dislike about it?

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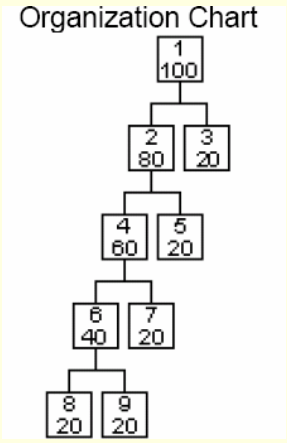
Organization Chart



A decision tree

The figure is from Barlow and Neville InfoVis 2001

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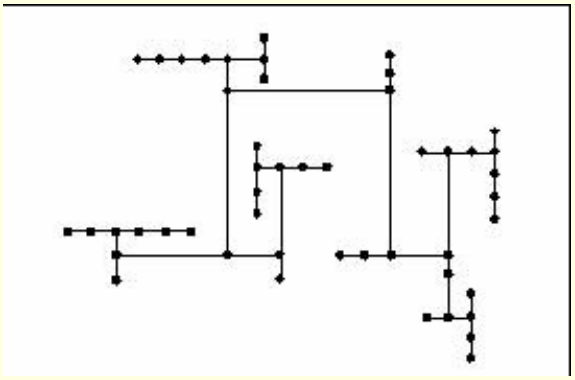
H-Tree Layout

- Work well only for binary trees



Herman, G. Melançon, M.S. Marshall, “Graph Visualization in Information Visualization: a Survey” In: *IEEE Transactions on Visualization and Computer Graphics*, 2000, pp. 24-44.

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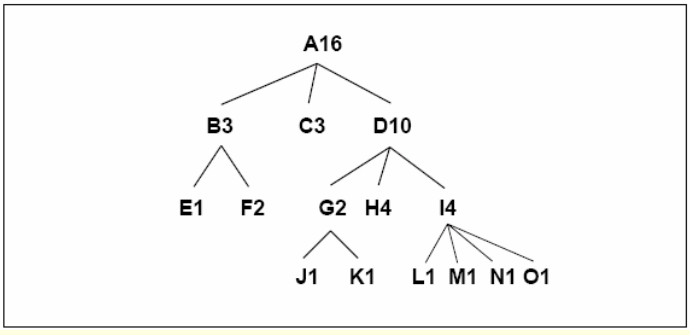
A Common Visualization



E. Kleiberg et. al. InfoVis 2001

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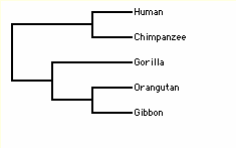
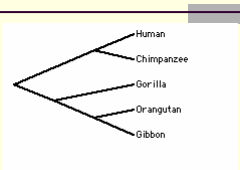
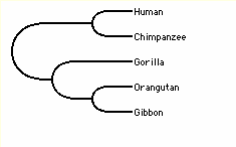
Different Styles



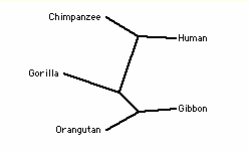
Rectangular: Well suited for displaying labeled/scaled trees.



Straight: Works well only on rooted binary trees.



Smooth Edges: Very similar to the rectangular mode



Radial: Works well for visualizing unrooted trees.

http://www.hyphy.org/docs/GUIExamples/treepanel.html

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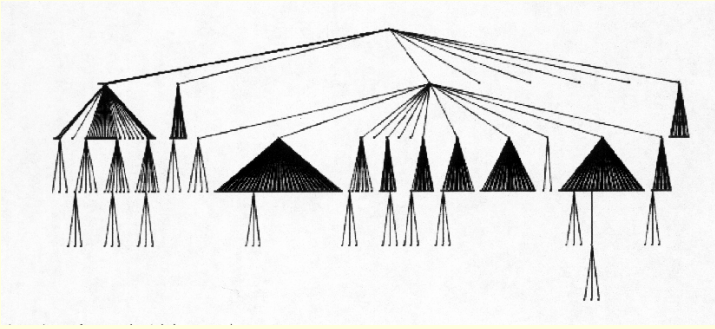
A Classical Hierarchical View



Position children “below” their common ancestors

Layout can be top-down, left-to-right and grid like positioning

Fast: linear time

E. Reingold and J. Tilford. *Tidier drawing of trees*. IEEE Trans. Softw. Eng., SE-7(2):223-- 228, 1981

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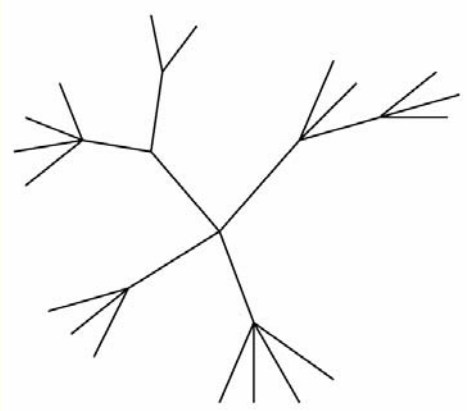
Why Put Root at Top (Left)



- Root can be at center with levels growing outward too
- Can any node be the root?

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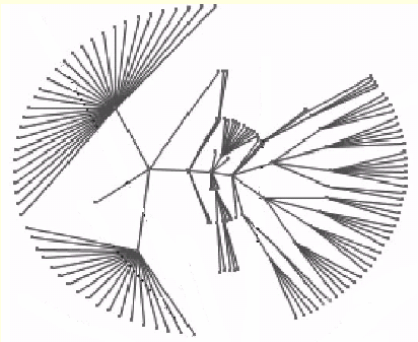
Radial View

- Recursively position children of a sub-tree into circular wedges
- the central angle of these wedges are proportional to the number of leaves



P. Eades, "Drawing Free Trees", *Bulleting of the Institute fro Combinatorics and its Applications,* 1992, pp. 10-36.

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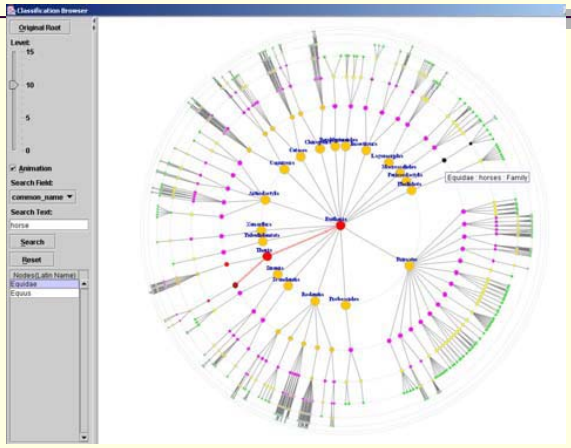
Radial View



Infovis contest 03 Treemap, Radial Tree, and 3D Tree Visualizations
Nihar et. al. Indiana University

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Balloon View

- Siblings of sub-trees are included in circles attached to the father node.

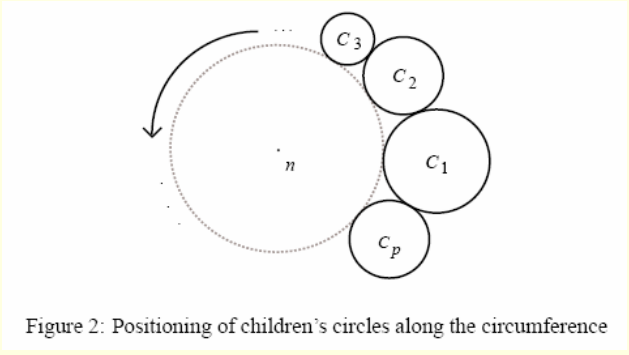

Figure 2: Positioning of children's circles along the circumference

Melancon, G., Herman, I.: Circular drawing of rooted trees. Reports of the Centre for Mathematics and Computer Sciences (CWI), INSR9817,

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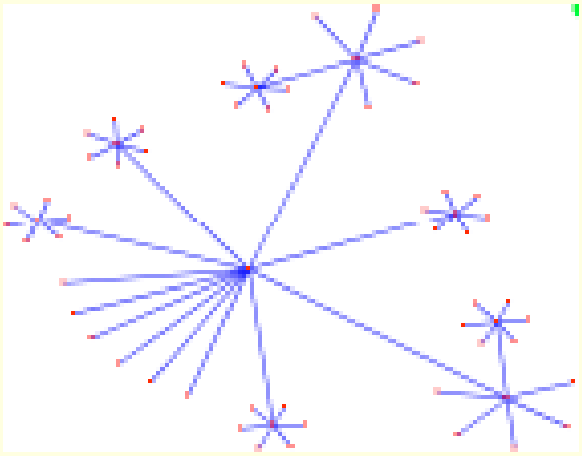
Balloon View



Melancon, G., Herman, I.: Circular drawing of rooted trees. Reports of the Centre for Mathematics and Computer Sciences (CWI), INSR9817,

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The Challenges

- Scalability
  - # of nodes increases exponentially
  - Available space increases polynomially (circular case)
- Showing more attributes of data cases in hierarchy or focusing on particular applications of trees
- Interactive exploration

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3D Tree

Tavanti and Lind, InfoVis 01

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Cone Tree

- Key ideas:
  - Add a third dimension into which layout can go
  - Compromise of top-down and centered techniques mentioned earlier
  - Children of a node are laid out in a cylinder “below” the parent
  - Siblings live in one of the 2D planes

Robertson, Mackinlay, Card CHI ‘91

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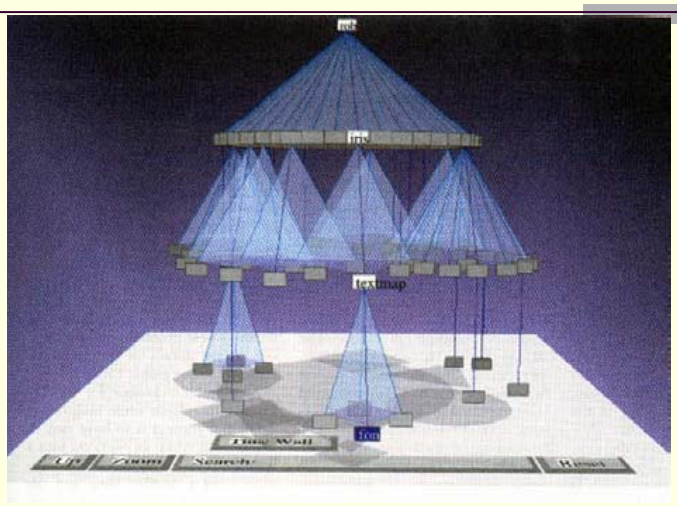
Cone Tree



Robertson, Mackinlay, Card CHI '91

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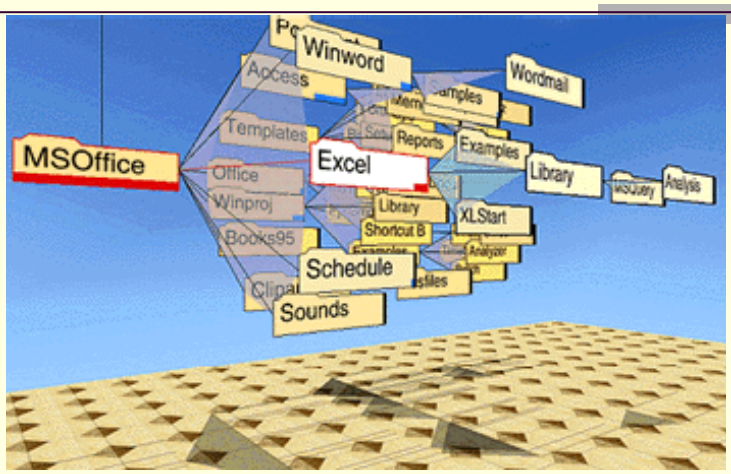
Alternative Views



Robertson, Mackinlay, Card CHI '91

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Advantages vs. Limitations

- Positive
  - More effective area to lay out tree
  - Use of smooth animation to help person track updates
  - Aesthetically pleasing
- Negative
  - As in all 3D, occlusion obscures some nodes
  - Non-trivial to implement and requires some graphics horsepower

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Hyperbolic Brower

- Key idea:
  - Find a space (hyperbolic space) that increases exponentially, lay out the tree on it
  - Transform from the hyperbolic space to 2D Euclidean space

J. Lamping and R. Rao, "The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies", *Journal of Visual Languages and Computing,* vol. 7, no. 1, 1995, pp. 33-55.

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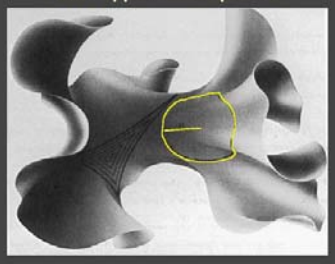
Hyperbolic space background

geometry with exponential "amount of room"
- good match for exponential node count of trees

2D hyperbolic plane



[Thurston and Weeks 84]

hemisphere area

hyperbolic: exponential

$$2\pi \sinh^2(r)$$

euclidean: polynomial

$$2\pi r^2$$

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http://graphics.stanford.edu/~munzner/talks/calgary02

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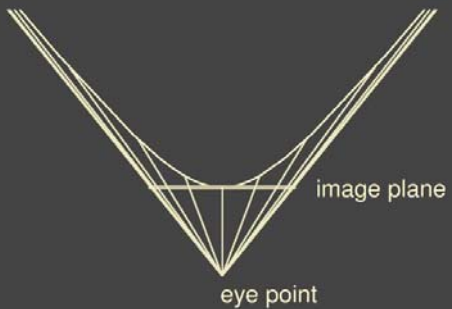
1D hyperbolic space

hyperbola projects to line



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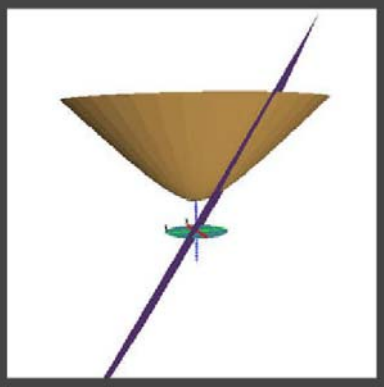
2D hyperbolic space

hyperboloid projects to disk



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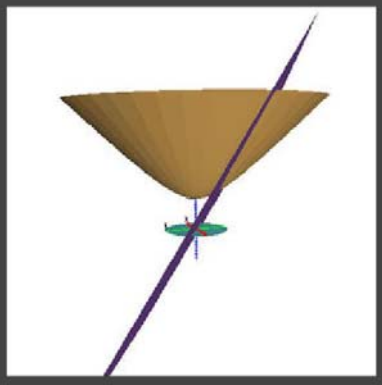
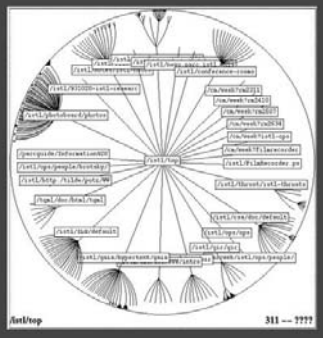
2D hyperbolic space

hyperboloid projects to disk





[Lamping et al 95]

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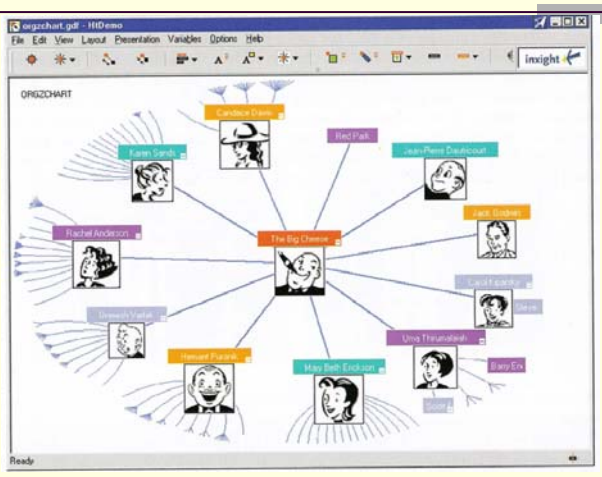
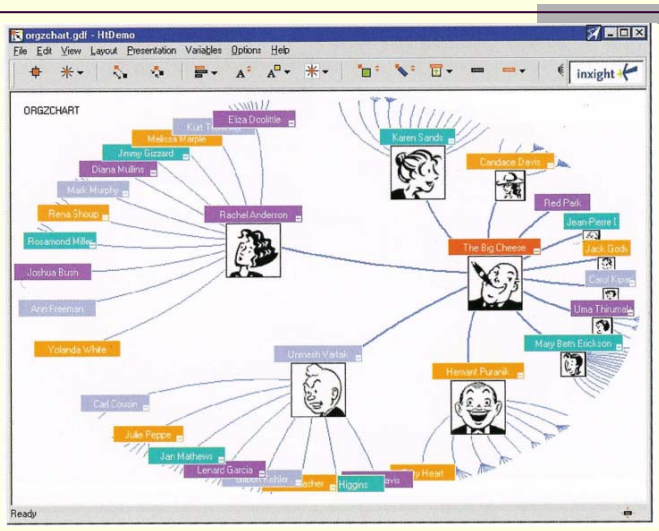
Hyperbolic Brower



R. Spence. Information Visualization

Change Focus



Key Attributes

- Natural magnification (fisheye) in center
- Layout depends only on 2-3 generations from current node
- Smooth animation for change in focus
- Don't draw objects when far enough from root (simplify rendering)

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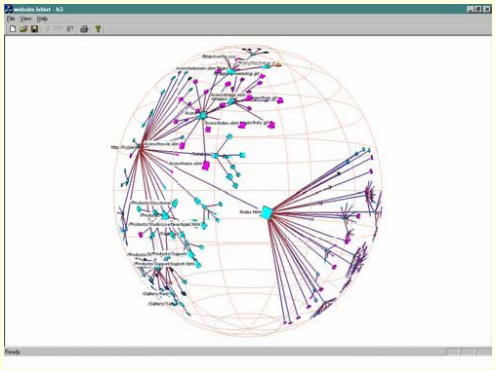
H3 Browser

- Use hyperbolic transformation in 3D space



Demo

Tamara Munzner: H3: laying out large directed graphs in 3D hyperbolic space. INFOVIS 1997: 2-10

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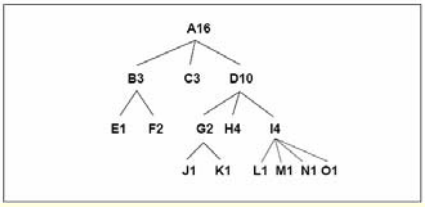
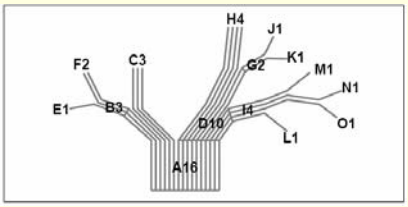
Botanical Tree [E. Kleiberg et. al. InfoVis 2001]

- Basic idea: we can easily see the branches, leaves, and their arrangement in a botanical tree
- Inspiration: Strand model of Holton
  - Strands: internal vascular structure of a botanical tree



Node and link diagram



Corresponding strand Model

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Botanical Tree [E. Kleiberg et. al. InfoVis 2001]

- Use strand model to create a 3-d directory tree:

Unsatisfied features: 1. Branching points 2. long and thin branches 3. cluttered leaves

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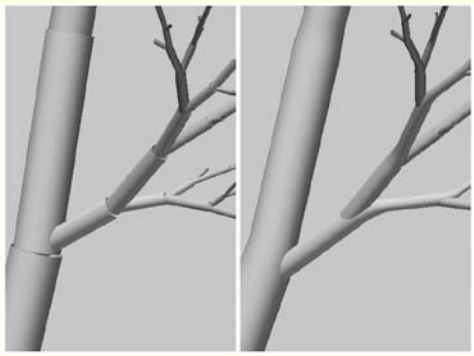
Botanical Tree [E. Kleiberg et. al. InfoVis 2001]

- Improve the first tree:



Adding smooth transition between two cylinders

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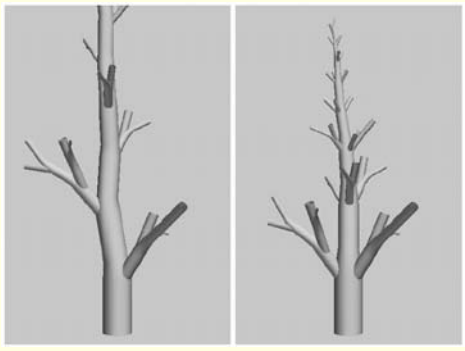
Botanical Tree [E. Kleiberg et. al. InfoVis 2001]

- Improve the first tree:



Use a general tree rather than a binary tree

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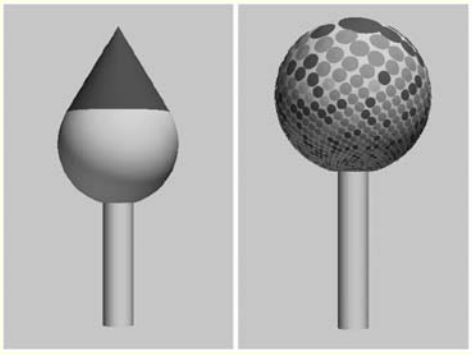
Botanical Tree [E. Kleiberg et. al. InfoVis 2001]

- Improve the first tree:



Phi-ball with one (left) and many (right) files

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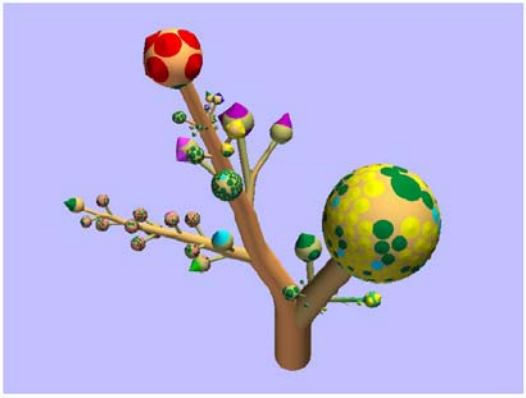
Botanical Tree [E. Kleiberg et. al. InfoVis 2001]

- Botanical tree:



Final model with the improvements

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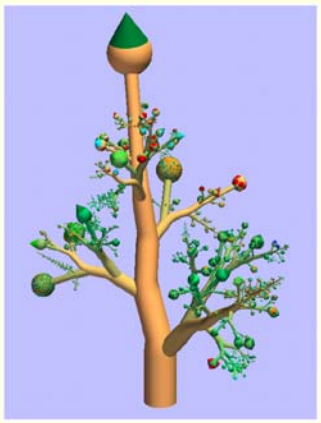
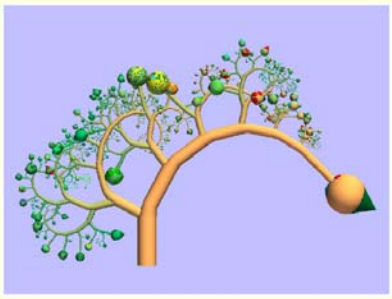
Botanical Tree [E. Kleiberg et. al. InfoVis 2001]

- Botanical tree:





The same directory with different settings

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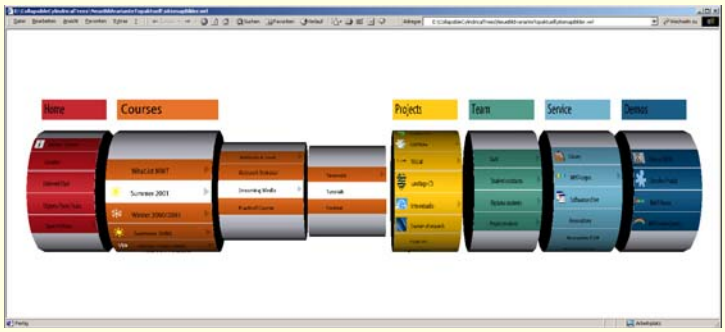
Collapsible Cylindrical Tree [Dachselt & Ebert Infovis 01]

- Basic idea: use a set of nested cylinders according to the telescope metaphor
- Limitation: one path is visible in once
- Interactions: rotation, go down/up



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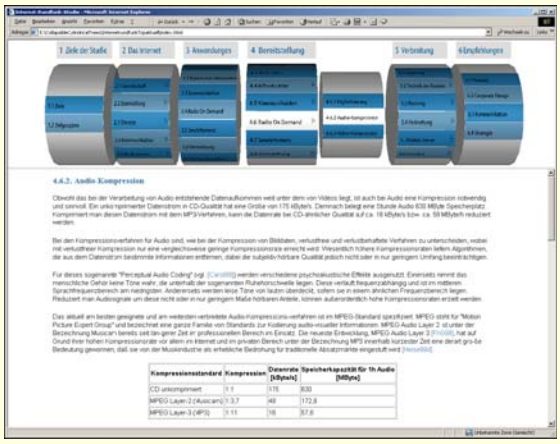
Collapsible Cylindrical Tree [R. Dachselt, J. Ebert Infovis 01]

- Example application: web document browsing



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Space-Filling Techniques

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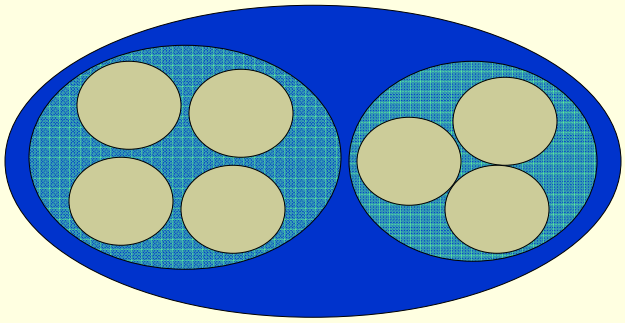
Space-Filling Techniques

- Each item occupies an area
- Children are “contained” within parent



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Visualization of Large Hierarchical Data by Circle Packing W.Wang et al. CHI 2006

- Key ideas:
  - tree visualization using nested circles
  - brother nodes represented by externally tangent circles
  - nodes at different levels displayed by using 2D nested circles or 3D nested cylinders

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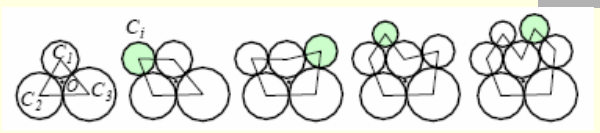
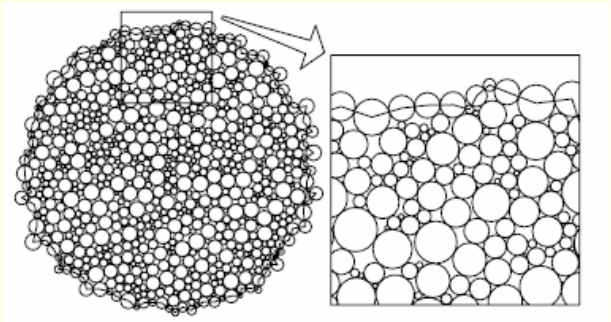
Visualization of Large Hierarchical Data by Circle Packing W.Wang et al. CHI 2006





(a) (b)

Figure 4. Packing 1000 circles with random radii

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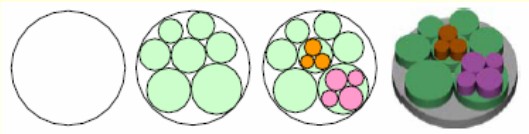
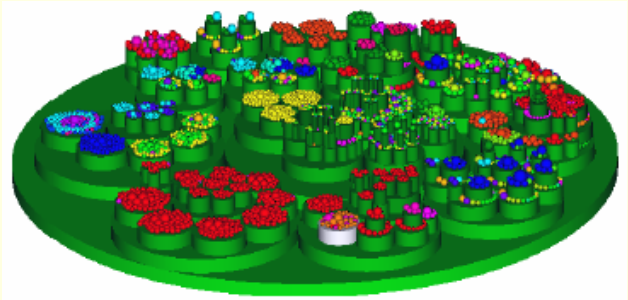
Visualization of Large Hierarchical Data by Circle Packing W.Wang et al. CHI 2006



(a) Level 0 (b) Level 1 (c) Level 2 (d) 3D view



(c) 3D nested cylinders and spheres

Figure 6. The visualization of a file system

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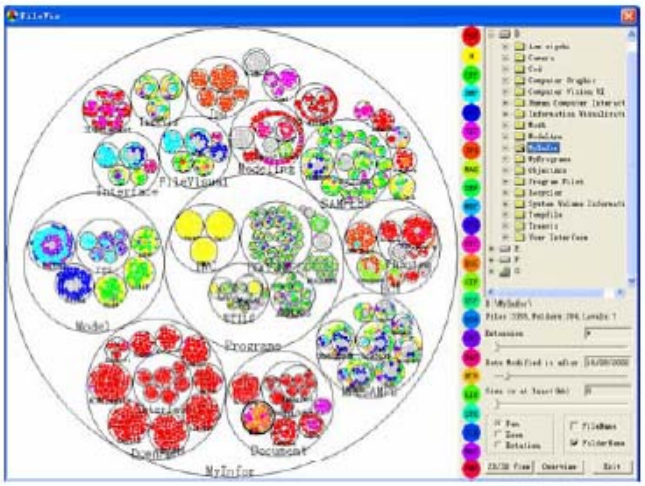
Visualization of Large Hierarchical Data by Circle Packing W.Wang et al. CHI 2006



(a) User interface and the overview of "D:\MyInfor"

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Treemap

- Children are drawn inside their parents
- Alternative horizontal and vertical slicing at each successive level
- Use area to encode other variables of data items

B. Johnson, Ben Shneiderman: Tree maps: A Space-Filling Approach to the Visualization of Hierarchical Information Structures. IEEE Visualization 1991: 284-291

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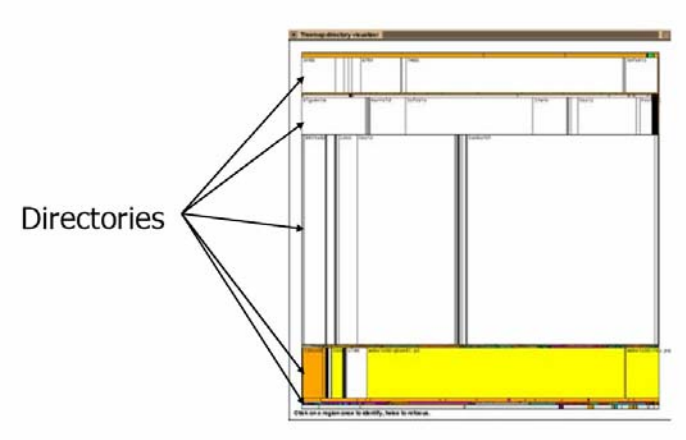
Treemap

- Example



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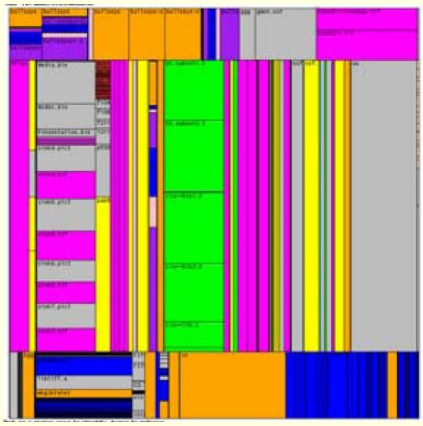
Treemap

- Example



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Treemap Algorithm

```
Draw()
{
    Change orientation from parent (horiz/vert)
    Read all files and directories at this level
    Make rectangle for each, scaled to size
    Draw rectangles using appropriate size and color
    For each directory
        Make recursive call using its rectangle as focus
}
```

J. Stasko's InfoVis class slides

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Treemap Affordances

- It is rectangular!
- Good representation of two attributes beyond node-link: color and area
- Not as good at representing structure
  - Can get long-thin aspect ratios
  - What happens if it's a perfectly balanced tree of items all the same size?

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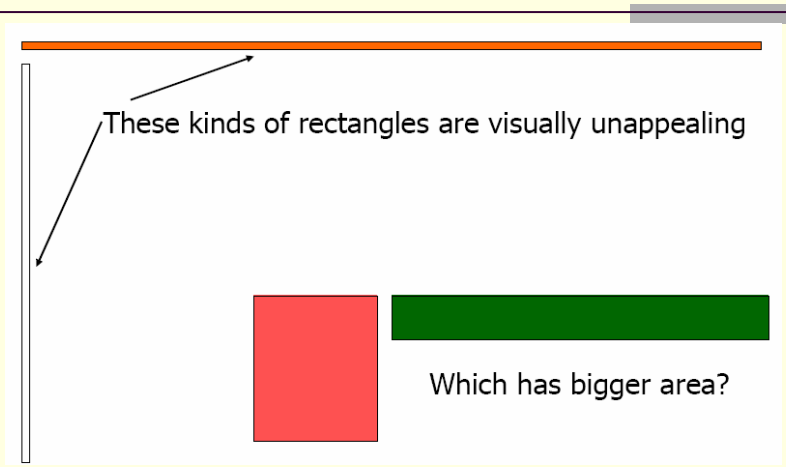
Aspect ratios



J. Stasko's InfoVis class slides

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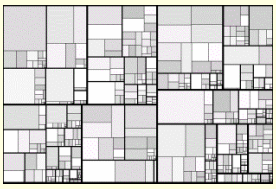
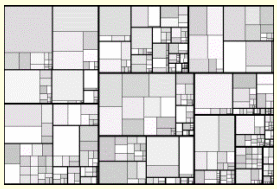
Treemap Variation

- Make rectangles more square

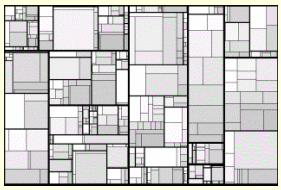
Slice-and-dice



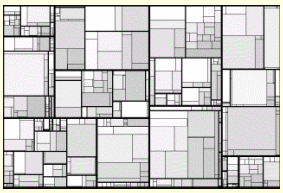
Cluster



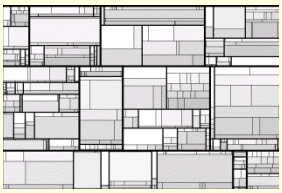
Squarified



Pivot-by-middle



Pivot-by-size



Strip

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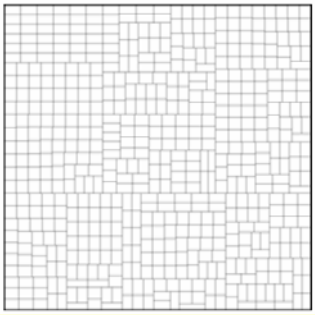
Showing Structure



A tree with 698 node (from [Balzer:infovis2005]

How about a perfectly balanced binary tree?

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Showing Structure

- Borderless treemap: hard to discern structure of hierarchy
  - What happens if it's a perfectly balanced tree of items all the same size?
- Variations:
  - Use border
  - Change rectangles to other forms

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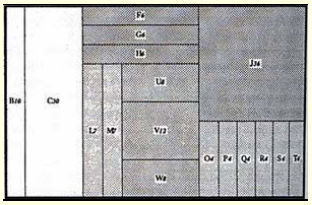
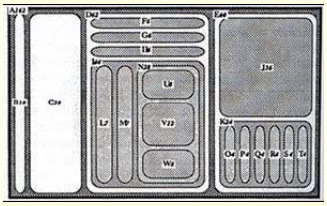
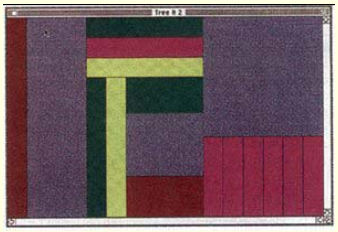
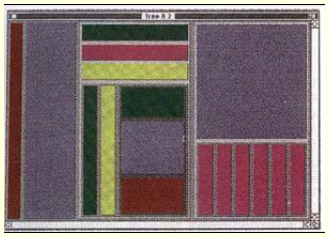
Nested vs. Non-nested









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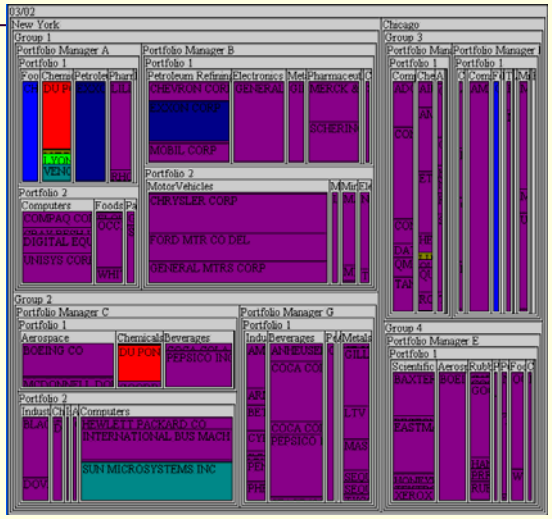
Non-nested Treemap

Nested Treemap

Nested Treemap

- Borders help on smaller trees, but take up too much area on large, deep ones



http://www.cs.umd.edu/hcil/treemap-history/treemap97.shtml

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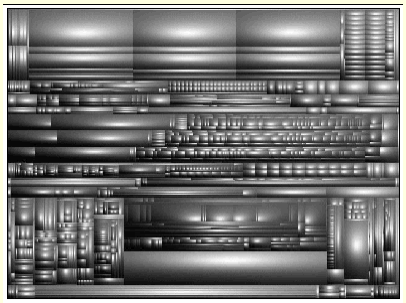
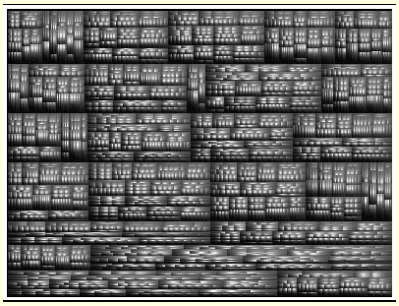
Cushion Treemap

- Add shading and texture (Van Wijk and Van de Wetering InfoVis'99)





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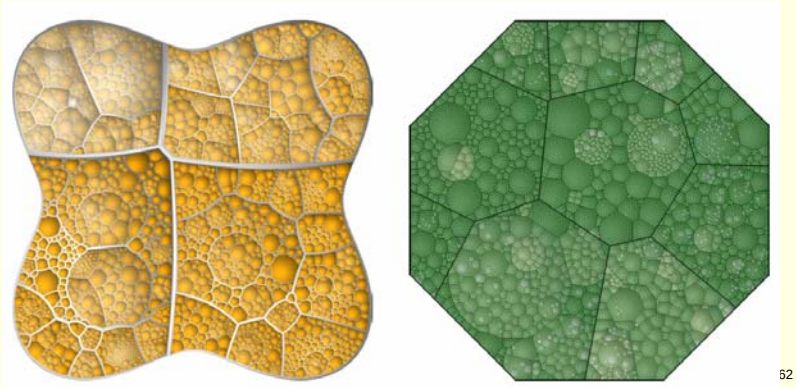
Voronoi Treemaps [balzer:infovis05]

- Enable subdivisions of and in polygons
- Fit into areas of arbitrary shape



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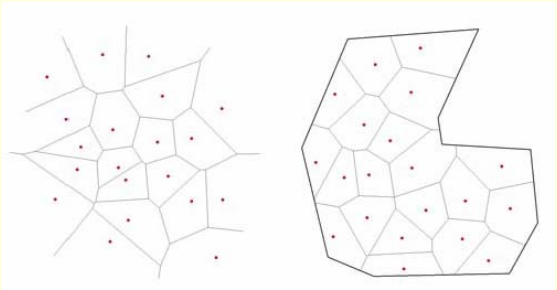
Basic Voronoi Tessellations

- Enable partitioning of m-dimensional space without holes or overlappings
- Planar VT in 2D:
  - P: = {p1, ..pn} a set of n distinct points –generators
  - Divide 2D space into n Voronoi regions V(Pi):
    - Any point q lies in the region V(Pi) if and only if
    - distance(pi, q) < distance(pj,q) for any j != i



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Weighted Voronoi Tessellations

- Basic VT: $distance_{\varepsilon}(p_i, q) := \|p_i - q\| = \sqrt{(x_i - x)^2 + (y_i - y)^2}$
- Additively weighted Voronoi (AW VT:

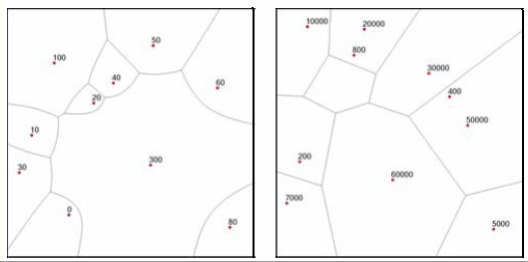
$$distance_{aw}(p_i, w_i, q) := \|p_i - q\| - w_i$$

- Additively weighted power voronoi (PW VT):

$$distance_{pw}(p_i, w_i, q) := \|p_i - q\|^2 - w_i$$

Left: AW VT

Right: PW VT



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Centroidal Voronoi Tessellations (CVT)

- Property of CVT: Each generator is itself center of mass(centroid) of corresponding voronoi region

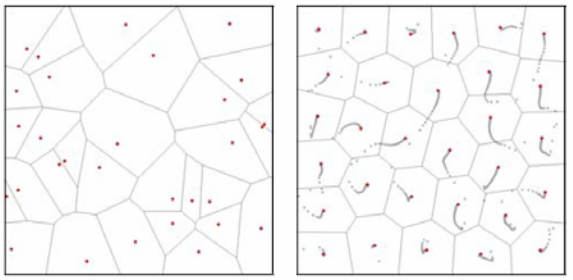

Figure 6: Voronoi tessellation of 20 random points and an associated CVT—traces illustrate the movements of the points during the computation of the CVT

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Centroidal Voronoi Tessellations (CVT)

- CVT minimize the energy function:

$$\mathcal{K}(P,\mathcal{V}(P)) = \sum_i \int_{V(p_i)} \|x - p_i\|^2 dx$$

- The energy of the CVT is equivalent to the overall aspect ratio of the subareas of the treemap layout

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Voronoi Treemap Algorithm

- Size of each Voronoi region should reflect size of the tree node
- Area size is not observed in CVT computation
- Extension:
  - Use iteration
  - In each iteration, adjust the area of regions by their weights
  - Weights are adjusted according to the size of the node
  - Iterate until the relative size error is under a threshold
- Video

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Treemap Applications

- Software visualization
- Multimedia visualization
- Tennis matches
- File/directory structures
- Basketball statistics
- Stocks and portfolios

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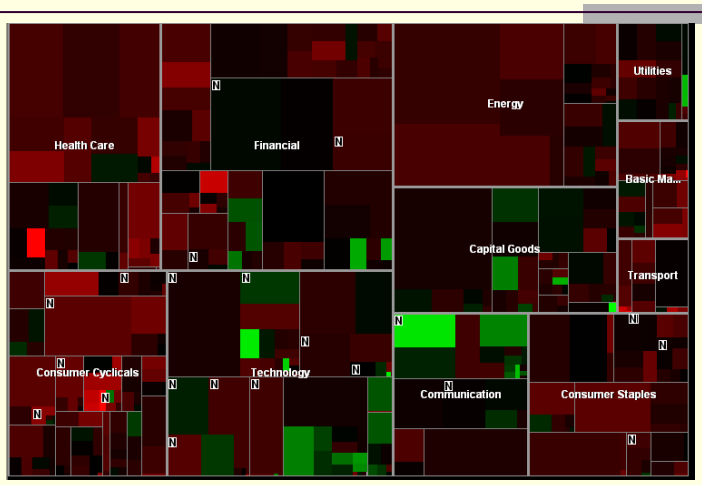
Marketmap



http://www.smartmoney.com/marketmap/

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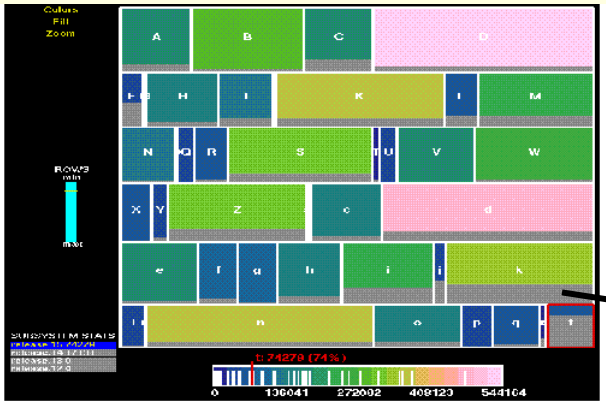
Software Visualization

- SeeSys (Baker & Eick, AT&T Bell Labs)



New code in this release

Figure 2: NCSL and new development by subsystem in a recent release.

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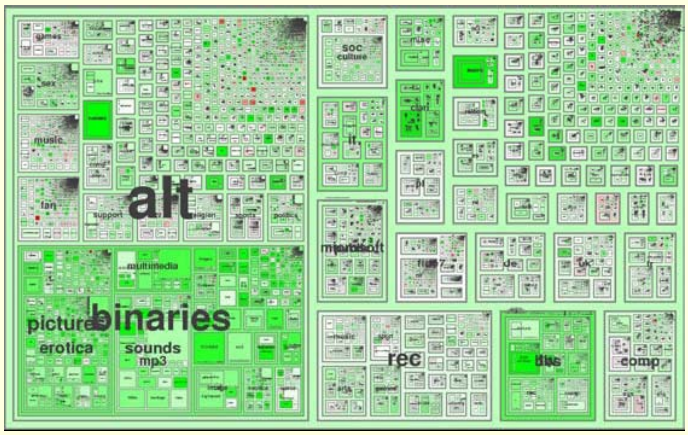
Internet News Groups

- Netscan (Fiore & Smith Microsoft)



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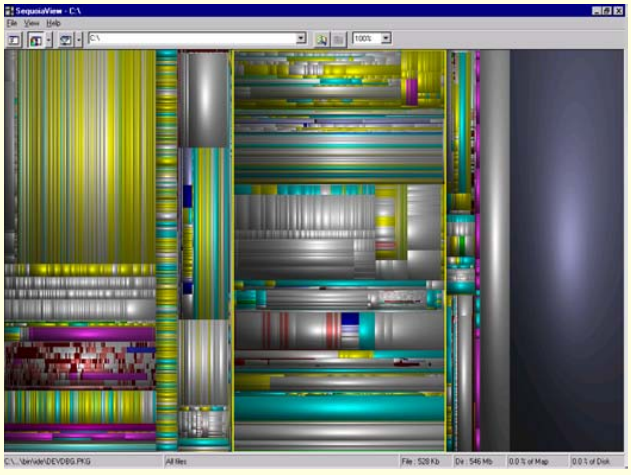
SequoiaView

- File visualizater www.win.tue.nl/sequoiaview/



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Photemesa

- Image browser (quantum and bubble treemap)
  http://www.cs.umd.edu/hcil/photomesa/

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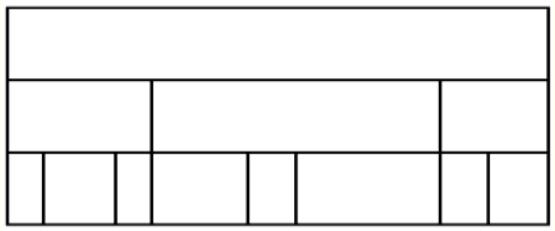
Space-Filling Techniques

- Each item occupies an area
- Children are “contained” within (under) parent



One Example

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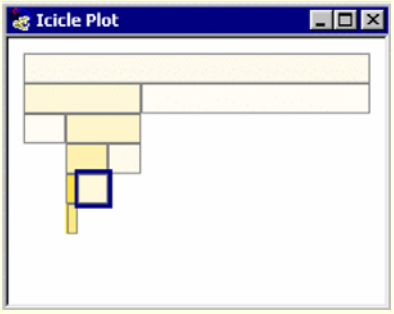
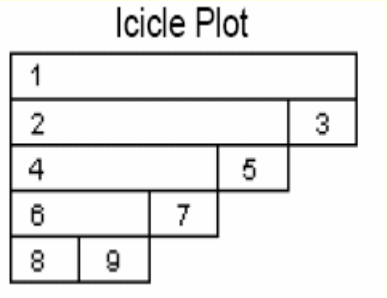
Icicle Plot

- Icicle plot (similar to Kleiner and Hartigan's concept of castles)
  - Node size is proportional to node width





Barlow and Neville InfoVis 2001

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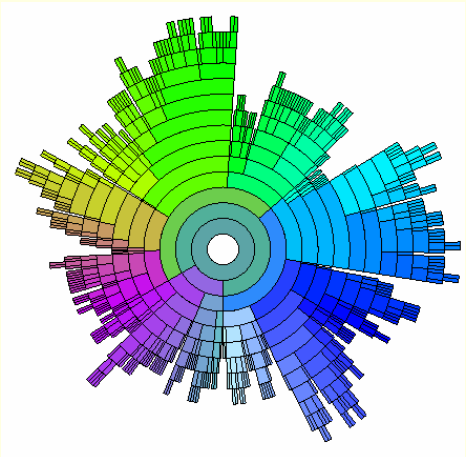
Radial Space Filing Techniques

- InterRing [Yang02]



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Node Link + Space Filling Techniques

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Elastic Hierarchies: Combining Treemaps and Node-Link Diagrams [zhao:infovis 05]

- A hybrid approach
- Dynamic
- Video

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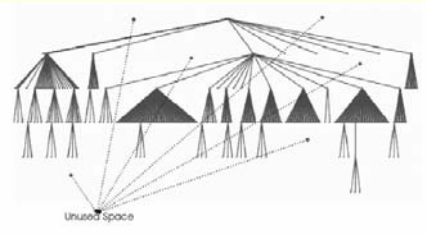
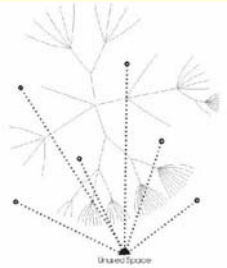
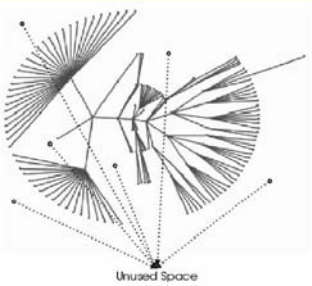
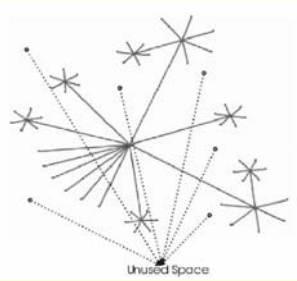
Space-Optimized Tree - Motivation









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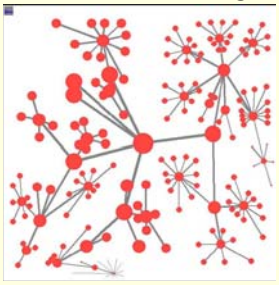
Q. Nguyen and M. Huang Infovis 02

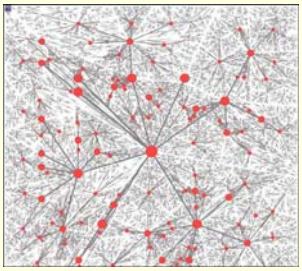
Space-Optimized Tree [Q. Nguyen and M. Huang Infovis 02]

Key idea:

- Partition display space into a collection of geometrical areas for all nodes
- Use node-link diagrams to show relational structure



Example: Tree with 150 nodes



Example: Tree with approximately 55000 nodes

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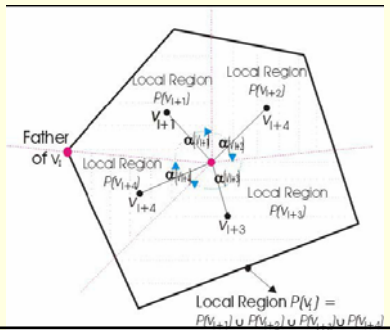
Space-Optimized Tree [Q. Nguyen and M. Huang Infovis 02]

Algorithm for dividing a region:

1. weight calculation for each direct child
2. wedge calculation for each direct child
3. vertex position calculation for each direct child



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Weight Calculation

$$w(v_i) = 1 + C\sum_{j=0}^{k-1} w(v_{l+j})$$

- V_i: the direct child
- V_l – V_{l+k} : Direct children of V_i
- Constant *C:* decide difference between vertexes with more descendants and vertexes with fewer descendants.

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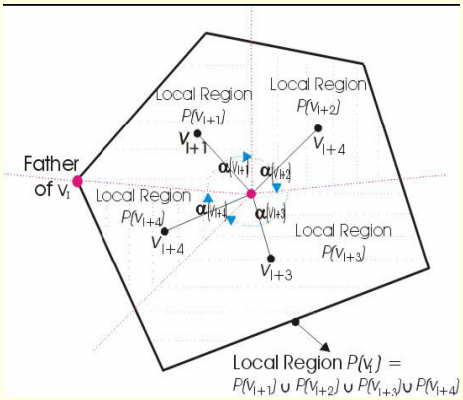
Wedge Calculation

$$\alpha(v_{l+m}) = A\frac{w(v_{l+m})}{\sum_{j=0}^{k} w(v_{l+j})}$$



Example of dividing the local region of one node

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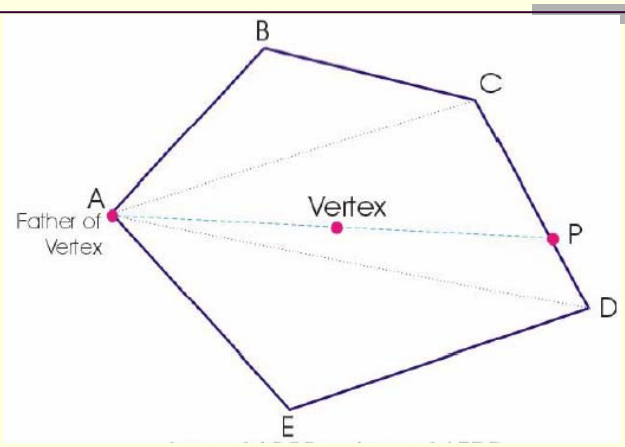
Vertex Position Calculation



Area ABCP = Area AEDP

Vertex is the midpoint of line AP

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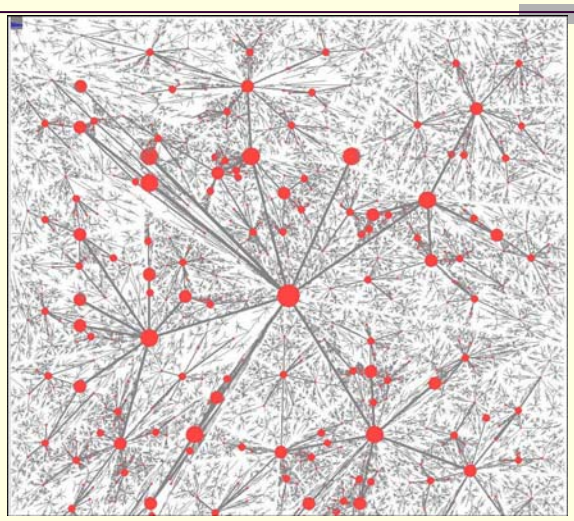
Space-Optimized Tree



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Example: Tree with approximately 55000 nodes