networks & hierarchies

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http://www.caida.org/tools/visualization/walrus/
Overview

A) Hierarchical visualization techniques

B) Visualizing networks & hierarchies

[Keim, 2001]
Part A

hierarchical visualization techniques
Problem

Data
multivariate data (e.g., Movie DB, Car dataset)

Presentation space
display dimensionality constrained to 2D or 3D

Task
meaningful representation of all variables within a single plot

How?
Example

4 variables:
longitude
latitude
ore grade
depth
Dimensional Stacking

[LeBlance et al. 1990]
Dimensional Stacking

Partitioning of the n-dim. attribute space in 2-dim. subspace, which are “stacked” into each other

Partitioning of the attribute value ranges into classes

Important attributes should be used on the outer levels

Adequate especially for data with **ordinal** attributes of **low** cardinality
Dimensional Stacking

Given

Variables $V_1 - V_m$

Power of the Domain: Cardinalities $K_1 - K_m$

Process

2 Variables $V_i, V_k \rightarrow K_i * K_k$ Grid
Example

Variables: $V_1$-$V_6$
Cardinalities: $K_1=4, K_2=2, K_3=2, K_4=3, K_5=3, K_6=2$
Pairs $P_1(V_1, V_3), P_2(V_4, V_5), P_3(V_2, V_6)$
Example - Combination: 4, 2, 3, 2, 2, 2
Worlds-within-Worlds

Partitioning of the n-dim. Space into 3-dim. Subspace

Nested 3-dim coordinates

3-dim coordinate = one property

Selected points --> new coordinates’ system
Worlds-within-Worlds

[Feiner & Besherss 1990]
Part B
visualizing networks & hierarchies
Illustrating example

Data: file system

Problem/task: disk is full --> free some space

How?
Tool?
Visualization?

Visualization Design

- **Data**
- **Task**
- **User**

**Representation & Interaction**

- **Expressiveness**
- ** Appropriateness**
- ** Effectiveness**
Basic Data Characteristics

network / graph
items (nodes) that have relationships (edges)
\[ G := \{N, E\} \]
no inherent hierarchical structure

hierarchy / tree
parent - child relationships
every node has at most one parent
exactly one root node
mostly non-leaf nodes are containers only

hierarchical network
Network examples

Airline map:=(Cities, Flights)

Team:=(People, Relationships)

Molecule:=(Atoms, Bonds)
Edges

- undirected / directed / mixed
- weighted / signed / labeled
- simple / multiplex
- certainty / probabilistic
- multi-modal

Graph theory
Multi-modal example :: Blogosphere

Bloggers know each other + Blogs link each other + Bloggers write blogs
(simple, undirected) (multiplex, directed) (bipartite)

= Blogosphere structure
(multiplex, mixed, multi-modal)
Basic Data Characteristics

Topology
- Nodes
- Edges

Node attributes

Edge attributes

*Node measures (derived)*

*Edge measures (derived)*

Network measures (derived)

Size / number of elements (complexity)

Tree: connected, unweighted, acyclic graph
Hierarchies

Hierarchical data are **very common**

Hierarchies are one of the most prevalent **organizing principles** for coping with information

application examples

organizations, org-charts, taxonomies, table of contents, sitemaps, file system, genealogies, ...
Tasks

What are the tasks the users want to perform? What are users’ goals?

- reducing complexity
- categorization - hierarchies (expand/collapse)
- overview of topology
- distribution
- examine relationships
- examine paths
- examine elements
- identify
- locate
- distinguish
- relate
- compare

specific

general
Part B.1
visualizing networks
Visual Encodings for Networks

connection / node-link

- convention: root mostly on top, leaves on bottom
- pros: popular, well-known
- cons: occlusion, edge crossing, scales badly

adjacency matrices

- graph as table
- nodes as rows/columns
- edges as table cells
- pros: large graphs, no occlusion, no edge crossing
- cons: no path finding
FAS.research

Social Network Analysis

http://www.fas.at/
Issues for representation

Positioning of nodes
   layout

Representation of edges
e.g., weights

Size / complexity
   High number of nodes & edges

Labeling

Interaction with graphs
Layout: Guiding criteria

drawing conventions
   edges only straight lines, rectilinear lines, or polygonal lines
   placing nodes on a fixed grid
   having all sibling nodes share the same vertical position

constraints
   particular node in the center
   group of nodes close to each other
   links from top to bottom or left to right

aesthetics
   minimize node overlap
   uniform edge length
   minimize line crossings
   maintain pleasing aspect ratio
   minimize total area of drawing
   minimize total length of edges
   minimize number of bends in edges
   minimize the number of distinct angles or curvatures
   symmetry
Layout

Multi-dimensional scaling (MDS)

Spring embedder

Force directed

  Two forces:
    spring between; electrical repulsion

Rectilinear

Hierarchical

Radial

HV layout (horizontal vertical)

Images:
- Jeffrey Heer, Tree Visualization, SIMS 247: Information Visualization and Presentation, 2005.
- Max Baker, Netdisco, http://netdisco.net/
Issues for representation

Positioning of nodes
layout

Representation of edges
e.g., weights

Size / complexity
High number of nodes & edges

Labeling

Interaction with graphs
Large graph

Image by C. Ware from [Görg et al., 2007]

3200 nodes
force-directed layout
Size / complexity

high number of nodes & edges

reducing complexity

edges - link reduction
  e.g., visualizing only the edges that have weights above a certain value
  eliminate redundant edges and maintain the most significant links
  minimum spanning trees (MST)
  pathfinder network scaling (PFNET)

nodes - node reduction
  clustering

preservation of global structure
Node-only
Link-only
Clustering

Image by P. Eades from [Görg et al., 2007]
Issues for representation

Positioning of nodes
   layout

Representation of edges
   e.g., weights

Size / complexity
   High number of nodes & edges

Labeling

Interaction with graphs
Labeling

non-trivial problem

non-overlapping

NP-hard problem

Image from [Ward et al., 2010]
Issues for representation

Positioning of nodes
  layout

Representation of edges
  e.g., weights

Size / complexity
  High number of nodes & edges

Labeling

Interaction with graphs
Interaction with graphs

- move nodes
- zoom & pan
- hide or show edges
- selection
- focus+context

Video
CGV
Part B.2
visualizing hierarchies
Visual Encodings for Hierarchies

**indentation**
- representation of hierarchy level via indentation
- focus on linear structure
- pros: well-known, simple, text-based
- cons: aspect ratio

**connection / node-link**
- convention: root mostly on top, leaves on bottom
- pros: popular, well-known
- cons: scales badly (space usage, aspect ratio)

**containment**
- summed values
  - propagation through hierarchy
- space-filling graphs
- pros: no occlusion, no edge crossing
- cons: labeling, reading order
Interaction

why?

aspect ratio
large information space
do not fit onto display space
Problem: large structures that don't fit on a single view/screen

expand / collapse

navigate

focus + context

see upcoming lecture for details
Demo application: Hierarchical Visualization System (HVS)

Acedemic prototype

Graz University of Technology, Institute for Information Systems and Computer Media (IICM)

Lead by Prof. Keith Andrews

Extensible InfoVis toolkit for visualizing hierarchically structured data

Visualizations provided:
- Tree View
- Information Pyramids
- Hyperbolic Tree
- Magic Eye
- InfoLens
- TreeMaps
- Sunburst

[Andrews, 2005]
Indented Lists

representation of hierarchy
level via indentation

focus on linear structure
SpaceTree / DOI Tree

http://www.cs.umd.edu/hcil/spacetree/

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

[Plaisant et al., 2002]

[Heer and Card, 2004]
Cone Trees

[Robertson, Mackinlay, Card 1991]

Figure 5: A Standard 2D Cone Tree.

Figure 9: A 3D Cone Tree.
Cone Trees vs. Cam Trees

Vertical (Cone Tree) vs. Horizontal (Cam Tree)

Shadows provide 2D structure
Cone Trees

Important: Interaction!

[Robertson, Mackinlay, Card 1991]
Starlight – File System

(Pacific Northwest National Laboratory – USA)
Balloon Trees

Flattened cone trees

[Herman, Melancon, and Marshall, 2000]
Hyperbolic Trees

Nodes are placed on hyperbolic geometry (inside of a sphere)

Projection into 2D

F+C

[Munzner, 1998]
Botanical Visualization of Huge Hierarchies

[Holton’s “Strang Modell”]

Node and link diagram

Figure 10. Complete hard disk with $\alpha = 45$ and $\beta = 360/\varphi$. 

[Kleiberg, van de Wetering & van Wijk, 2001]
Botanical Visualization

[Figures 12 and 13: Visualizations of Unix home-directories, with accompanying text]

Alternative 3D Visualization to Big Hierarchies

Branches Clash Seldom, Even Though no Particular Algorithm is Included

Adapted Phi-Balls are Appropriate for Big Files
Containment

[Shneiderman 1992; Johnson, 1993]
Venn-Diagram --> Treemaps

 Nested Treemap

[Shneiderman 1992; Johnson, 1993]
Example: File Structure to Tree

File System:
3 Folders
6 Files

1) Root -> whole Screen
Example: File Structure to Tree

File System:
3 Folders
6 Files

2) Cutting - according to the size
(30% and 70% of the space)
Example: File Structure to Tree

File System:
3 Folders
6 Files

3) Iteration: folder and subfolder
Example: File Structure to Tree

File System:
- 3 Folders
- 6 Files

One Solution
**Treemap:** View Large Trees with Node Values

- Space filling
- Space limited
- Color coding
- Size coding
- Requires learning

TreeViz (Mac, Johnson, 1992)
NBA-Tree (Sun, Turo, 1993)
Winsurfer (Teittinen, 1996)
Diskmapper (Windows, Micrologic)
Treemap3 (Windows, UMd, 2001)

http://www.cs.umd.edu/hcil/treemap/

(Shneiderman, *ACM Trans. on Graphics*, 1992)
Finance Analysis
Gainers (bright green)

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

Losers (bright red)

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

http://newsmap.jp
TreeMaps Summary

Turning a tree into a planar space-filling map

Capacity to see tens of thousands of nodes in a fixed space and find large areas or duplicate directories is very powerful

Treemap algorithms
  BinaryTree
  Ordered
  SliceAndDice
  Squarified
  Strip
  Beamtree

Map of the market [Wattenberg, smartmoney.com]
Icicle Trees

Tree levels side by side horizontal / vertical

Subdivision by size

Sunburst Tree

Radial version of icicle trees

Interaction facilities to navigate / zoom

Sunburst Tree: Focus + Context

Selected element is redrawn and expanded in outer semi-circle

[Andrews, 2005]
Bertin’s taxonomy

[Bertin, 1983]
Summary

Hierarchical visualization techniques
Re-usage of display dimensions

Visualization of networks & hierarchies
Common data structure in many domains
Connection & containment

Representations
Indented lists
Node-Link diagrams
Containment diagrams
Adjacency matrices
Useful Stuff

Treemap

HCIL Treemap Browser <http://www.cs.umd.edu/hcil/treemap>
Map of the Market <http://www.smartmoney.com/marketmap>
Newsmap <http://newsmap.jp>
The Hive Group <http://www.hivegroup.com>
HyperTree Java Library <http://hypertree.sourceforge.net/>

SpaceTree <http://www.cs.umd.edu/hcil/spacetree>

Tree Visualizer <http://www.randelshofer.ch/oop/treeviz/index.html>

VisualComplexity.com <http://www.visualcomplexity.com>

ManyEyes <http://www.many-eyes.com>

Search Engines / Clustering

Clusty <http://clusty.com>
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Literature

