Hierarchies and Trees 1 (Mostly Node-link)

CS 7450 - Information Visualization
November 7, 2016
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Learning Objectives

- Define hierarchical data & related terms
  - root, node, link, leaf, depth, parent, child, sibling
- List example tasks for hierarchical data
- Be able to draw reasonable 2D tree
  - Understand basic approach/algorithm and method
- Describe particular drawing techniques and explain +/- of each
  - SpaceTree, Cone Tree, Hyperbolic tree, H3 tree, DOI tree, FlexTree, Space-optimized tree
- Explain general limitations of node-link approach
- Understand treemap algorithm
  - Be able to draw slice-and-dice treemap given a hierarchy

Hierarchies

- Definition
  - 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 in the World

- Pervasive
  - Family histories, ancestries
  - File/directory systems on computers
  - Organization charts
  - Animal kingdom: Phylum,…, genus,…
  - Object-oriented software classes
  - …

Analysis Tasks

- Example tasks?
  - Describe/understand structure
  - Find items
  - What are the parent/children/siblings of x?
  - Where is this subtree?
  - Where are nodes with particular values located?
  - What kind of attributes does this subtree have?
  - …

"Quiz"

Draw a representation for the following hierarchy:
Node: Child1, Child2, … (order means nothing)

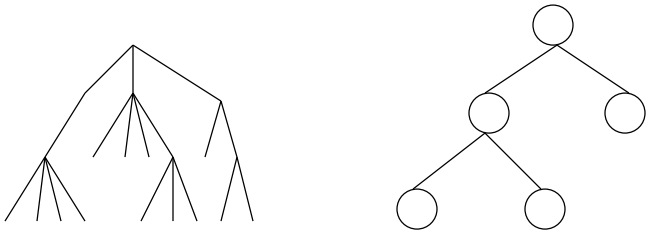
```
A: J, H, U, F
J: E, P
H: D, R, L, W, B
F: S, M, N
E: T, K
P: V, C, O, I
S: Q, G
```

Trees

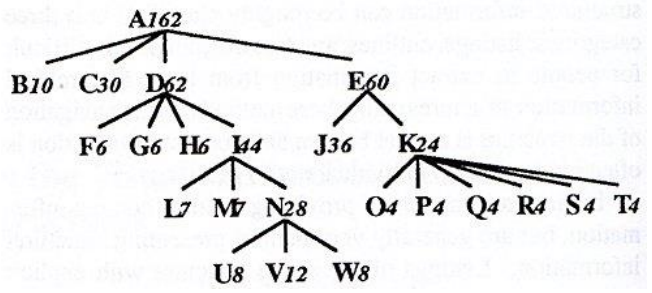
- Hierarchies often represented as trees
  - Directed, acyclic graph
- Two main representation schemes
  - Node-link
  - Space-filling

Node-Link Diagrams

- Root at top, leaves at bottom is very common



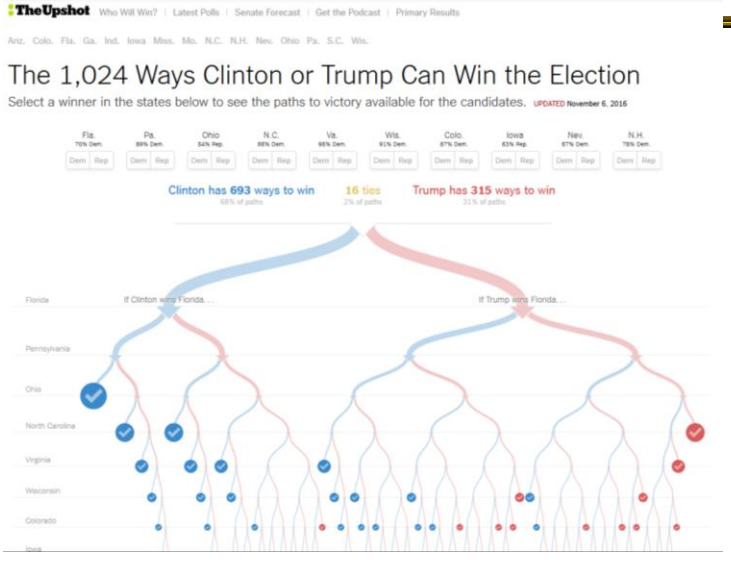
Sample Representation



From: Johnson & Shneiderman, '91

http://www.nytimes.com/interactive/2016/upshot/clinton-trump-paths-to-win-election.html?_r=0

Election '16



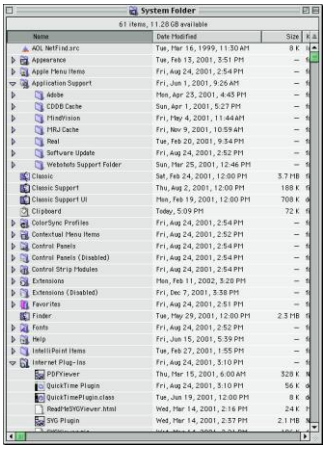
Examples

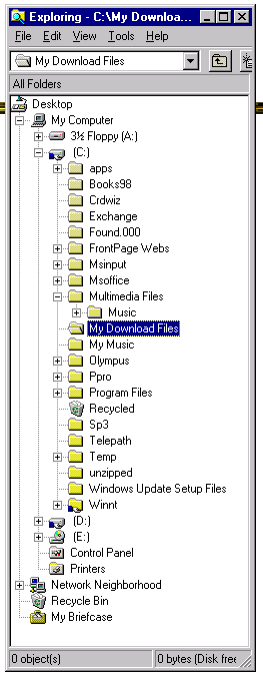
Good for?

Search

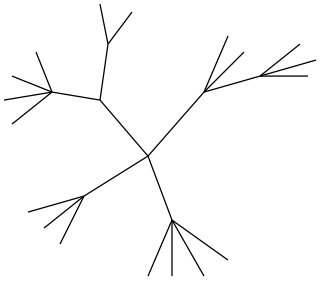
Bad for?

Understanding structure





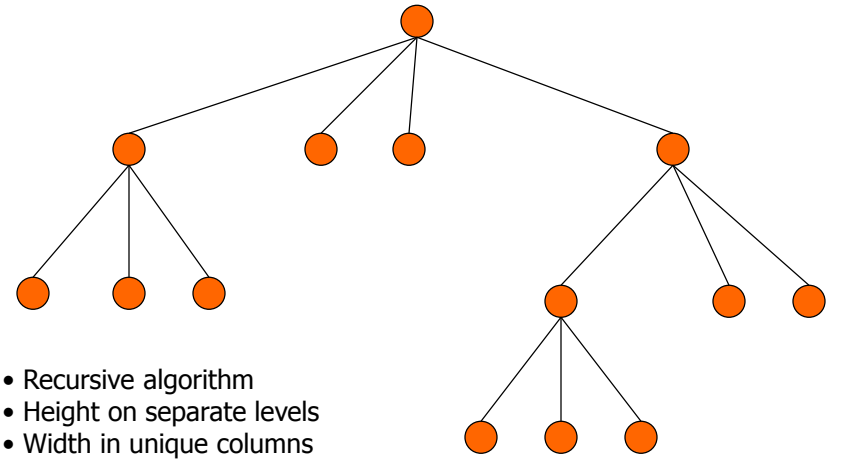
Why Put Root at Top?



Root can be at center with levels growing outward too

Can any node be the root?

Basic Algorithm

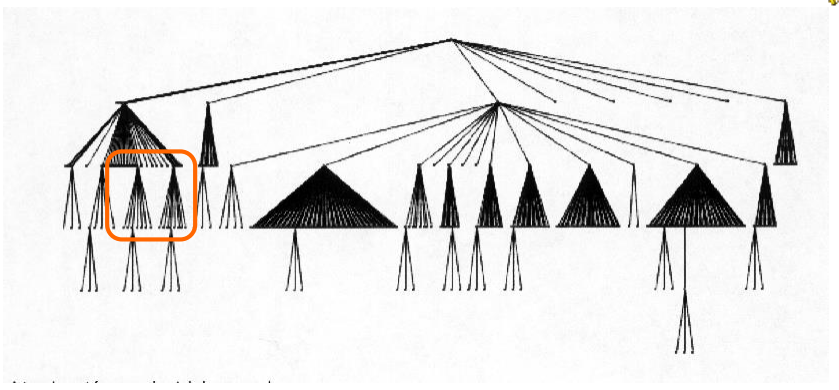


- Recursive algorithm
- Height on separate levels
- Width in unique columns
- Make room for subtrees upwards

Potential Problems

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

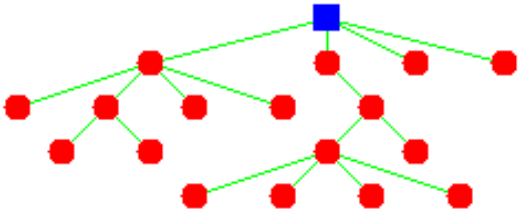
More Sophisticated



In what way?
- Regions compressed horizontally

Reingold-Tilford Algorithm

Compact layout
Uses symmetry
Depth on levels



Generalized from binary trees by Walker
Running time improved (linear) by Buchheim et al

InfoVis Solutions

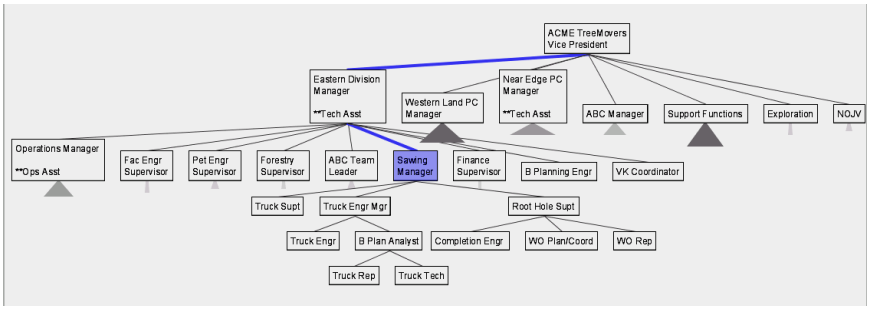
- Techniques developed in Information Visualization largely try to assist the problems identified in the last slide
- Alternatively, Information Visualization techniques attempt to show more attributes of data cases in hierarchy or focus on particular applications of trees

Discuss

- How could we do better?
- What design changes could we make to help?

SpaceTree

- Uses conventional 2D layout techniques with some clever additions



Video & Demo

Grosjean, Plaisant, Bederson
InfoVis '02

Characteristics

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

Design Features

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

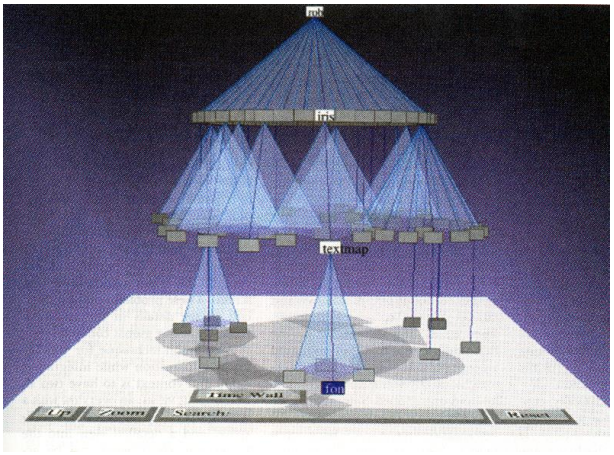
3D Approaches

- 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

Cone Trees

Developed at Xerox PARC

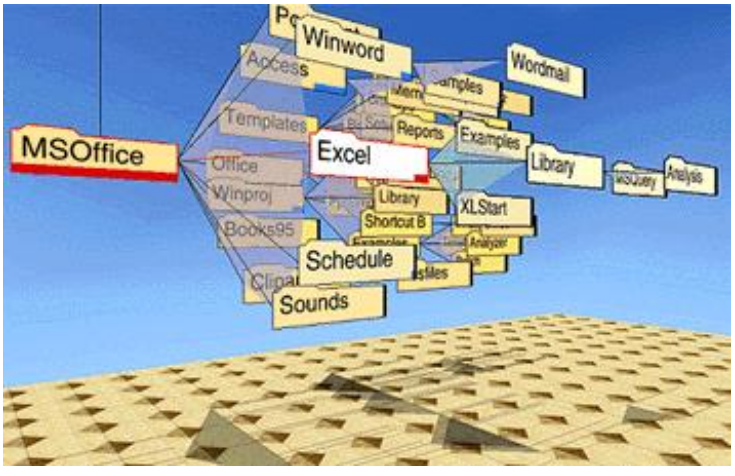
3D views of hierarchies such as file systems



Robertson, Mackinlay, Card
CHI '91

Video

Alternate Views



Cone Trees

- Pros & Cons?
  - Discuss

Cone Trees

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

Alternative Solutions

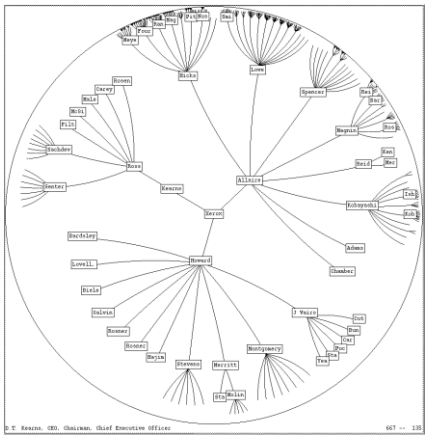
- Change the geometry
- Apply a hyperbolic transformation to the space
- Root is at center, subordinates around
- Apply idea recursively, distance decreases between parent and child as you move farther from center, children go in wedge rather than circle

Hyperbolic Browser

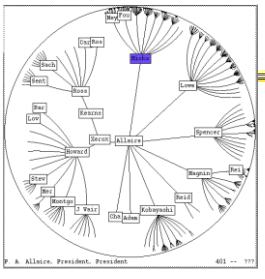
- Focus + Context Technique
  - Detailed view blended with a global view
- First lay out the hierarchy on the hyperbolic plane
- Then map this plane to a disk
- Start with the tree's root at the center
- Use animation to navigate along this representation of the plane

Lamping and Rao, JVLC '96

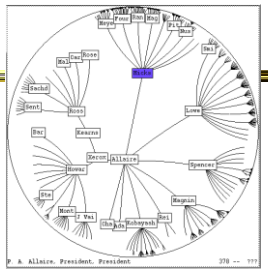
2D Hyperbolic Browser



- **Approach:** Lay out the hierarchy on the hyperbolic plane and map this plane onto a display region.
- **Comparison**
  - A standard 2D browser: 100 nodes (w/3 character text strings)
  - Hyperbolic browser: 1000 nodes, about 50 nearest the focus can show from 3 to dozens of characters



1



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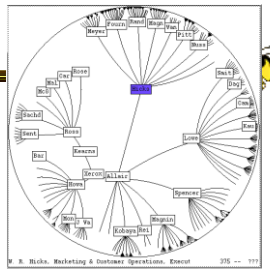

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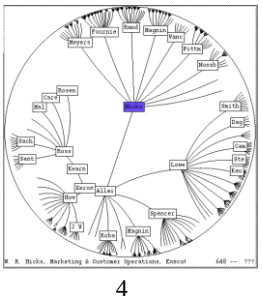

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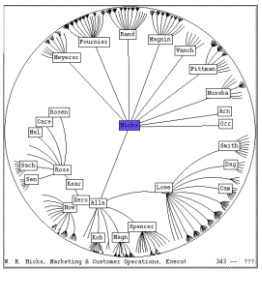


5

Clicking on the blue node brings it into focus at the center

Watch it Work

- Video
- Demo from prefuse system

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)

Problems

- What might be problems with this approach?

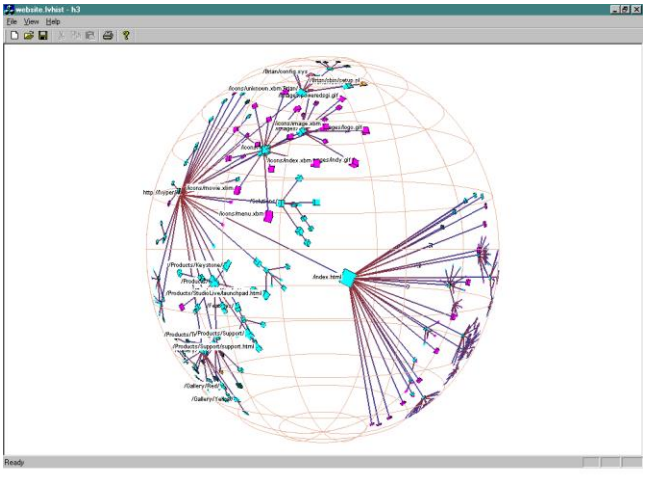
Problems

- 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

How about 3D?

- Can same hyperbolic transformation be applied, but now use 3D space?
- Sure can
- Have fun with the math!

H3Viewer



Munzner,
IEEE CG&A '98

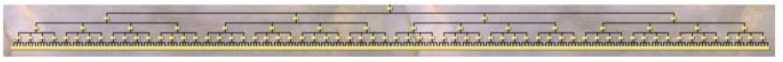
Video

Old School

- After all the interest in 3D and hyperbolic techniques in the ’90’s, recently, there has been renewed interest in the old 2D methods (just done better)
  - SpaceTree presented earlier
  - Next 3 papers…

Degree-of-Interest Trees

- Problem: Trees quickly degrade into line

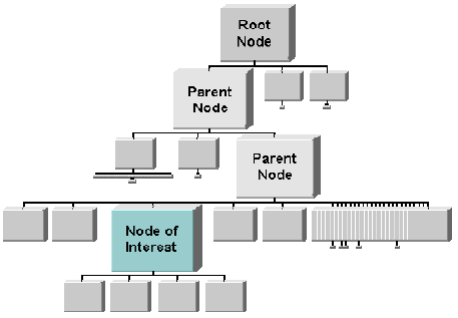


- Approach: Use fisheye-like focus & context ideas to control how a tree is drawn

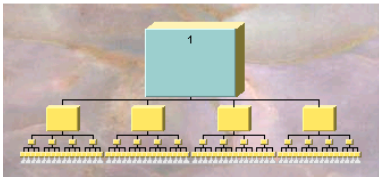
Card & Nation
AVI ‘02

Approach

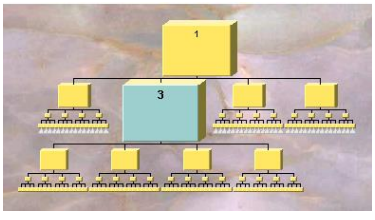
- Combine multiple ideas:
  - Expanded DOI computation
  - Logical filtering to elide nodes
  - Geometric scaling
  - Semantic scaling
  - Clustered representation of large unexpended branches
  - Animated transition



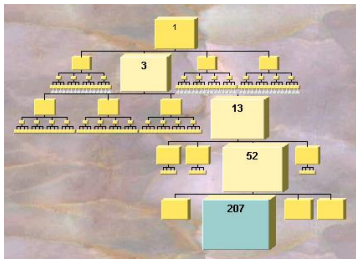
Example Operations



1. Display of a uniform tree of 4 levels



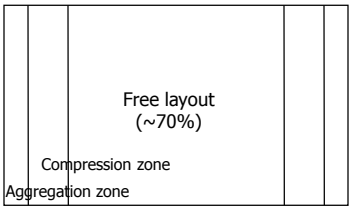
2. Same table with focus on Node 3

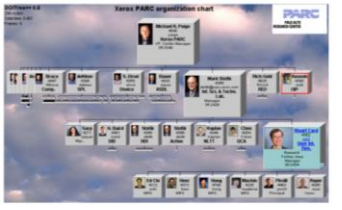


3. Same tree expanded down to a leaf node

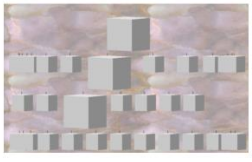
Compression

- For nodes: compress to fit (compress in X or in Y)

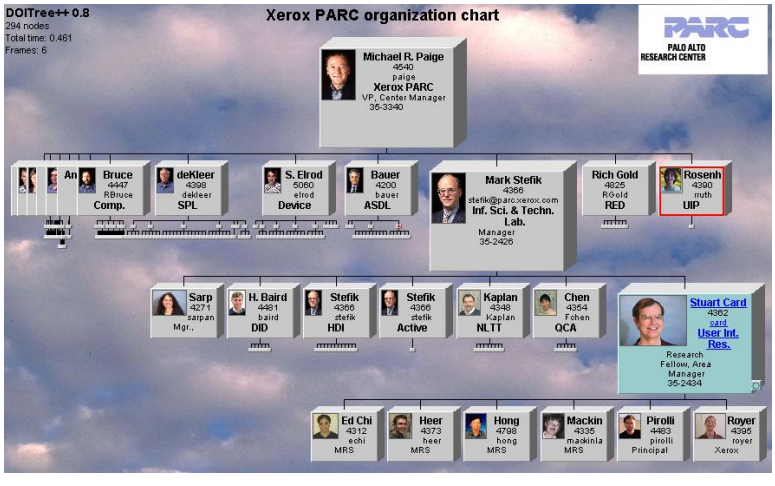




- Within-node compression
  - Data deletion
  - Word abbreviation
  - Node rotation



Better View of Org Chart



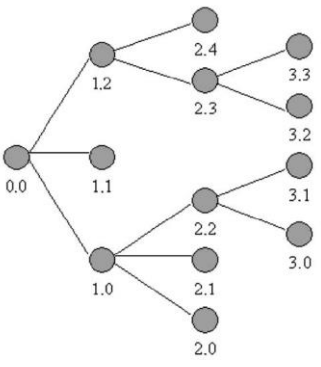
Organization chart with over 400 nodes accessible over WWW through Web browser

FlexTree

- Horizontally-drawn tree with compression along vertical dimension
- One focus is on showing decision trees well
- Contextual multi-foci view
- Basic idea: Push all nodes down as far as you can

Song, Curran & Sterritt
Information Visualization '04

Example



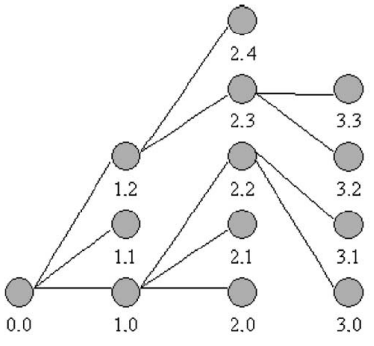


Figure 3 Concept diagram of FlexTree – space between nodes is compressed to achieve a compact view.

Bar Chart and Partial Views

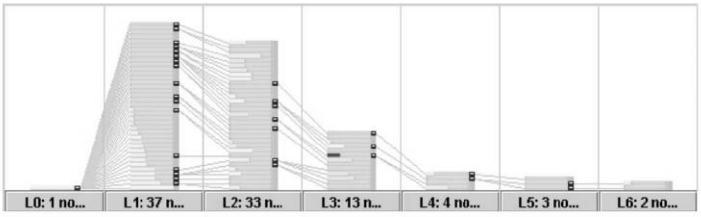


Figure 4 *Bar chart view* of FlexTree – nodes within the same level stack closely to each other in a space-filling manner.

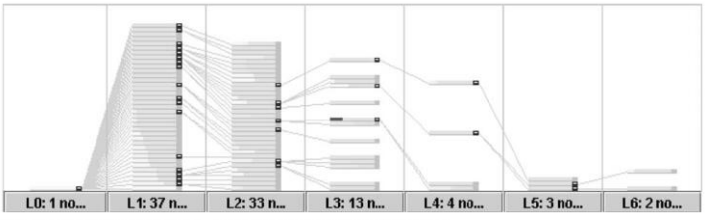


Figure 5 *Partial tree view* of FlexTree – the structure of the tree is partially revealed.

Full Tree View

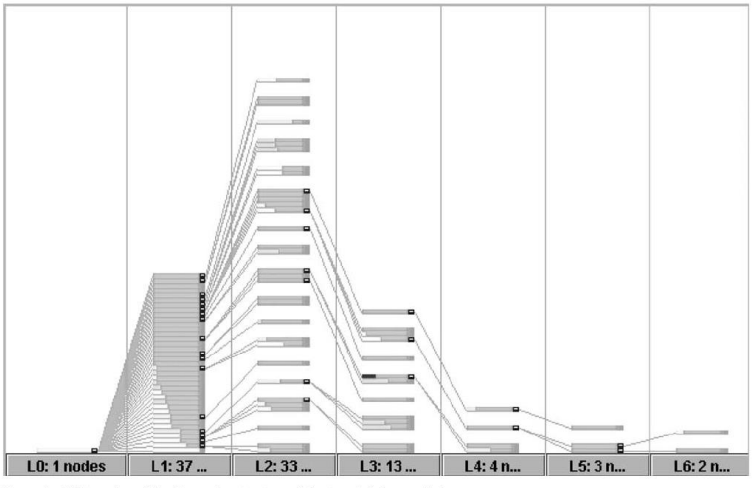


Figure 6 *Full tree view* of FlexTree – the structure of the tree is fully revealed.

Node Details

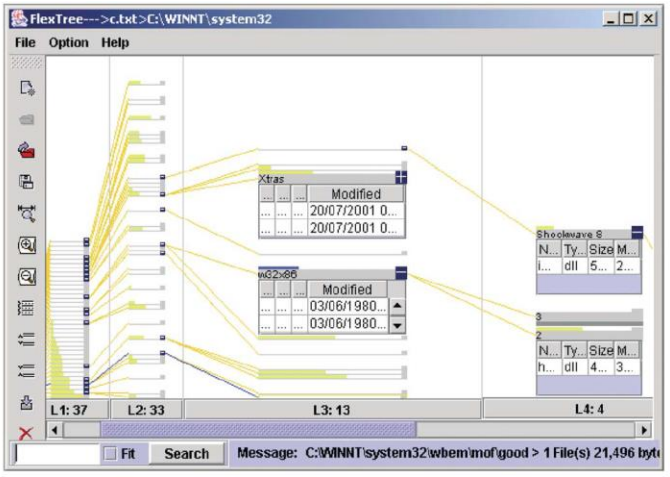


Figure 9 Zooming into multiple foci of interest within the context of the hierarchy. This demonstrates how the user can zoom into a tree and generate details on demand. The *w32 × 86* node itself is shown in blue, rather than yellow as the other nodes, because all files in this folder were modified in 1980, which is much earlier than files in the other folders.

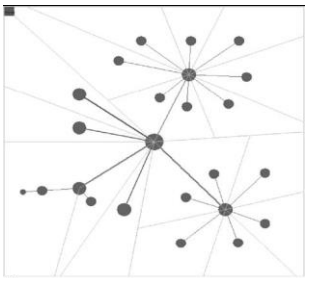
Space-Optimized Tree

- Put root node at center, then draw children out radially
- Key: Smart positioning to optimize placement of braches (Voronoi diagram-like approach)

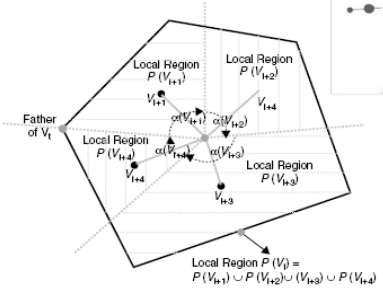
Nguyen & Huang
Information Visualization '03

Space-optimized tree

- Connections + Enclosures
  - Goal: Show relationships and optimize space

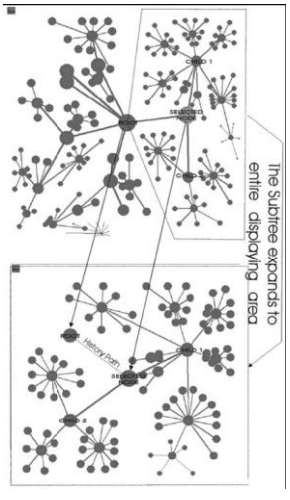


- Layout
  - Vertex
  - Subtree
  - Wedge
  - Polygon



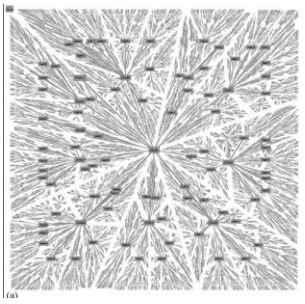
Viewing and Navigation

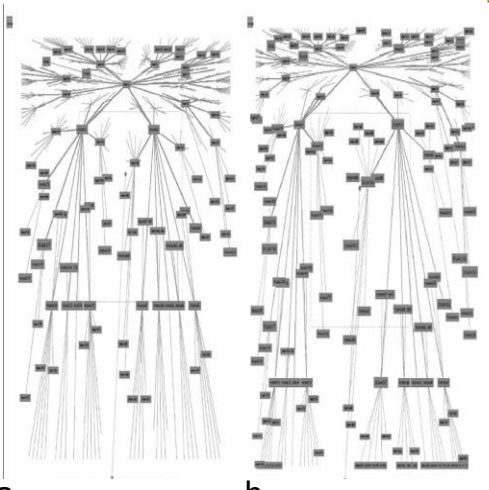
- Modified Semantic Zooming
  - Reduce density of tree
  - Selected Node to Root
  - History Path



Viewing and Navigation

- Focus + Context
  - Browsing (a)
  - Distortion (b)





a b

Compare & Critique

- Which of the techniques do you find most appealing?
- Why?

Food for Thought

- Which of these techniques are useful for what purpose?
- How well do they scale?
- What if we want to portray more variables of each case?

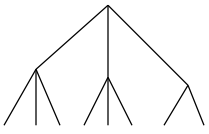
Node-link Shortcoming?

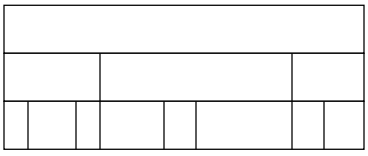
- Difficult to encode more variables of data cases (nodes)
  - Shape
  - Color
  - Size
  - …but all quickly clash with basic node-link structure

Space-Filling Representation

Each item occupies an area

Children are "contained" under parent



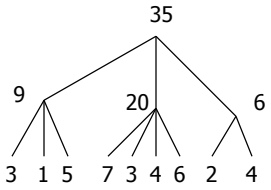


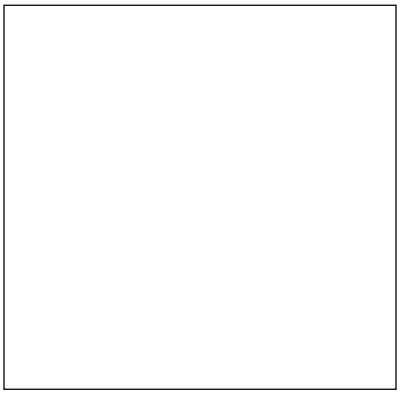
One example: "Icicle plot"

Treemap

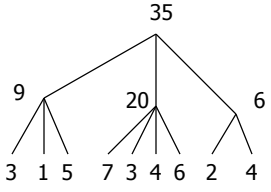
- Space-filling representation developed by Shneiderman and Johnson, Vis '91
- Children are drawn inside their parent
- Alternate horizontal and vertical slicing at each successive level
- Use area to encode other variable of data items

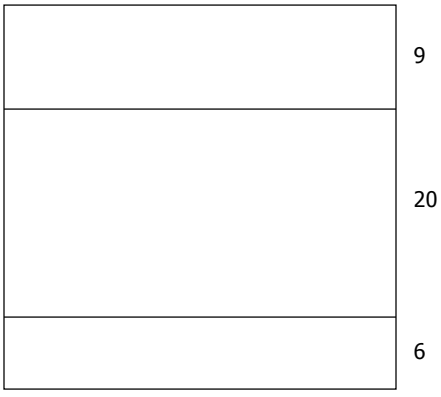
Example



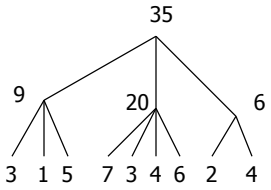


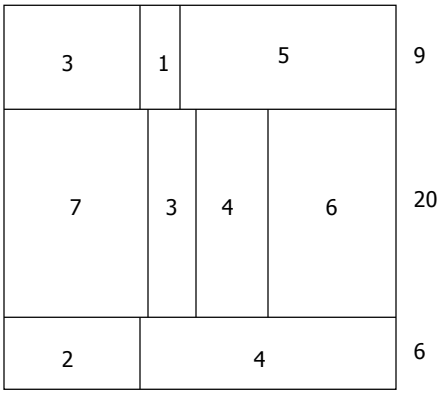
Example





Example

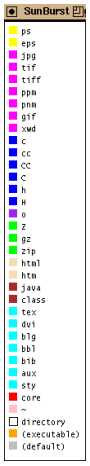


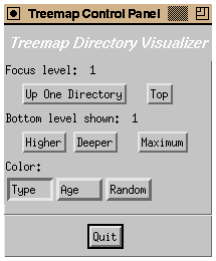


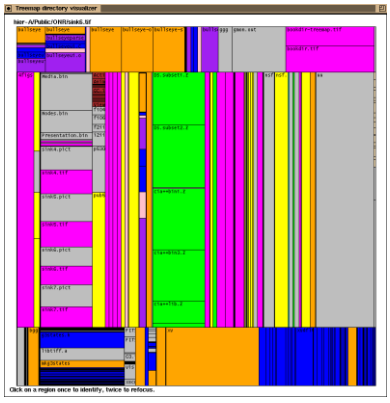
Treemap

- Example

Treemap Example





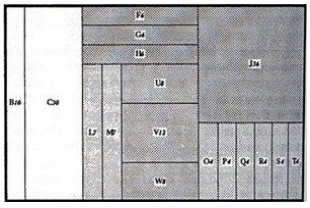


Old one I built for our Sun workstations

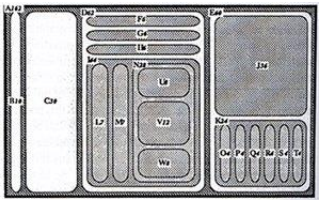
Treemap Algorithm

```
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
}
```

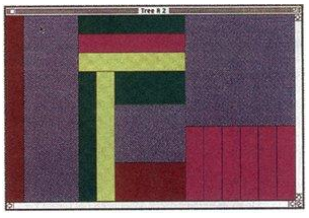
Nested vs. Non-nested

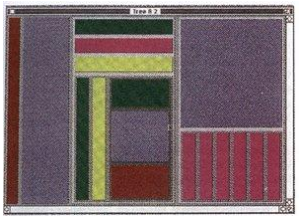


Non-nested Tree-Map



Nested Tree-Map





Learning Objectives

- Define hierarchical data & related terms
  - root, node, link, leaf, depth, parent, child, sibling
- List example tasks for hierarchical data
- Be able to draw reasonable 2D tree
  - Understand basic approach/algorithm and method
- Describe particular drawing techniques and explain +/- of each
  - SpaceTree, Cone Tree, Hyperbolic tree, H3 tree, DOI tree, FlexTree, Space-optimized tree
- Explain general limitations of node-link approach
- Understand treemap algorithm
  - Be able to draw slice-and-dice treemap given a hierarchy

Project Updates

- Progress
- Meetings
  - Sign up sheet: At least 24 hours in advance

Upcoming

- Hierarchies 2 – More on Space-filling reps
- Graphs & Networks 1