Hierarchies and Trees 1
(Mostly Node-link)

CS 4460 – Intro. to Information Visualization

October 30, 2017

John Stasko

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
- 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?
  - …

Activity

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

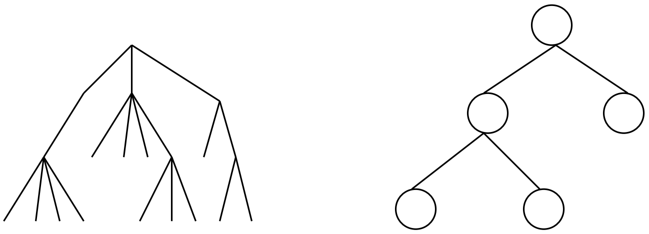
```
A: J, H, U, F
J: E, P
H: D, R, L, W, B
F: S, M, N
E: T, K
P: V, C, O, I
S: Q, G
```

Trees

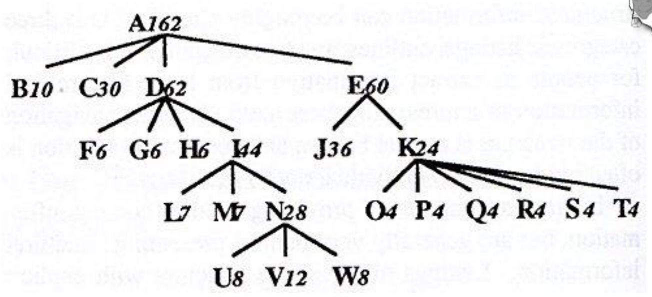
- Hierarchies often represented as trees
  - Directed, acyclic graph
- Two main representation schemes
  - Node-link
  - Space-filling

Node-Link Diagrams

- Root at top, leaves at bottom is very common



Sample Representation



From: Johnson & Shneiderman, '91

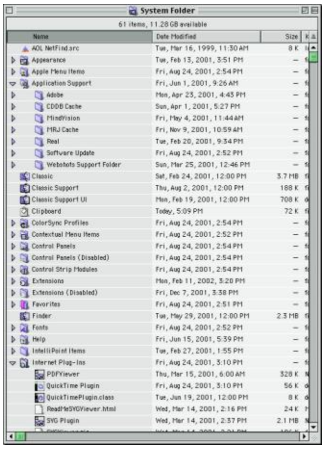
Examples

Good for?

Search

Bad for?

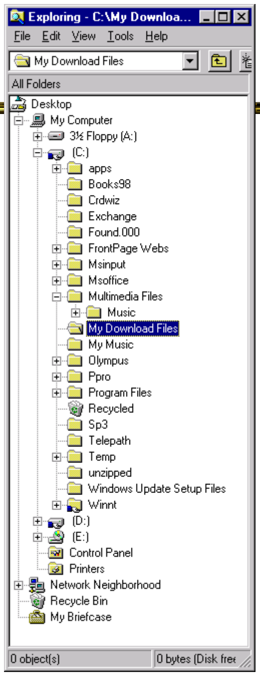
Understanding structure



System Folder

61 items, 11.28 GB available

Name	Date Modified	Size	K
AOL NetFind.src	Tue, Mar 16, 1999, 11:30 AM	8 K	l
Appearance	Tue, Feb 13, 2001, 3:51 PM	–	f
Apple Menu Items	Fri, Aug 24, 2001, 2:54 PM	–	f
Application Support	Fri, Jun 1, 2001, 9:26 AM	–	f
Adobe	Mon, Apr 23, 2001, 4:45 PM	–	f
CDDB Cache	Sun, Apr 1, 2001, 5:27 PM	–	f
MindVision	Fri, May 4, 2001, 11:44 AM	–	f
MRJ Cache	Fri, Nov 9, 2001, 10:59 AM	–	f
Real	Tue, Feb 20, 2001, 9:34 PM	–	f
Software Update	Fri, Aug 24, 2001, 2:52 PM	–	f
Webshots Support Folder	Sun, Mar 25, 2001, 12:46 PM	–	f
Classic	Sat, Feb 24, 2001, 12:00 PM	3.7 MB	f
Classic Support	Thu, Aug 2, 2001, 12:00 PM	188 K	f
Classic Support UI	Mon, Feb 19, 2001, 12:00 PM	708 K	d
Clipboard	Today, 5:09 PM	72 K	f
ColorSync Profiles	Fri, Aug 24, 2001, 2:54 PM	–	f
Contextual Menu Items	Fri, Aug 24, 2001, 2:52 PM	–	f
Control Panels	Fri, Aug 24, 2001, 2:54 PM	–	f
Control Panels (Disabled)	Fri, Aug 24, 2001, 2:54 PM	–	f
Control Strip Modules	Fri, Aug 24, 2001, 2:54 PM	–	f
Extensions	Mon, Feb 11, 2002, 3:20 PM	–	f
Extensions (Disabled)	Fri, Dec 7, 2001, 3:38 PM	–	f
Favorites	Fri, Aug 24, 2001, 2:51 PM	–	f
Finder	Tue, May 29, 2001, 12:00 PM	2.3 MB	f
Fonts	Fri, Aug 24, 2001, 2:52 PM	–	f
Help	Fri, Jun 15, 2001, 5:39 PM	–	f
IntelliPoint Items	Tue, Feb 27, 2001, 1:55 PM	–	f
Internet Plug-Ins	Fri, Aug 24, 2001, 3:10 PM	–	f
PDFViewer	Thu, Mar 15, 2001, 6:00 AM	328 K	N
QuickTime Plugin	Fri, Aug 24, 2001, 3:10 PM	56 K	d
QuickTimePlugin.class	Tue, Jun 19, 2001, 12:00 PM	8 K	d
ReadMeSVGViewer.html	Wed, Mar 14, 2001, 2:16 PM	24 K	H
SVG Plugin	Wed, Mar 14, 2001, 2:37 PM	2.1 MB	N



Exploring - C:\My Downloa...

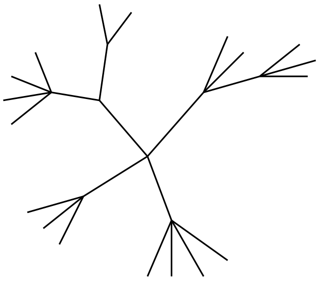
My Download Files

All Folders

- Desktop
  - My Computer
    - 3½ Floppy (A:)
    - (C:)
      - apps
      - Books98
      - Crdwiz
      - Exchange
      - Found.000
      - FrontPage Webs
      - Msinput
      - Msoffice
      - Multimedia Files
        - Music
      - My Download Files
      - My Music
      - Olympus
      - Ppro
      - Program Files
      - Recycled
      - Sp3
      - Telepath
      - Temp
      - unzipped
      - Windows Update Setup Files
      - Winnt
    - (D:)
    - (E:)
    - Control Panel
    - Printers
  - Network Neighborhood
  - Recycle Bin
  - My Briefcase

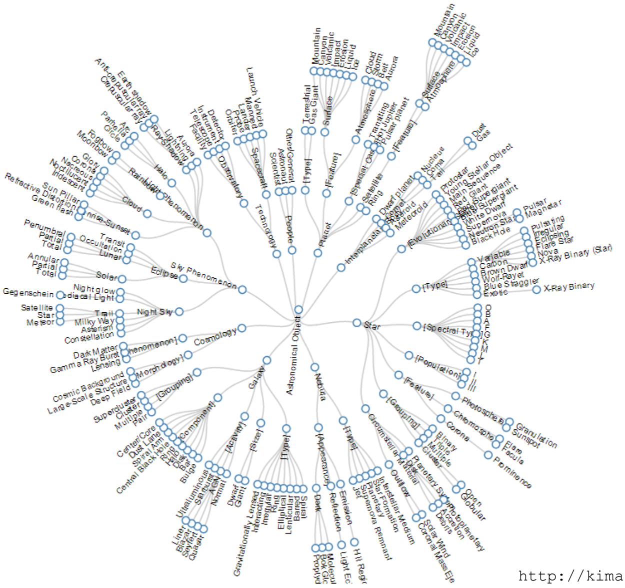
0 object(s) | 0 bytes (Disk free

Why Put Root at Top?



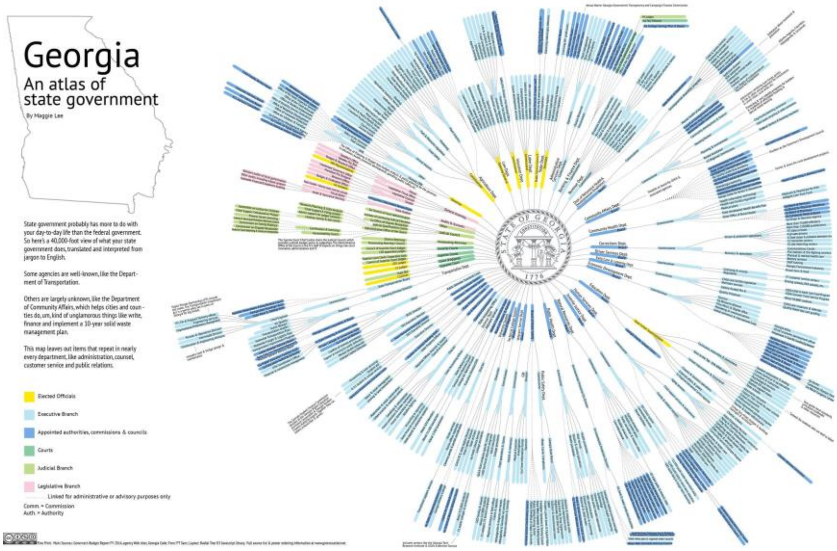
Root can be at center with levels growing outward too

Can any node be the root?



http://kimalbrecht.com/viztypo/?p=27

Even Georgia Does It!



Georgia

An atlas of state government

By Maggie Lee

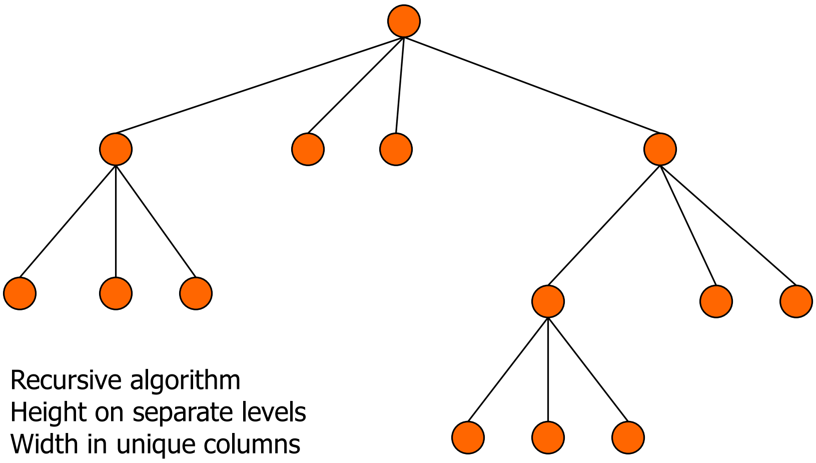
State government probably has more to do with your day-to-day life than the federal government. So here's a 40,000-foot view of what your state government does, translated and interpreted from jargon to English.

Some agencies are well-known, like the Department of Transportation.

Others are largely unknown, like the Department of Community Affairs, which helps cities and counties do, um, kind of unglamorous things like write, finance and implement a 10-year solid waste management plan.

This map leaves out items that repeat in nearly every department, like administration, counsel, customer service and public relations.

Basic Algorithm

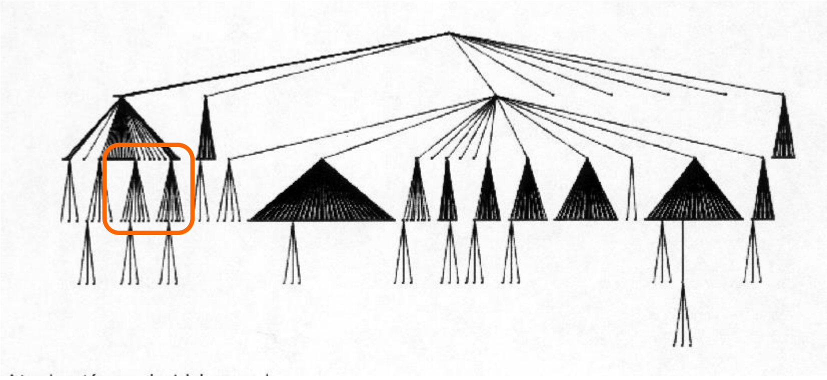


- Recursive algorithm
- Height on separate levels
- Width in unique columns
- Make room for subtrees upwards

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

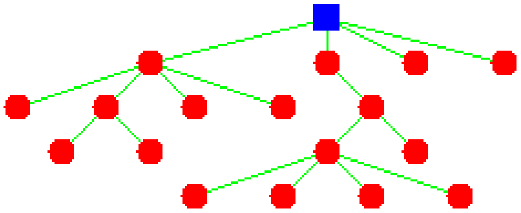


In what way?

- 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

Scale

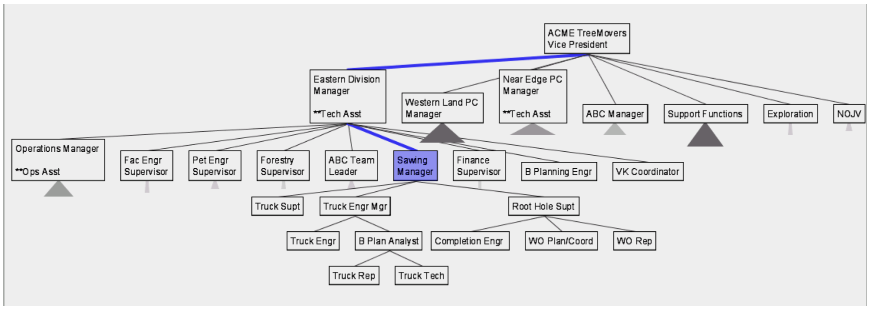
- Real challenge – Get hundreds or thousands of nodes

- Approaches?
  - Interaction
  - Only show some items or attributes
  - Clustering & aggregation
  - Smart layout

InfoVis Solutions

SpaceTree

- Uses conventional 2D layout techniques with some clever additions



Video

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

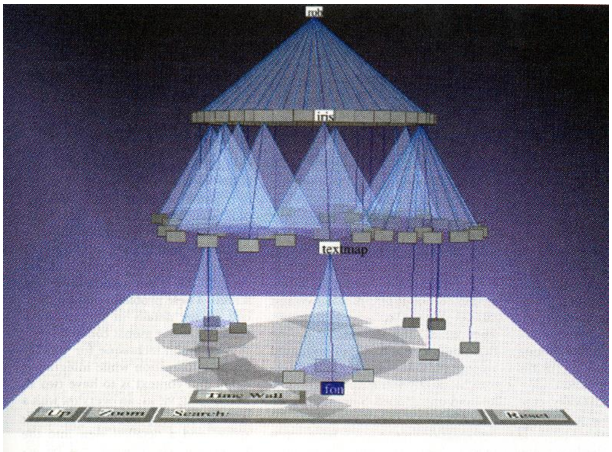
3D Approaches

- 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

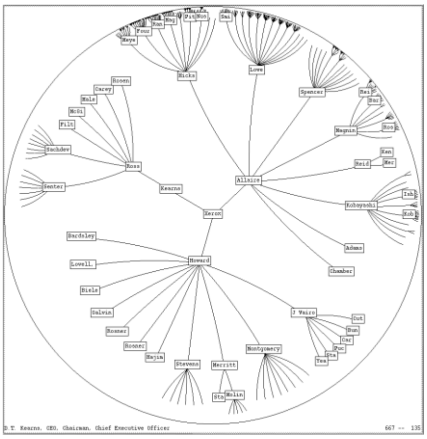


Robertson, Mackinlay, Card
CHI ‘91

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

Hyperbolic Browser



- Focus+Context technique
- Approach: Lay out the hierarchy on the hyperbolic plane and map this plane onto a display region
- Use interaction & animation to move focus to different nodes

Video
Demo from Prefuse system

Lamping and Rao
JVLC ‘96

Key Attributes

- Natural magnification [illegible]ye) in center
- Layout depends only [illegible] 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

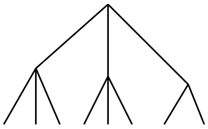
Node-link Shortcoming?

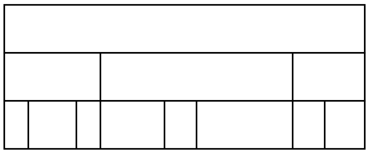
- What if we want to portray more variables of each case?
  - Difficult to encode more variables of data cases (nodes)
    - Shape
    - Color
    - Size
  - …but all quickly clash with basic node-link structure

Space-Filling Representation

Each item occupies an area

Children are "contained" under parent

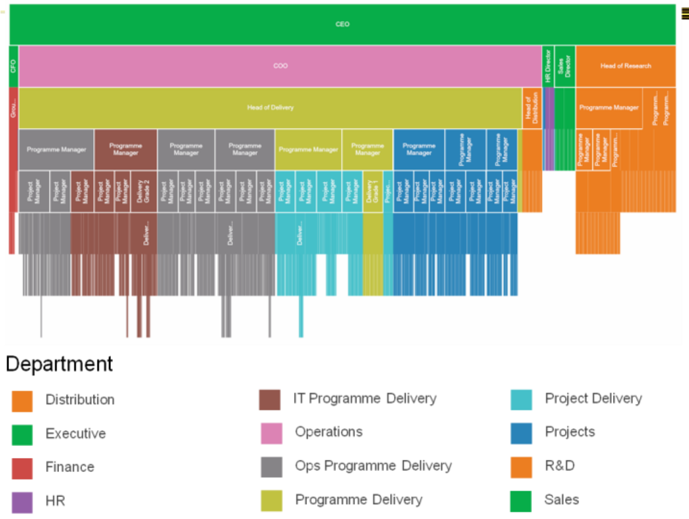




One example: "Icicle plot"

http://blog.orgvue.com/ideal-span-control-see-intervene/

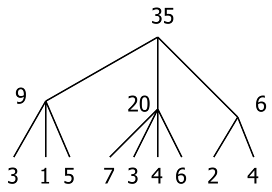
Icicle Plot



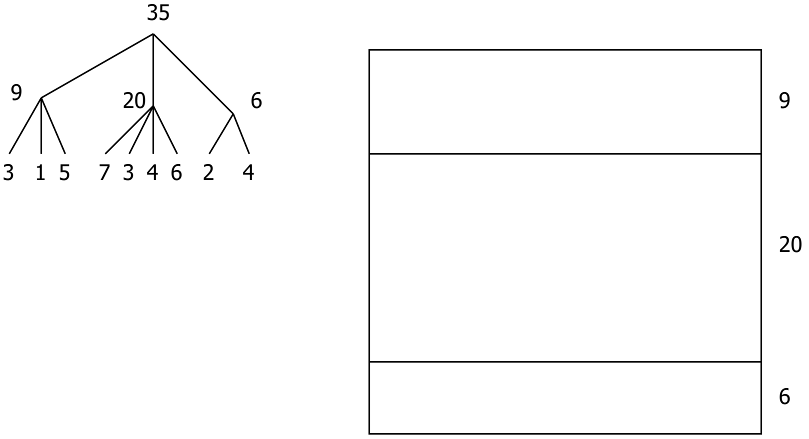
Treemap

- 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

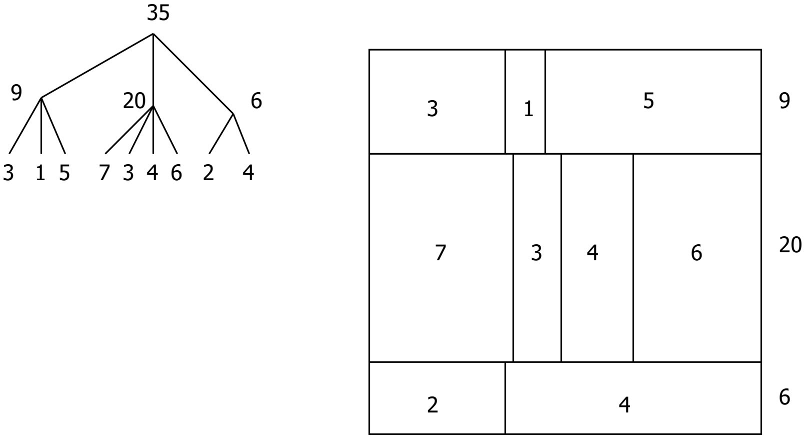
Example



Example

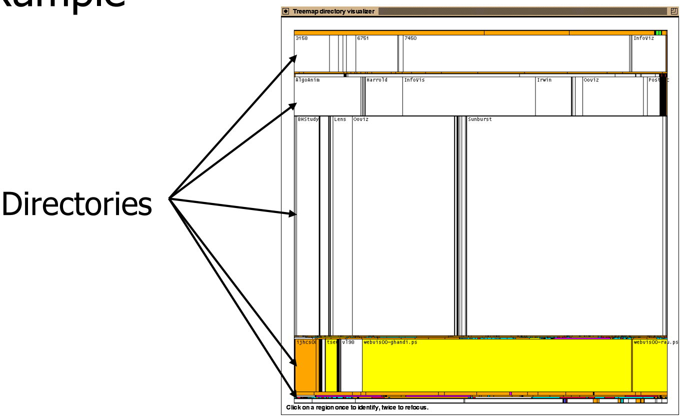


Example



Treemap

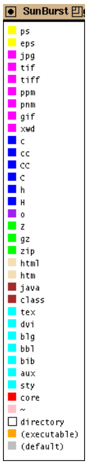
- Example



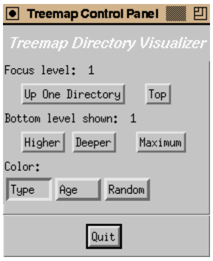
Directories

Click on a region once to identify, twice to refocus.

Treemap Example



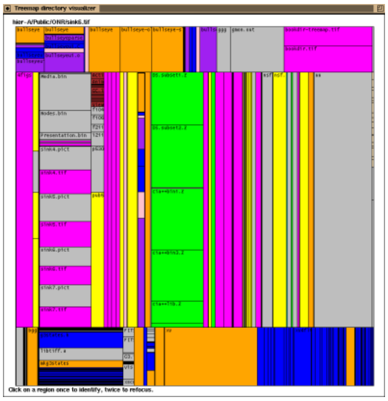
🟨	ps
🟨	eps
🟪	jpg
🟪	tif
🟪	tiff
🟪	ppm
🟪	pnm
🟪	gif
🟪	xwd
🟦	c
🟦	cc
🟦	cc
🟦	c
🟦	h
🟦	H
🟪	o
🟩	z
🟩	gz
🟩	zip
▧	html
▧	htm
🟫	java
🟫	class
▦	tex
▦	dvi
▦	blg
▦	bbl
▦	bib
▦	aux
▦	sty
🟥	core
▧	~
□	directory
🟧	(executable)
▩	(default)



Focus level: 1

Bottom level shown: 1

Color:



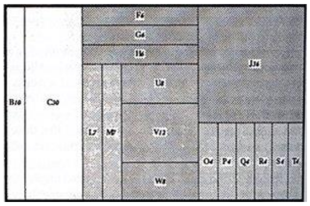
Click on a region once to identify, twice to refocus.

Old one I built for our Sun workstations

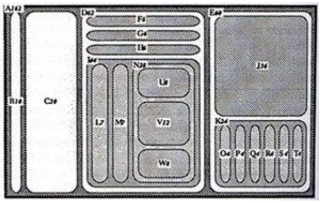
Treemap Algorithm

```
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
}
```

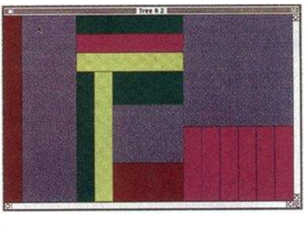
Nested vs. Non-nested

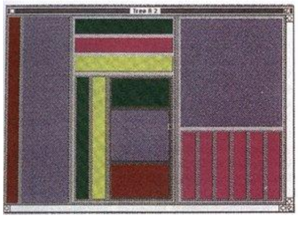


Non-nested Tree-Map



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
- Explain general limitations of node-link approach
- Understand treemap algorithm
  - Be able to draw slice-and-dice treemap given a hierarchy

Upcoming

- Hierarchies 2 – More on Space-filling reps
  - Prep: Johnson & Shneiderman article

- Lab 7 – D3 Animation & transition 1