Leibniz Universität Hannover

# Mensch-Computer-Interaktion 2

## Visualization

(based on slides by Marti Hearst and Jeff Heer)

Human-Computer Interaction Group

Prof. Dr. Michael Rohs
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# Lectures

| Session | Date | Topic | |
|---|---|---|---|
| 1 | 6.4. | Introduction | |
| 2 | 13.4. | Interaction elements | GUI toolkits, interaction techniques |
| 3 | 20.4. | Event handling | |
| 4 | 27.4. | Scene graphs | |
| 5 | 4.5. | Interaction techniques | |
| | 11.5. | no class (CHI) | |
| | 18.5. | no class (spring break) | |
| 6 | 25.5. | Experiments | design and analysis of experiments |
| 7 | 1.6. | Data Analysis | |
| 8 | 8.6. | Data Analysis | |
| 9 | 15.6. | Modeling interaction | |
| 10 | 22.6. | Visualization | current topics beyond-desktop UIs |
| 11 | 29.6. | Visualization | |
| 12 | 6.7. | Computer vision for interaction | |
| 13 | 13.7. | Computer vision for interaction | |

Klausur:
28.7.2016
8-11 Uhr
HG E214

# What is Information Visualization?

Visualize: to form a mental image or vision of ...

Visualize: to imagine or remember as if actually seeing

*American Heritage dictionary, Concise Oxford dictionary*

# What is Information Visualization?

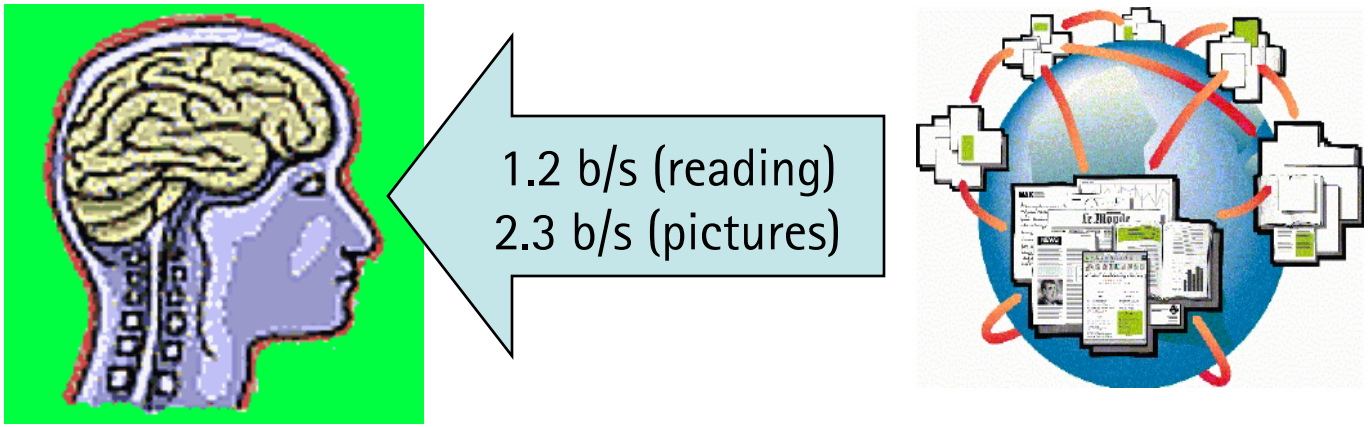
"Transformation of the symbolic into the geometric"
(McCormick et al., 1987)

"finding the artificial memory that best supports our natural means of perception."
(Bertin, 1983)

"The depiction of information using spatial or graphical representations, to facilitate comparison, pattern recognition, change detection, and other cognitive skills by making use of the visual system"
(Hearst 03)

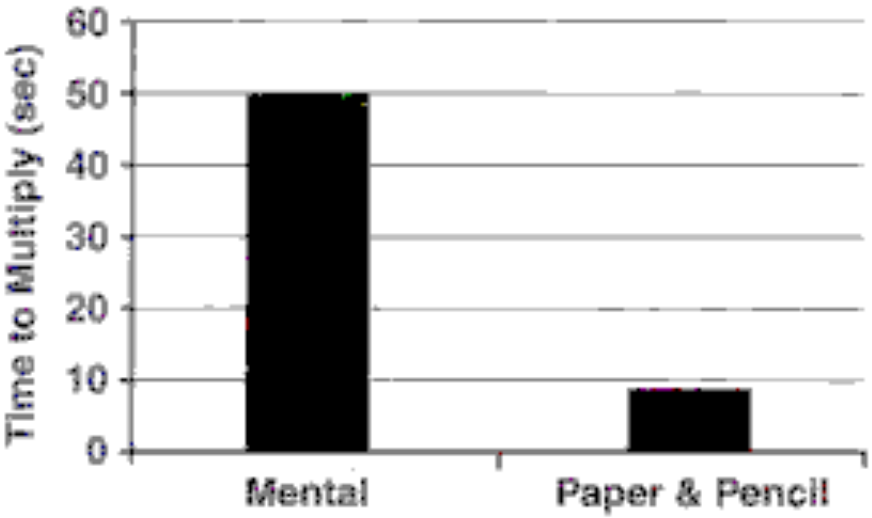
# Information Visualization

Leverage highly-developed human visual system
to achieve rapid uptake of abstract information.



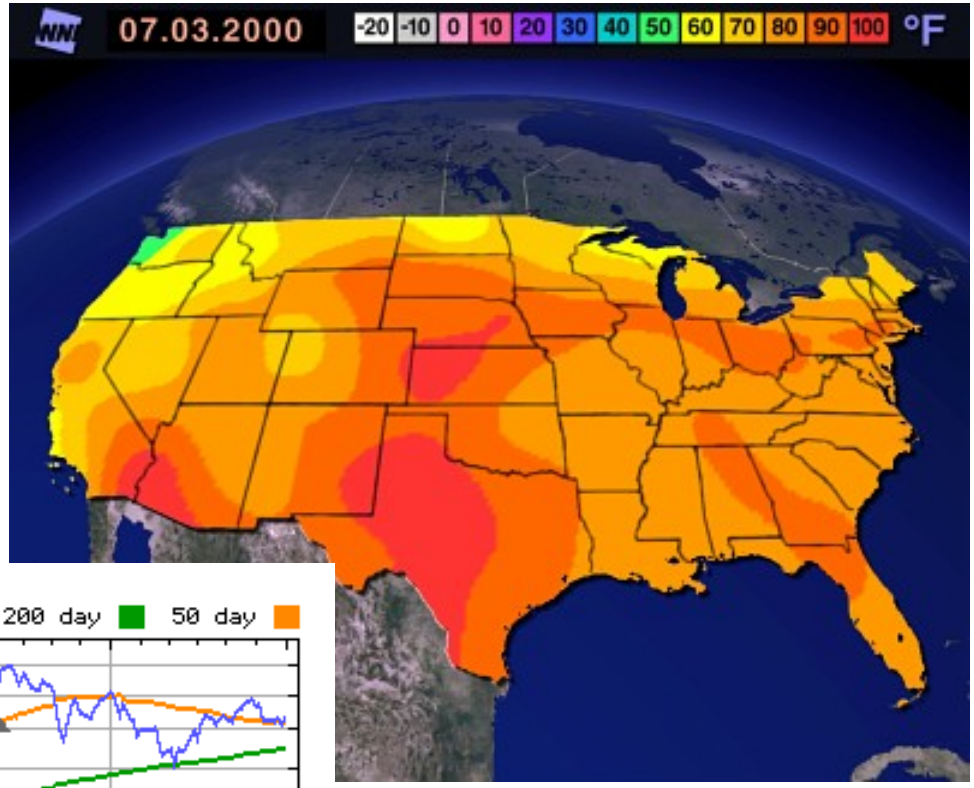

(slide PARC User Interface Research Group)

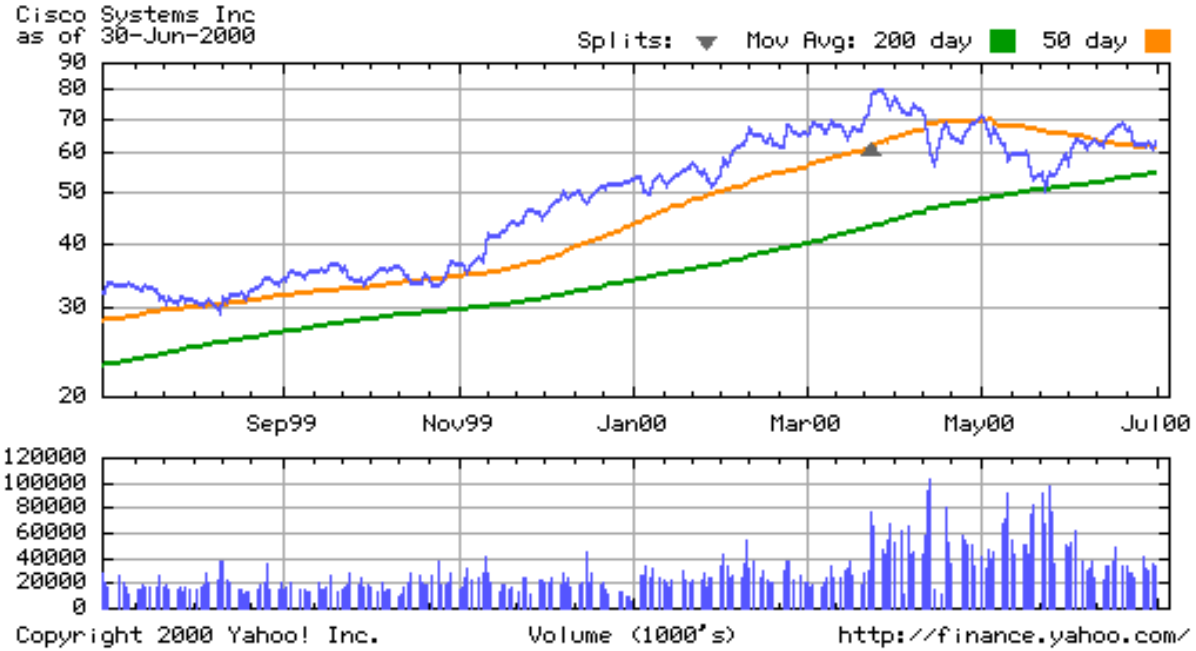
# Visual Aids for Thinking




- We build external representations to amplify cognition
- Example: Multiplication (Card, Moran, Shneiderman)
  - In your head, multiply 35 x 95
  - Now do it on paper
  - People are 5 times faster with the visual aid

# The Power of Info. Visualization




Images from yahoo.com

# The Power of Visualization

1. Start out going Southwest on ELLSWORTH AVE
   Towards BROADWAY by turning right.
2: Turn RIGHT onto BROADWAY.
3. Turn RIGHT onto QUINCY ST.
4. Turn LEFT onto CAMBRIDGE ST.
5. Turn SLIGHT RIGHT onto
   MASSACHUSETTS AVE.
6. Turn RIGHT onto RUSSELL ST.

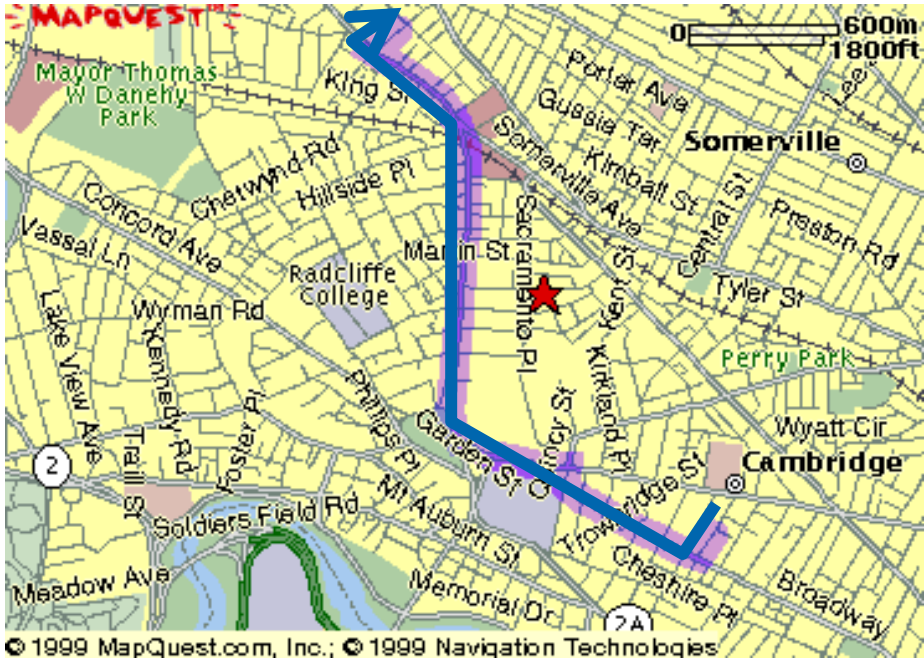


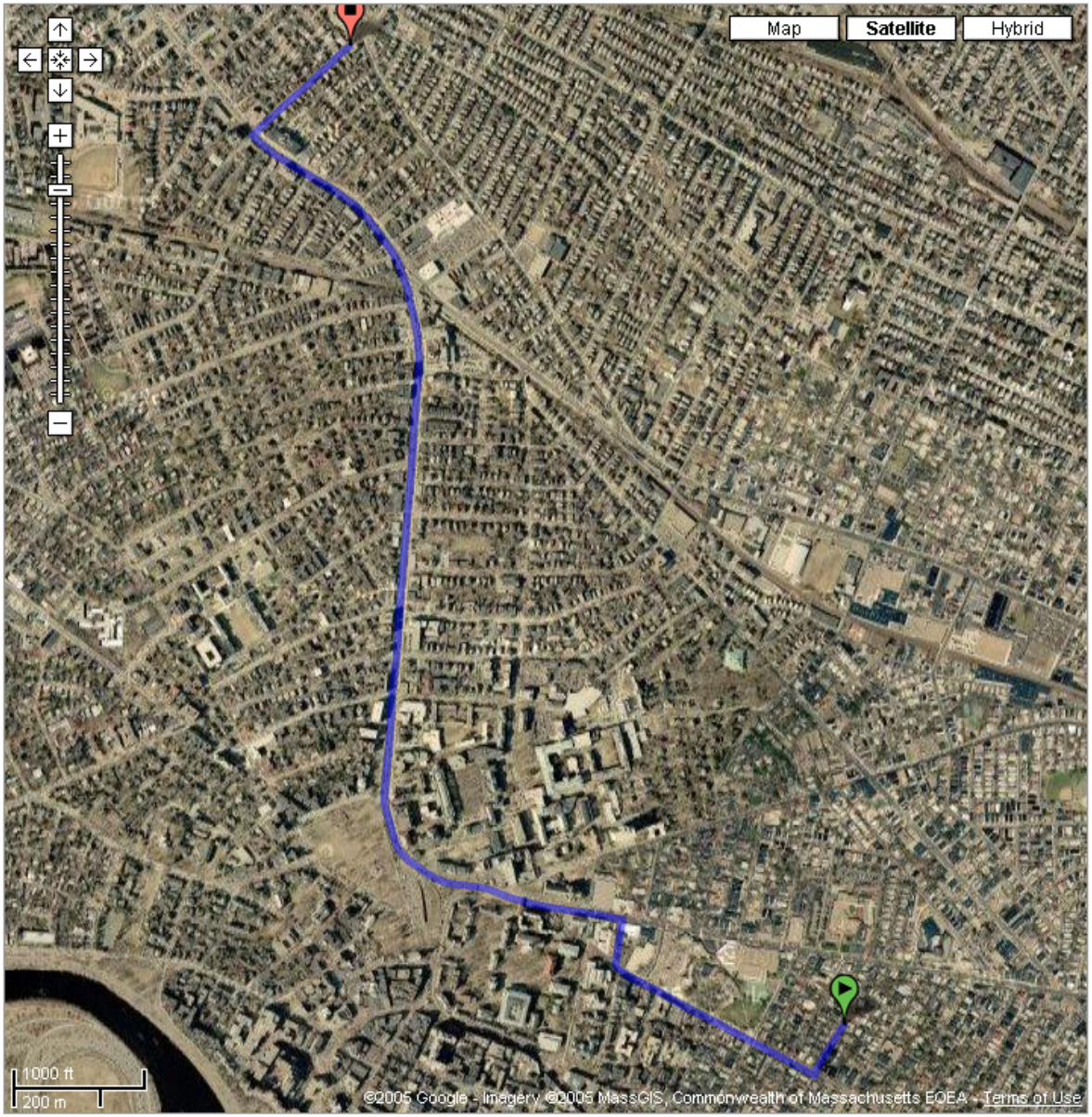

Image from mapquest.com

Maps Local Search **Directions**

17 Ellsworth Ave, Cambridge, MA 02139 ⇄ 77 Russell St, Somerville, MA 02144 Search Help

Start address End address

## Maps




Print Email Link to this page

| | |
|---|---|
| Start address: | 17 Ellsworth Ave<br>Cambridge, MA 02139 |
| End address: | 77 Russell St<br>Somerville, MA 02144 |
| Distance: | 2.2 mi (about 3 mins) |

Reverse directions

| | |
|---|---|
| 1. | Head **southwest** from **Ellsworth Ave** - go **0.1 mi** |
| 2. | Turn **right** at **Broadway** - go **0.3 mi** |
| 3. | Turn **right** at **Prescott St** - go **0.1 mi** |
| 4. | Turn **left** at **Cambridge St** - go **0.3 mi** |
| 5. | Bear **right** at **Massachusetts Ave** - go **1.2 mi** |
| 6. | Turn **right** at **Russell St** - go **0.2 mi** |

These directions are for planning purposes only. You may find that construction projects, traffic, or other events may cause road conditions to differ from the map results.

Map data ©2005 NAVTEQ™, Tele Atlas

# Visualization for Problem Solving

Mystery: What is causing a cholera epidemic in London in 1854?

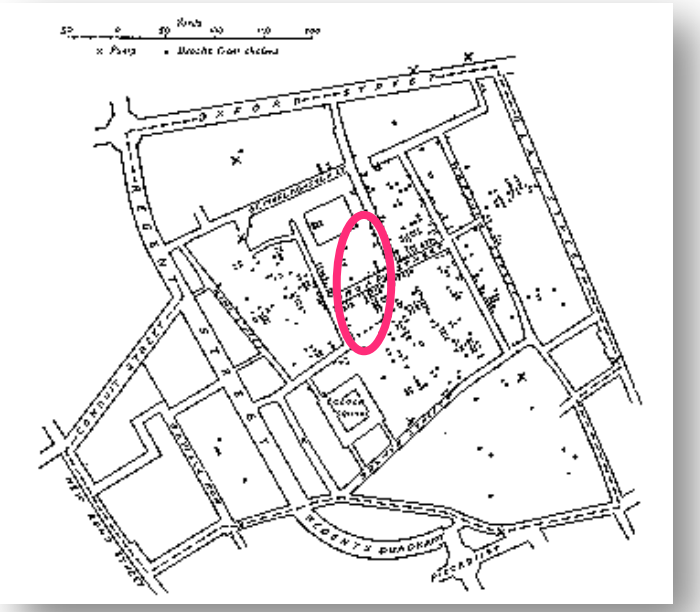
# Visualization for Problem Solving

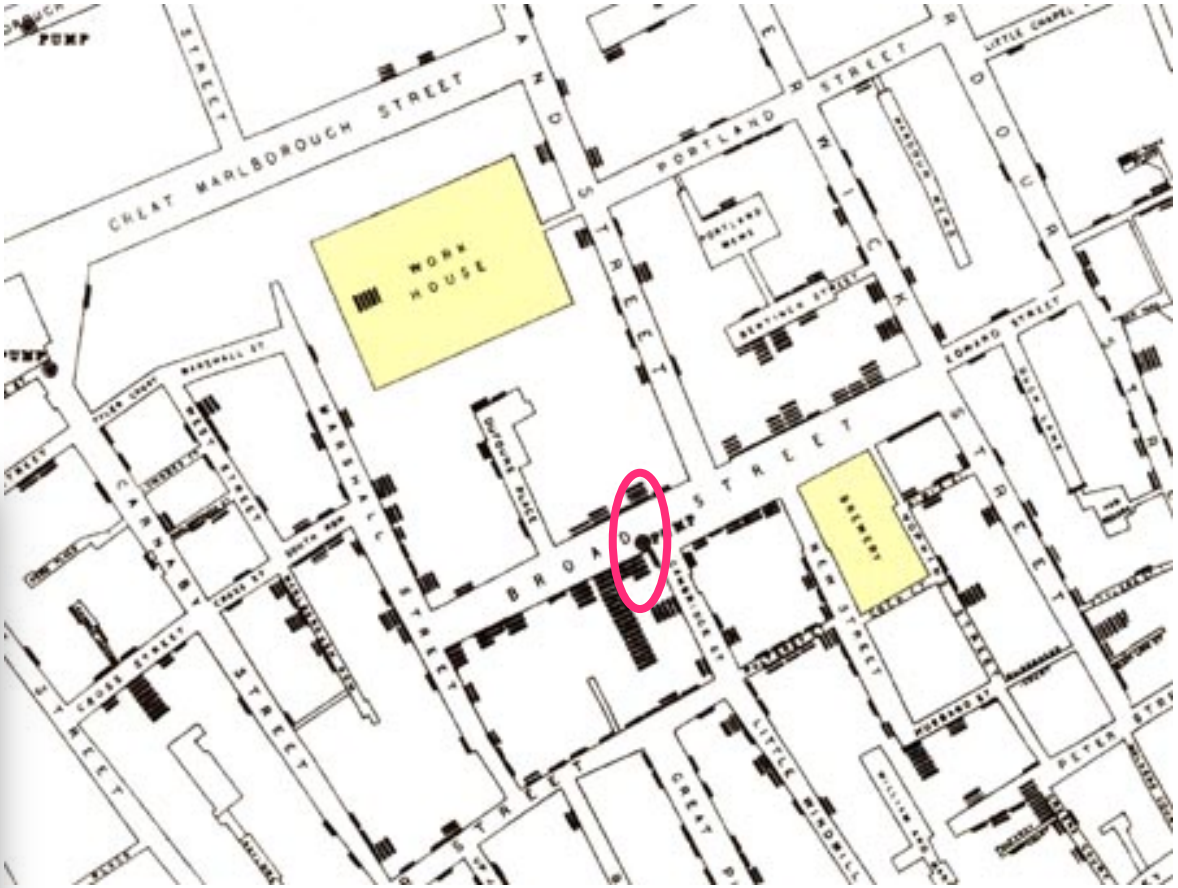
Illustration of John Snow's deduction that a cholera epidemic was caused by a bad water pump, circa 1854.

Horizontal lines indicate location of deaths.

From Visual Explanations by Edward Tufte, Graphics Press, 1997

# Visualization for Problem Solving






From Visual Explanations by Edward Tufte, Graphics Press, 1997

# Visualization for Eliciting Knowledge from Data

- Which state has highest income?
- Relationship between income and education?
- Outliers?

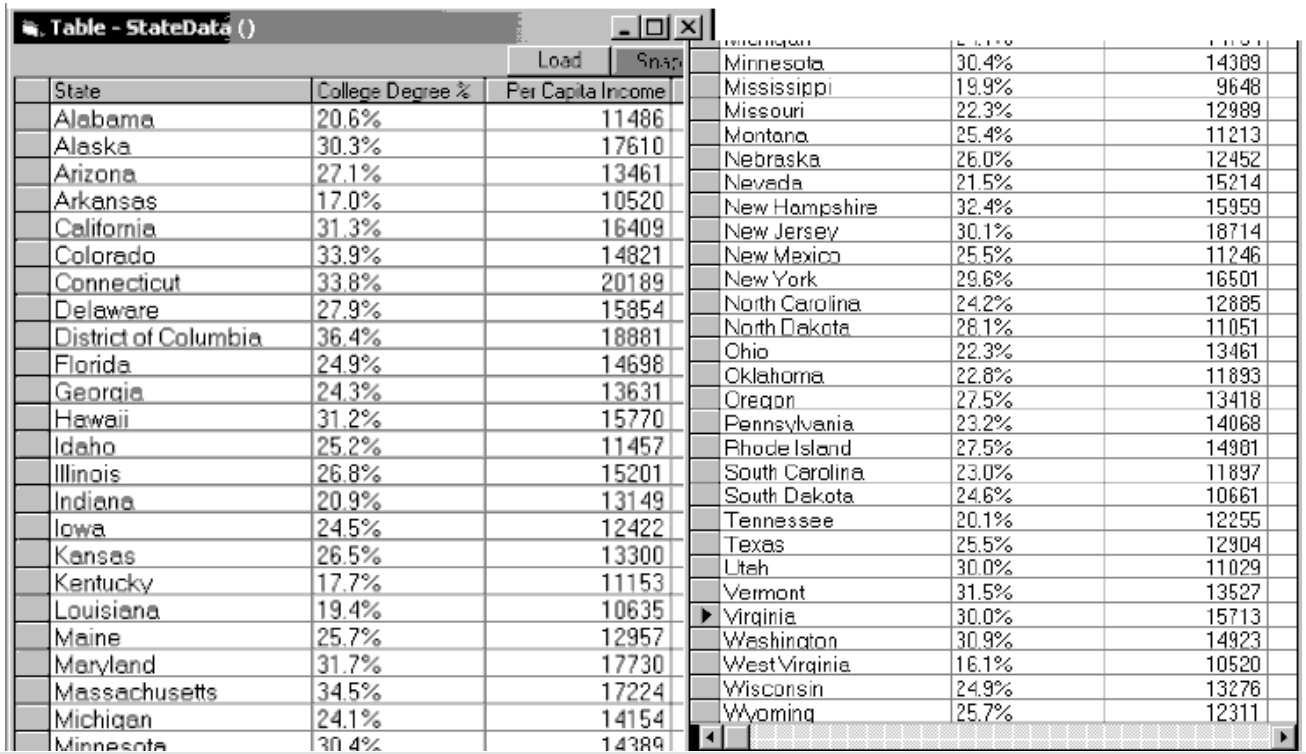
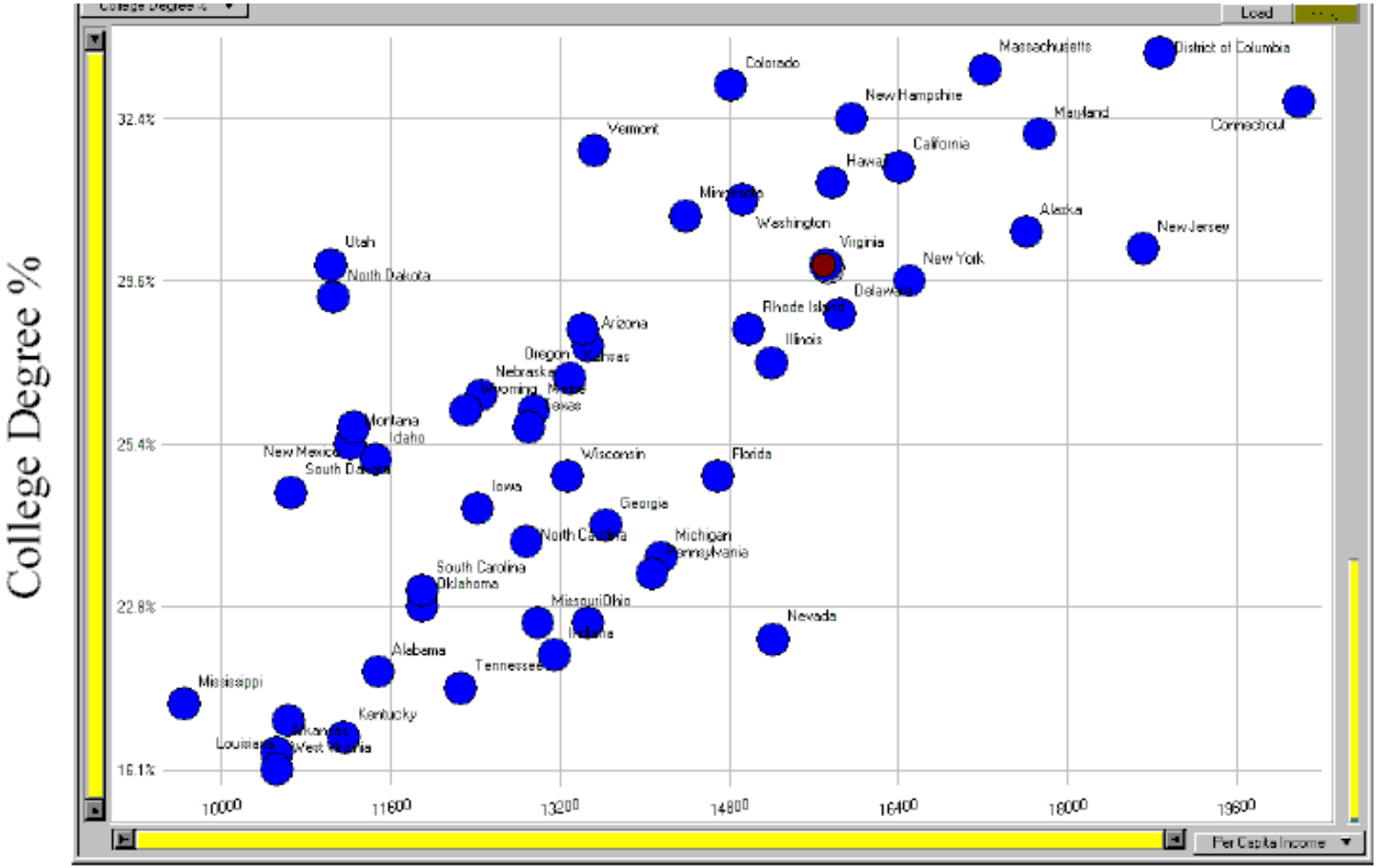


Table - StateData ()

Load | Snap

| State | College Degree % | Per Capita Income |
|---|---|---|
| Alabama | 20.6% | 11486 |
| Alaska | 30.3% | 17610 |
| Arizona | 27.1% | 13461 |
| Arkansas | 17.0% | 10520 |
| California | 31.3% | 16409 |
| Colorado | 33.9% | 14821 |
| Connecticut | 33.8% | 20189 |
| Delaware | 27.9% | 15854 |
| District of Columbia | 36.4% | 18881 |
| Florida | 24.9% | 14698 |
| Georgia | 24.3% | 13631 |
| Hawaii | 31.2% | 15770 |
| Idaho | 25.2% | 11457 |
| Illinois | 26.8% | 15201 |
| Indiana | 20.9% | 13149 |
| Iowa | 24.5% | 12422 |
| Kansas | 26.5% | 13300 |
| Kentucky | 17.7% | 11153 |
| Louisiana | 19.4% | 10635 |
| Maine | 25.7% | 12957 |
| Maryland | 31.7% | 17730 |
| Massachusetts | 34.5% | 17224 |
| Michigan | 24.1% | 14154 |
| Minnesota | 30.4% | 14389 |
| Mississippi | 19.9% | 9648 |
| Missouri | 22.3% | 12989 |
| Montana | 25.4% | 11213 |
| Nebraska | 26.0% | 12452 |
| Nevada | 21.5% | 15214 |
| New Hampshire | 32.4% | 15959 |
| New Jersey | 30.1% | 18714 |
| New Mexico | 25.5% | 11246 |
| New York | 29.6% | 16501 |
| North Carolina | 24.2% | 12885 |
| North Dakota | 28.1% | 11051 |
| Ohio | 22.3% | 13461 |
| Oklahoma | 22.8% | 11893 |
| Oregon | 27.5% | 13418 |
| Pennsylvania | 23.2% | 14068 |
| Rhode Island | 27.5% | 14901 |
| South Carolina | 23.0% | 11897 |
| South Dakota | 24.6% | 10661 |
| Tennessee | 20.1% | 12255 |
| Texas | 25.5% | 12904 |
| Utah | 30.0% | 11029 |
| Vermont | 31.5% | 13527 |
| Virginia | 30.0% | 15713 |
| Washington | 30.9% | 14923 |
| West Virginia | 16.1% | 10520 |
| Wisconsin | 24.9% | 13276 |
| Wyoming | 25.7% | 12311 |

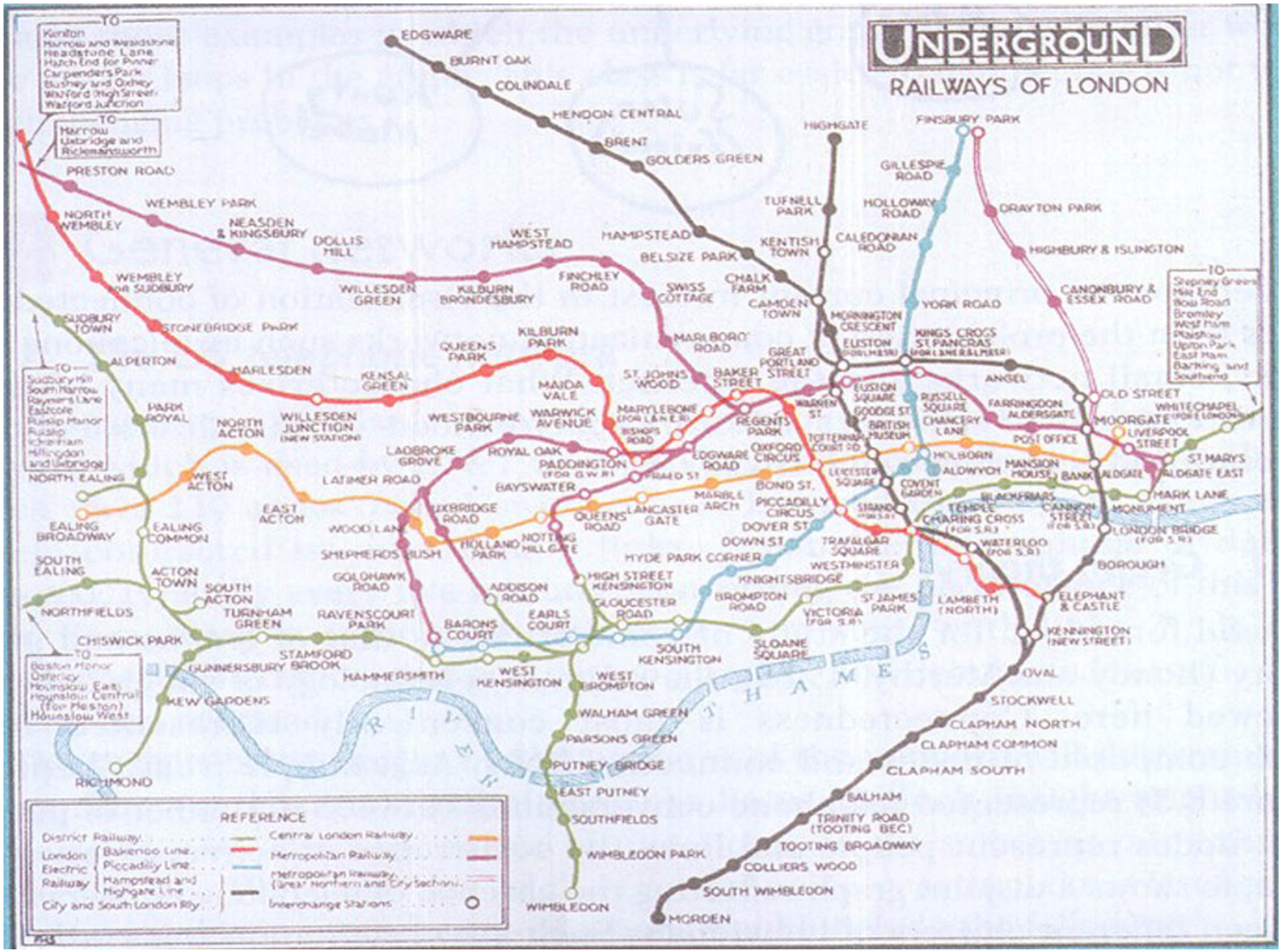
# Visualization for Eliciting Knowledge from Data



# Visualization for Clarification

- London subway map example
- Abstract away details for easier understanding


# London Underground Map 1927



# London Underground Map 1990s




From http://www.ideography.co.uk/

# Two Different Primary Goals of Visualization

Explore/Calculate

- Analyze
- Reason about Information

Communicate

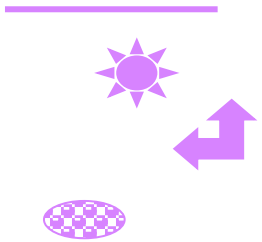
- Explain
- Make decisions
- Reason about Information

# Goals of Information Visualization

- Visualization should
  - Make large datasets coherent
    - Present huge amounts of information compactly
  - Present information from various viewpoints
  - Present information at several levels of detail
    - from overviews to fine structure
  - Support visual comparisons
  - Tell stories about the data

# Human Perceptual Facilities

- Use the eye for pattern recognition; people are good at
  - scanning
  - recognizing
  - remembering images
- Graphical elements facilitate comparisons via
  - length
  - shape
  - orientation
  - texture



- Animation shows changes across time
- Color helps make distinctions
- Aesthetics make the process appealing

# Case Study: The Journey of the TreeMap

- The TreeMap (Johnson & Shneiderman '91)
- Idea:
  - Show a hierarchy as a 2D layout
  - Fill up the space with rectangles representing objects
  - Nested rectangles indicated levels of hierarchy
  - Size on screen indicates relative size of underlying objects

# Case Study: The Journey of the TreeMap

(Johnson & Shneiderman '91)

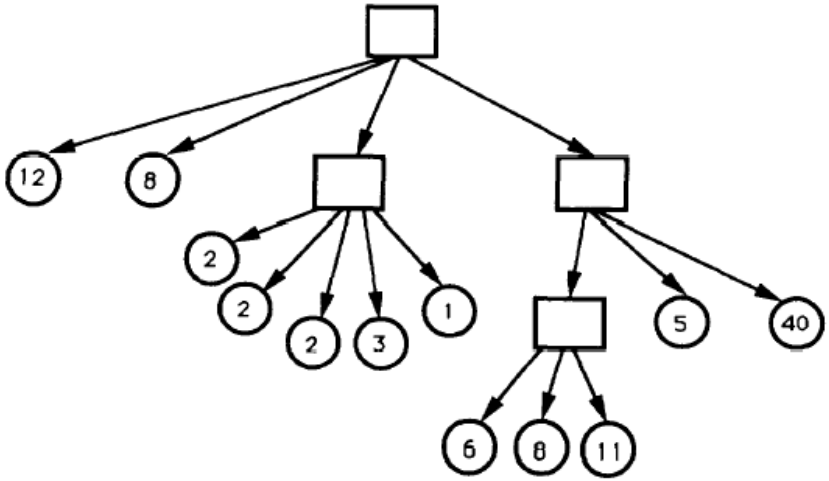



Fig. 1. Typical 3-level tree structure with numbers indicating size of each leaf node.

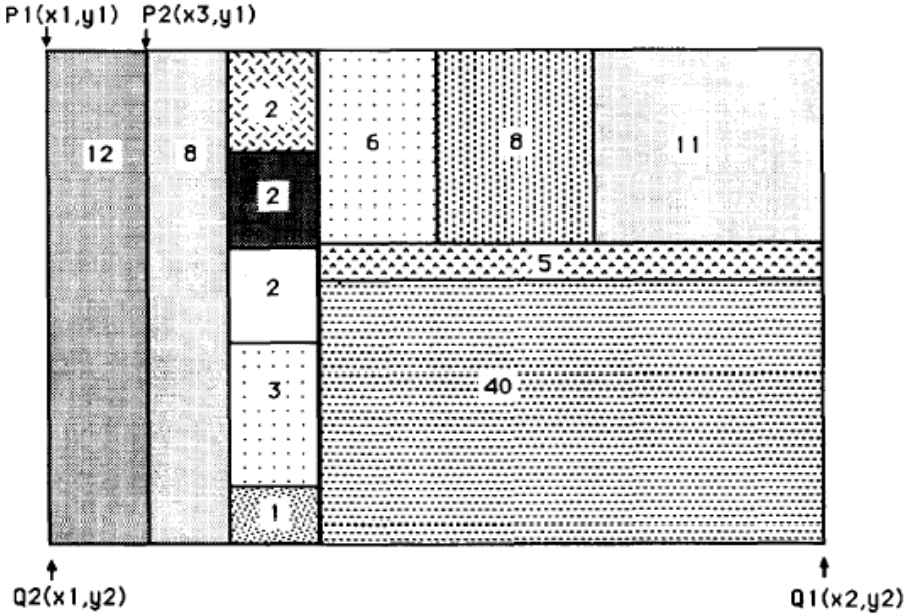



Fig. 2. Tree-map of Figure 1.

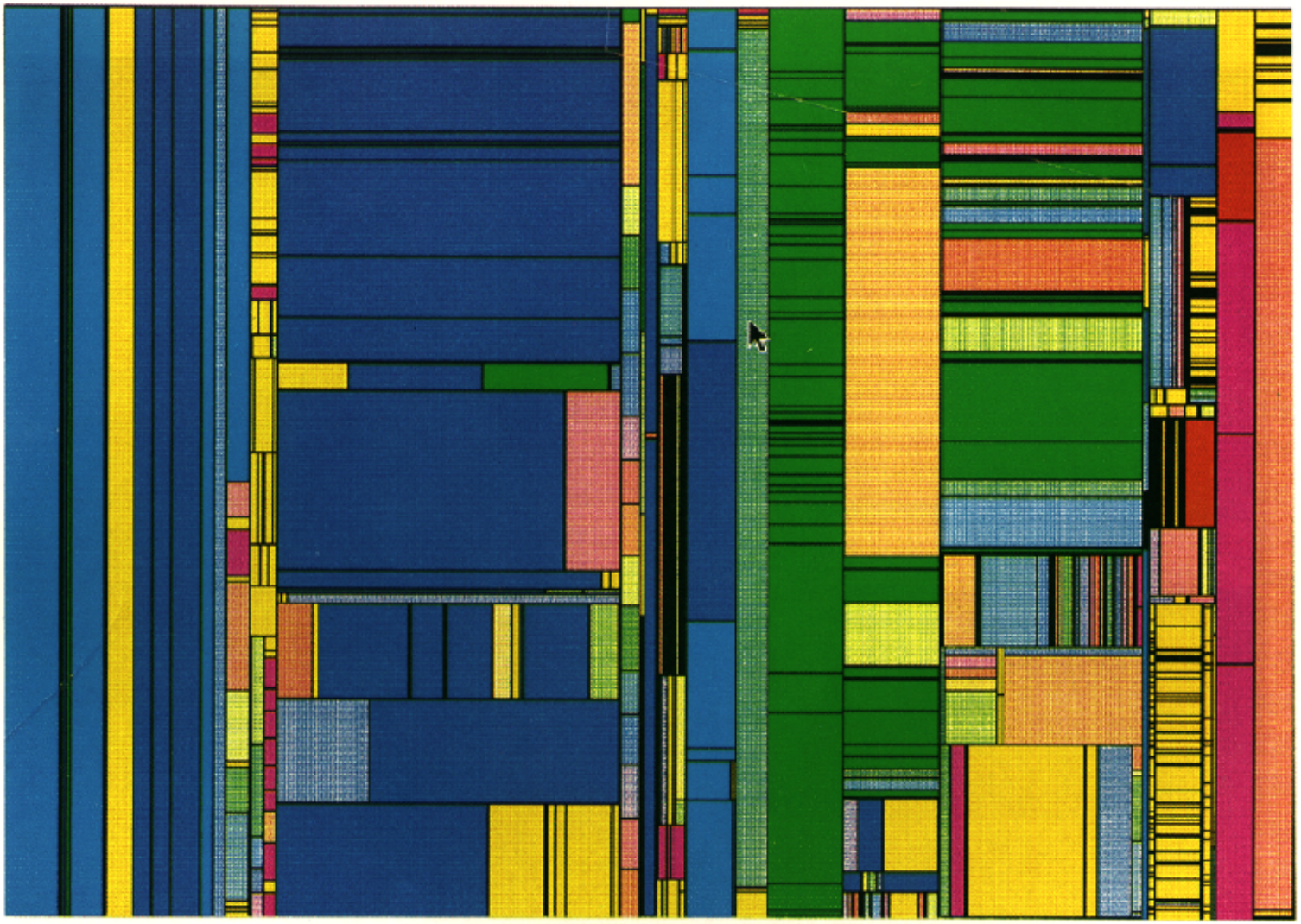
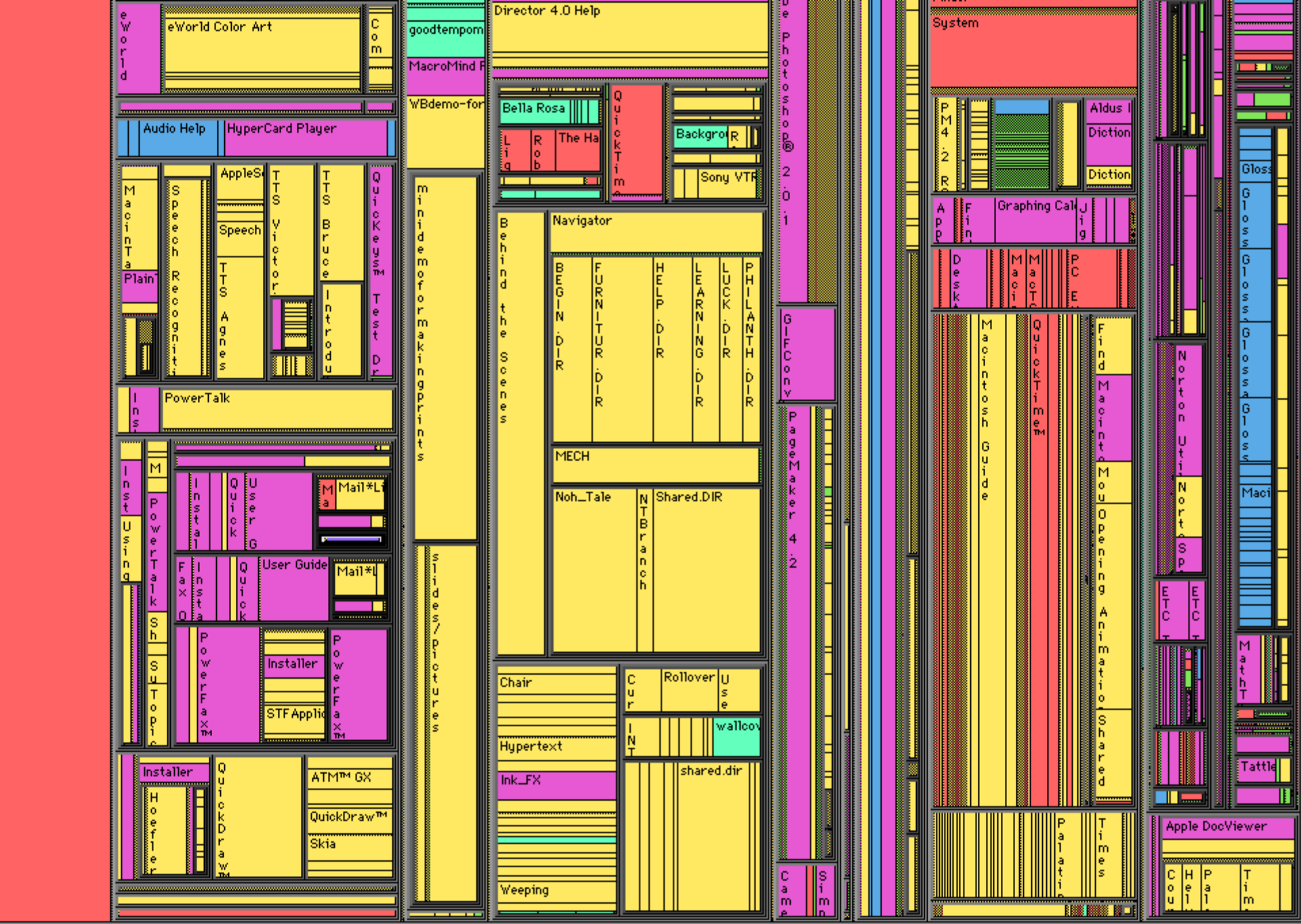


Fig. 4. 850 files at four levels with color coding by tile type. File name pops up when cursor rests on a file.


eWorld Color Art
Director 4.0 Help
System
Audio Help
HyperCard Player
PowerTalk
Navigator
BEGIN.DIR
FURNITUR.DIR
HELP.DIR
LEARNING.DIR
LUCK.DIR
PHILANTH.DIR
MECH
Noh_Tale
NTBranch
Shared.DIR
Behind the Scenes
Chair
Hypertext
Ink_FX
Weeping
shared.dir
Installer
ATM™ GX
QuickDraw™
Skia
Hoefler
Graphing Calc
Macintosh Guide
QuickTime™
Apple DocViewer
Palatino
Times
Bella Rosa
Sony VTR
Speech Recognition
Speech
TTS Victor
TTS Bruce
TTS Agnes
Introdu
QuickKeys™ Test Dr
Mail*Li
User Guide
PowerFax™
STF Applic
goodtempom
MacroMind F
WBdemo-for
minidemoformakingprints
slides/pictures
GIFConv
PageMaker 4.2
Find
Macintosh Guide
QuickTime™
Opening Animatio
Shared
Norton Uti
Norto
Gloss
Maci
MathT
Tattle
Size
% Total
Type
Creator
Creation Date
Modification Date
Text
Graphics
Archives/Stacks
Programming
Applications
System

# Treemap Problems

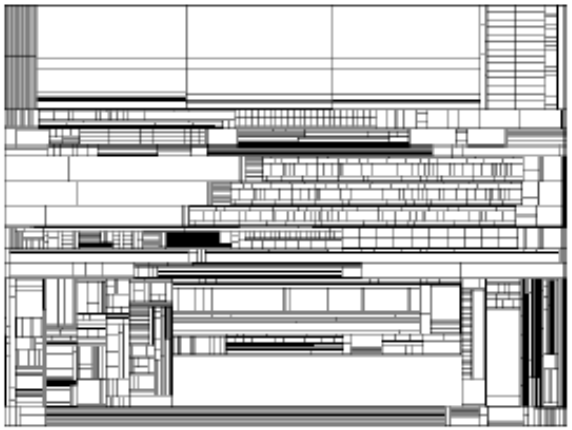
- Too disorderly
  - What does adjacency mean?
  - Aspect ratios uncontrolled leads to lots of skinny boxes that clutter
- Hard to understand
  - Must mentally convert nesting to hierarchy descent
- Color not used appropriately
  - In fact, is meaningless here
- Wrong application
  - Don't need all this to just see the largest files in the OS

# Successful Application of Treemaps

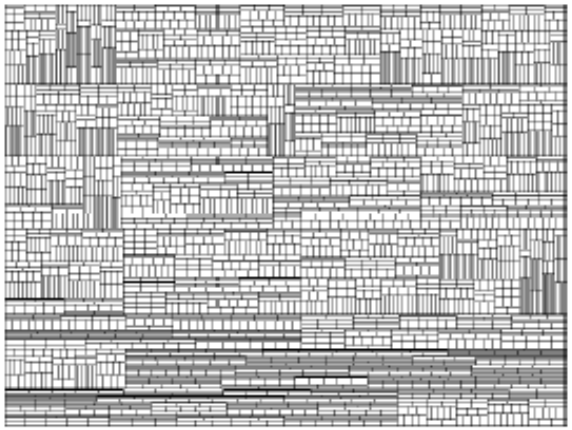
- Think more about the use
  - Break into meaningful groups
- Make appearance more usable
  - Fix these into a useful aspect ratio
- Use visual properties properly
  - Use color to distinguish meaningfully
- Provide excellent interactivity
  - Access to the real data

# Squarified Treemaps

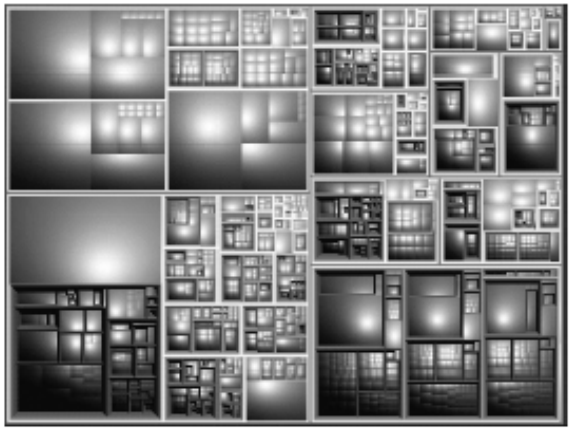
- Bruls, Huizing, van Wijk, 1999
- Rectangles constrained to approximate squares



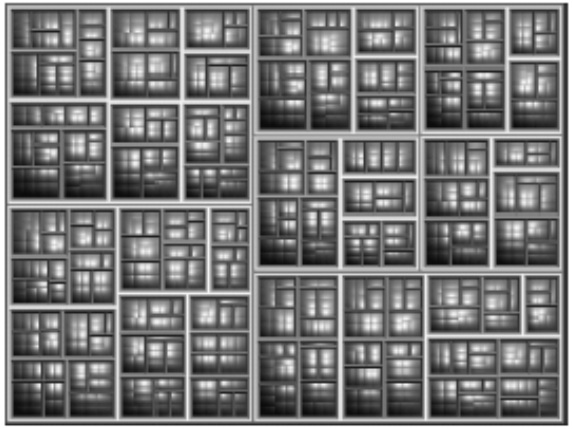
(a) File system



(b) Organization



(a) File system

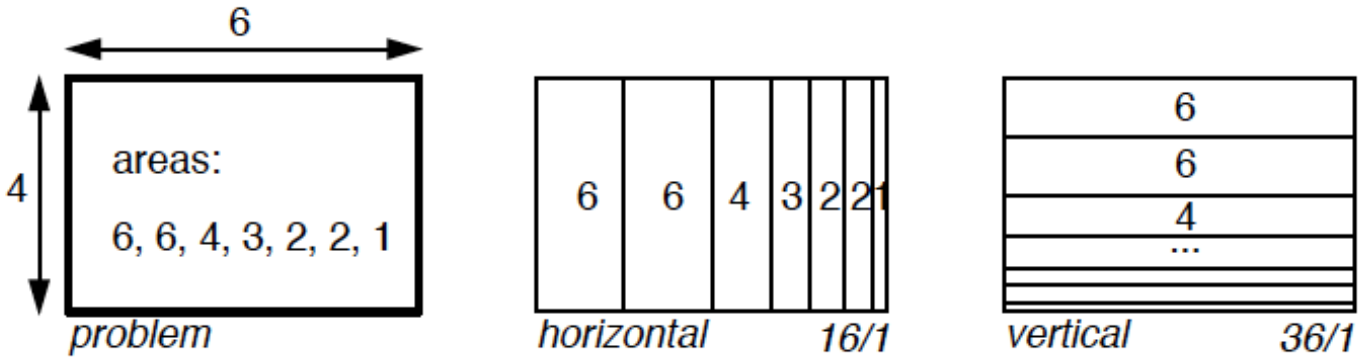


(b) Organization

https://www.win.tue.nl/~vanwijk/stm.pdf

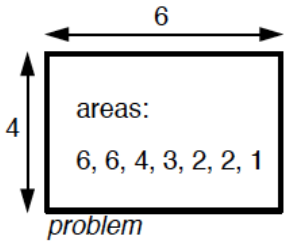
# Squarified Treemaps

- Standard subdivision:

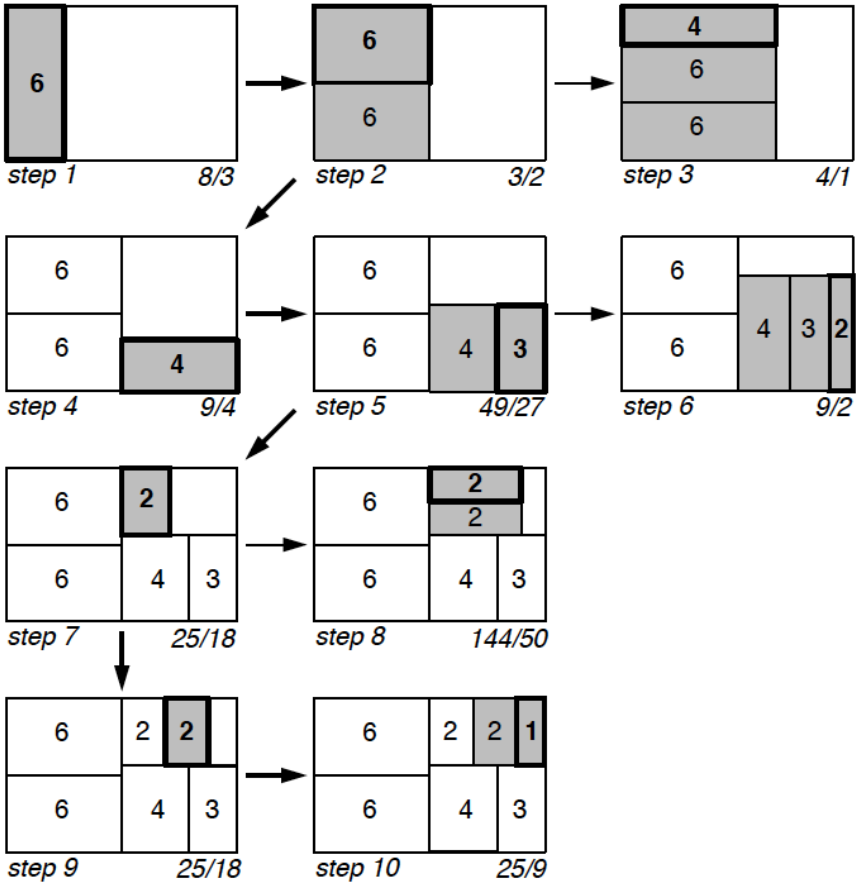



- Aspect ratios
  - 16/1 (horizontal subdivision: 4 / (1/24 * 6))
  - 36/1 (vertical subdivision: 6 / (1/24 * 4))

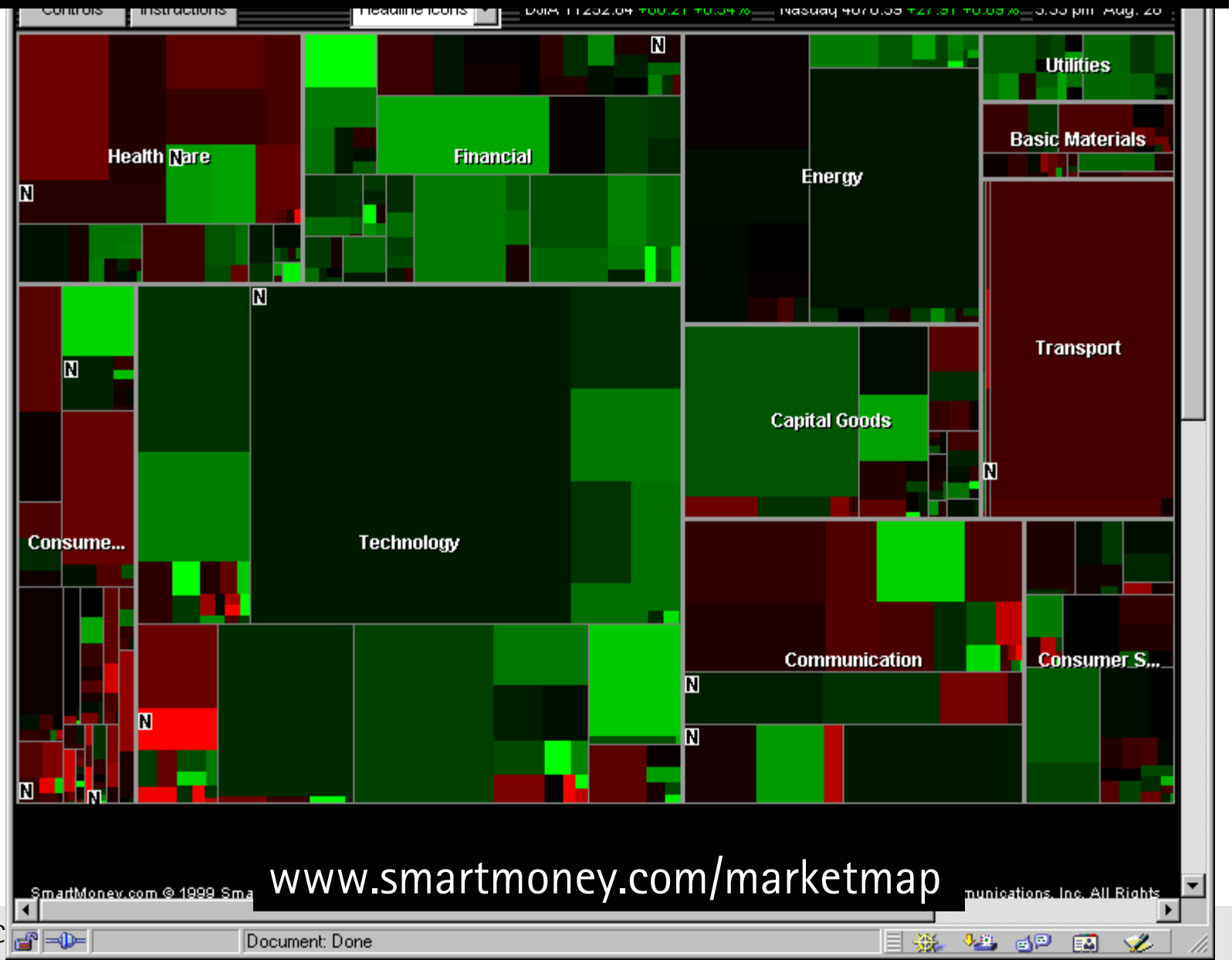
# Squarified Treemaps




- Subdivision algorithm (not opt.):
  1. Add 6 left (because initial is wider than tall): aspect ratio 2.67
  2. Add 6 above: aspect ratio 1.50
  3. Add 4 above: aspect ratio 4.00 (increased)
  4. Move 4 right, add to bottom (because higher than wide): aspect ratio 2.25
  5. Add 3 right: aspect ratio 1.81
  6. Add 2 right: aspect ratio 4.50 (increases)
  7. Move 2 up, add to left (because wider than high): ratio 1.39

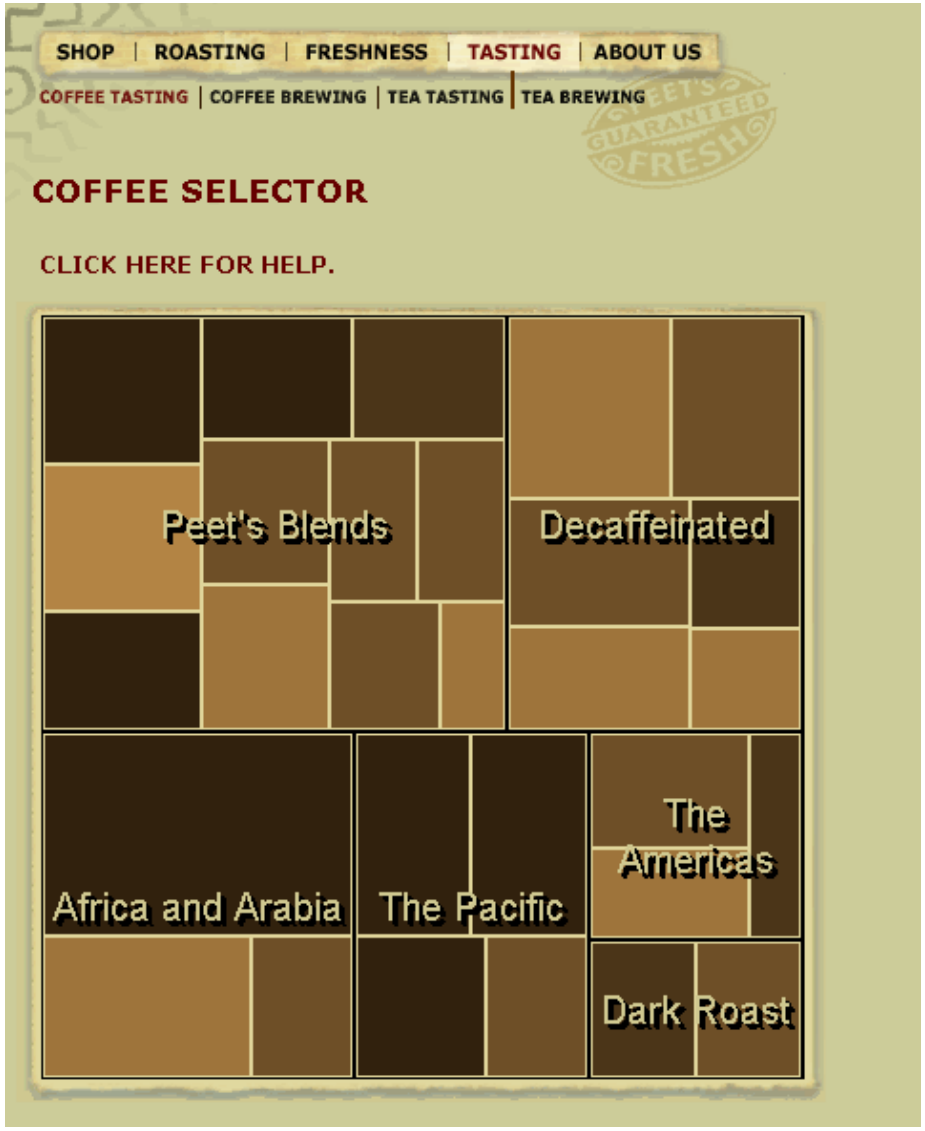


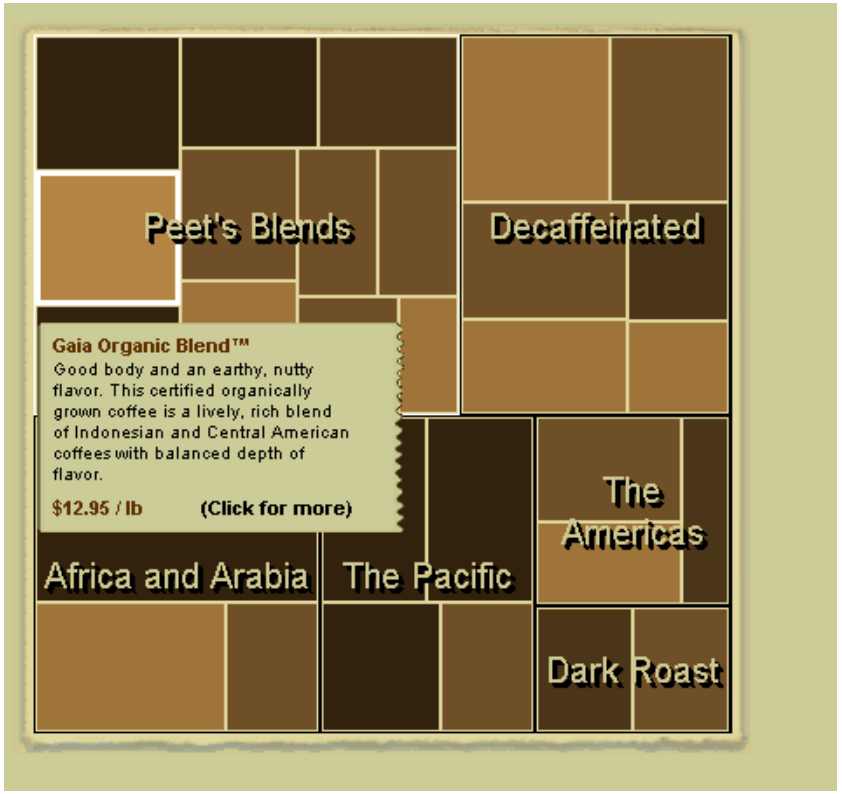
# A Good Use of TreeMaps and Interactivity




www.smartmoney.com/marketmap

# Treemaps in Peet's Coffee & tea Site

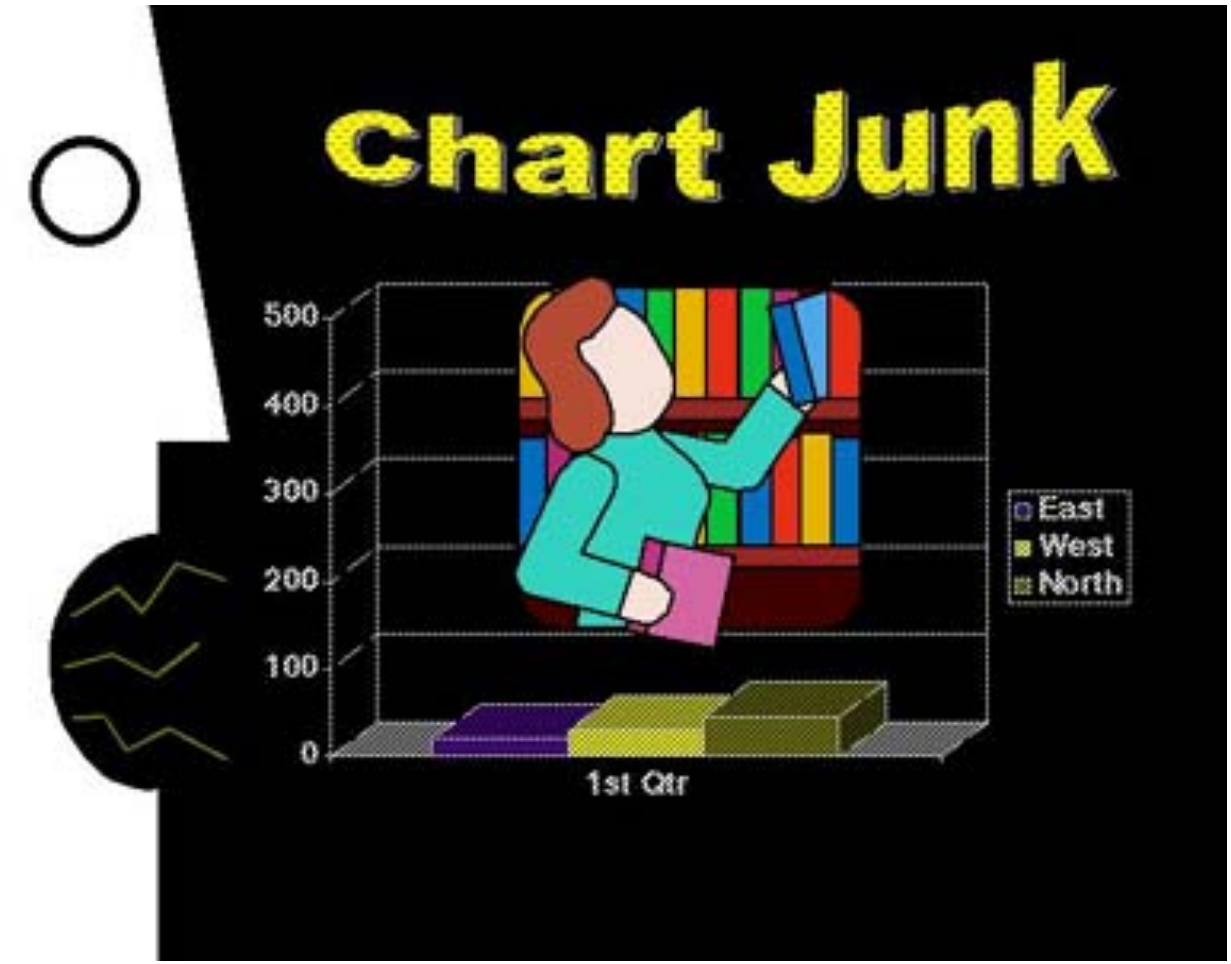


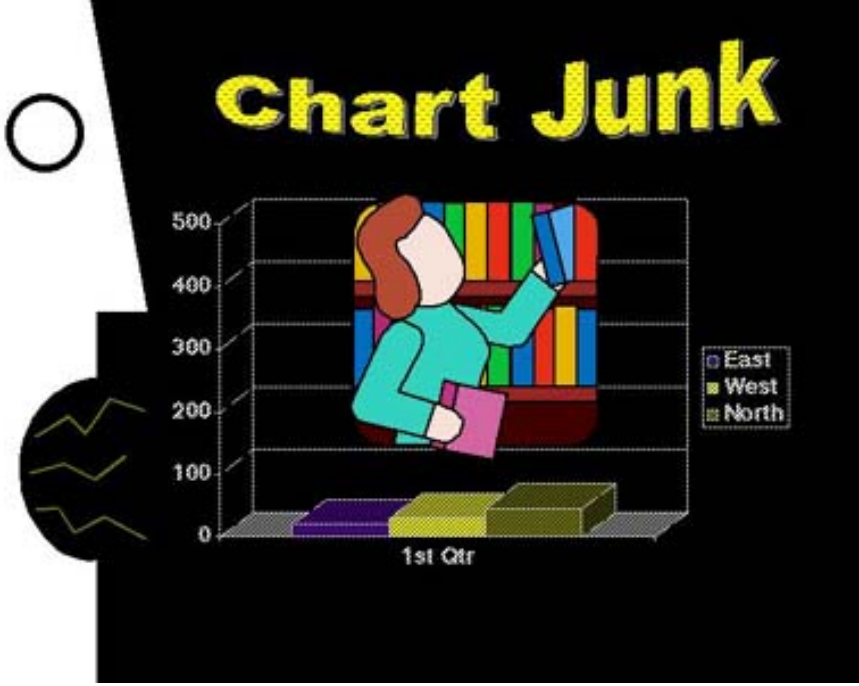
# Analysis vs. Communication

- MarketMap's use of TreeMaps allows for sophisticated analysis
- Peets' use of TreeMaps is more for presentation and communication
- This is a key contrast

# Why does this suck?

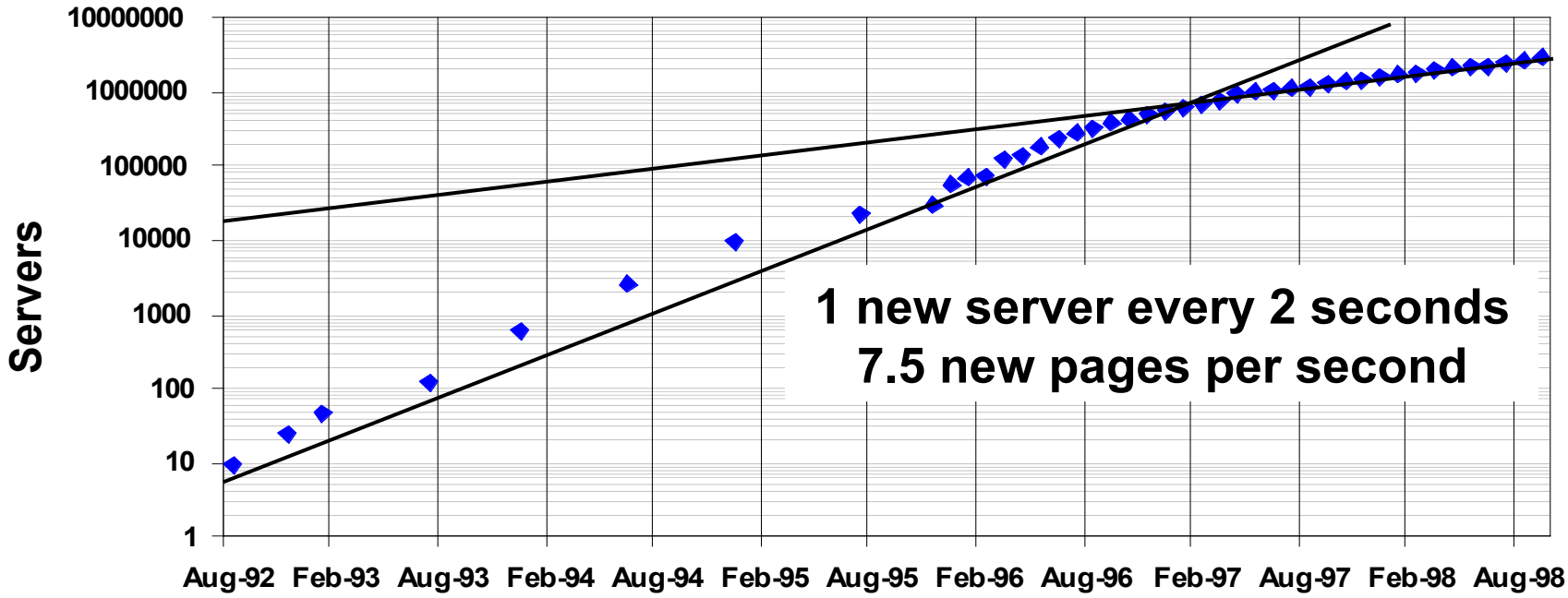


# Some of the reasons it sucks




- y-axis unlabeled
- needless use of 3D bar chart
- color used instead of x-axis labels
- x-axis label should be the title, and be more informative
- giant face on left side
  - distracting by engaging human face perception
  - distracting by creating figure/ground separation illusion
- chart junk
  - useless image of librarian, tacky word art
- missing context
  - nothing to compare the numbers to

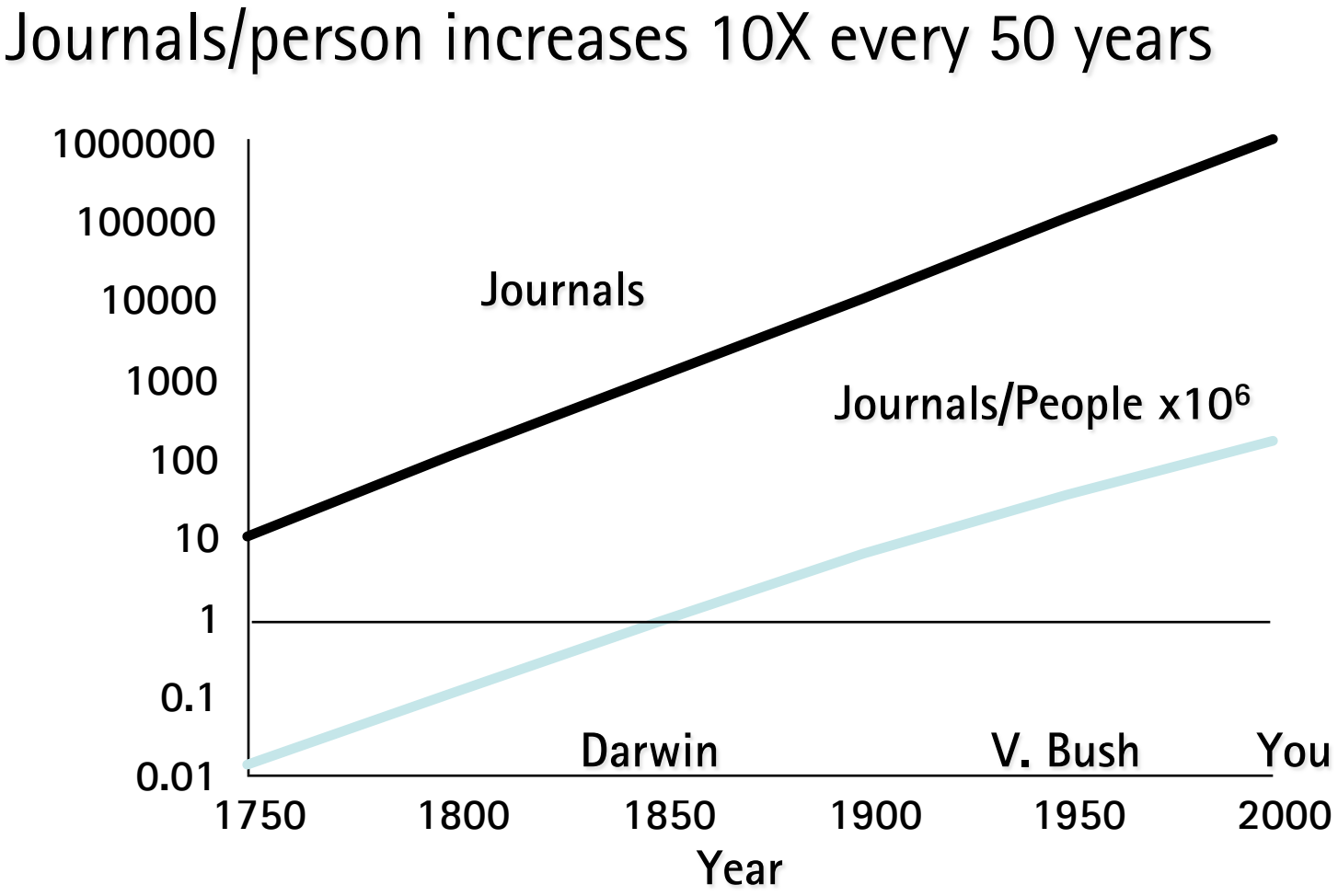
# Web




**Source: World Wide Web Consortium, Mark Gray, Netcraft Server Survey**

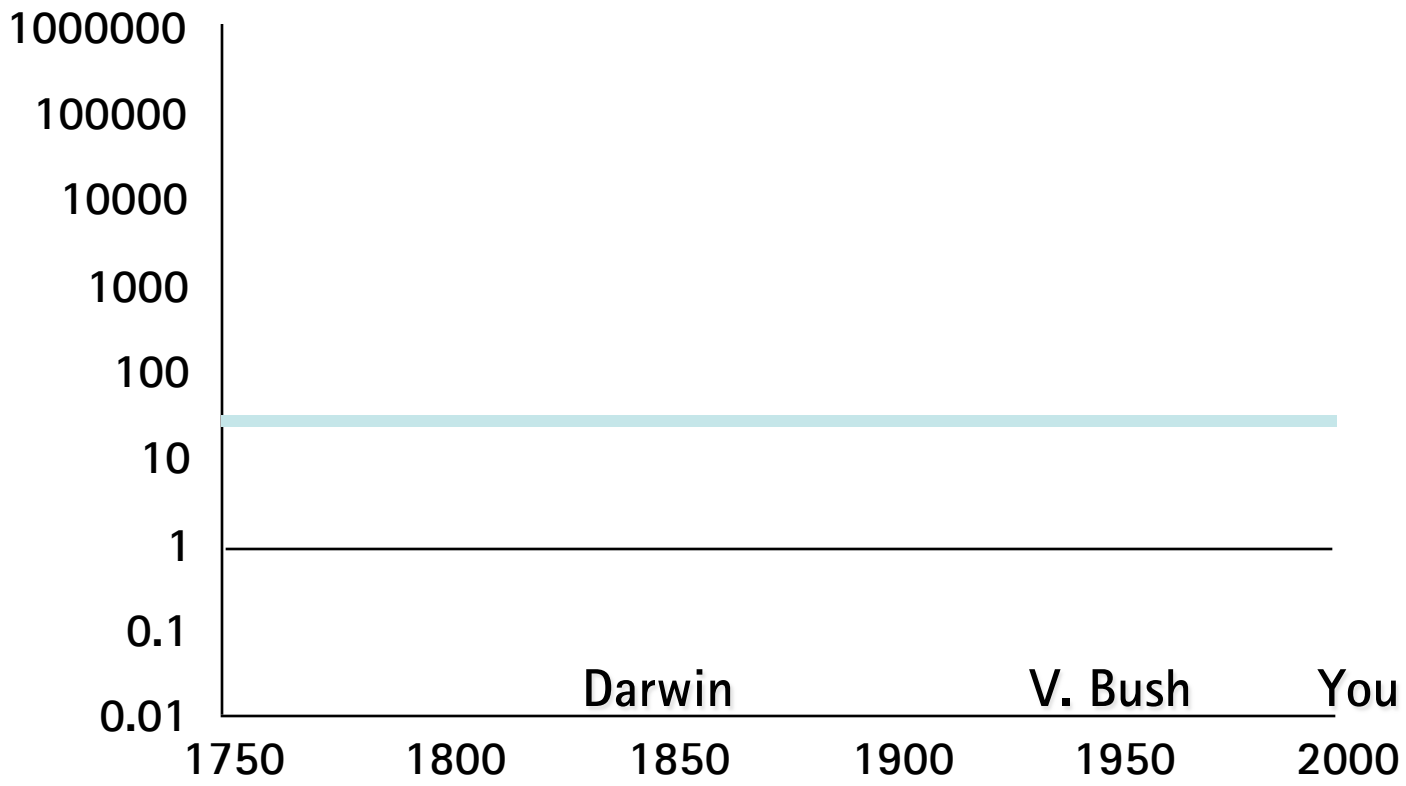
(slide from PARC User Interface Research Group)

# Scientific Journals




(slide from PARC User Interface Research Group)

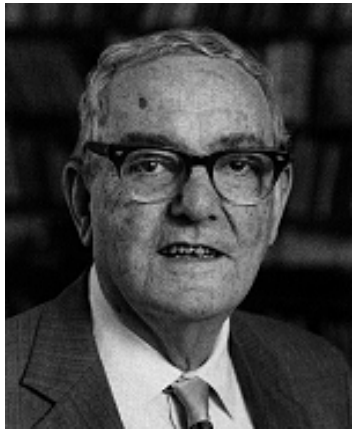
# Innate Human Capacity




(slide from PARC User Interface Research Group)

# Attentional Processes

"What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."

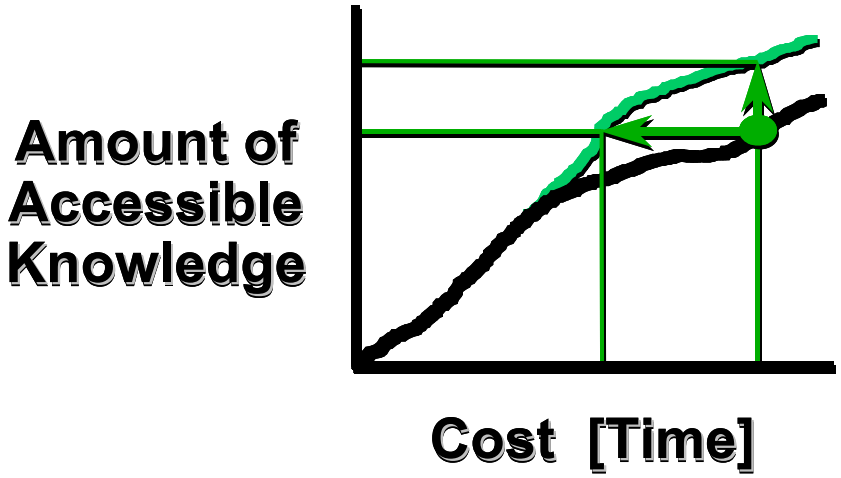


Herb Simon
as quoted by Hal Varian
Scientific American
September 1995

(slide from PARC User Interface Research Group)

# Human-Information Interaction

- The real design problem is not increased access to information, but greater efficiency in finding useful information.
- Increasing the rate at which people can find and use relevant information improves human intelligence.



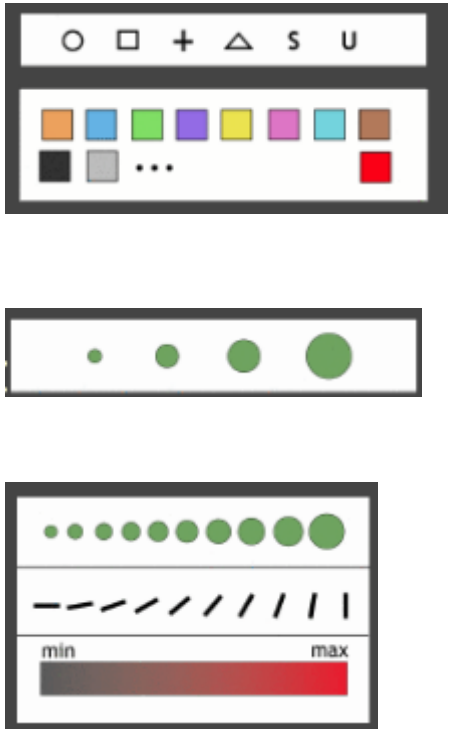

(slide from PARC User Interface Research Group)

# Augmented Cognition

- Using external artifacts to amplify human mental abilities
  - Classic examples: pen and paper, slide rules
  - A primary goal of Information visualization
- In the case of InfoVis, how?
  - Increased resources
  - Reduced search
  - Enhanced pattern recognition
  - Perceptual inference
  - Perceptual monitoring
  - Manipulable medium

# Basic Types of Visual Encodings

- "Retinal" properties
  - spatial position (e.g., x-y axes)
  - size
  - shape
  - color
  - orientation
  - texture
- "Gestalt" properties
  - connectivity
  - grouping (e.g., enclosure)
- Animation
  - view transitions
  - animated elements



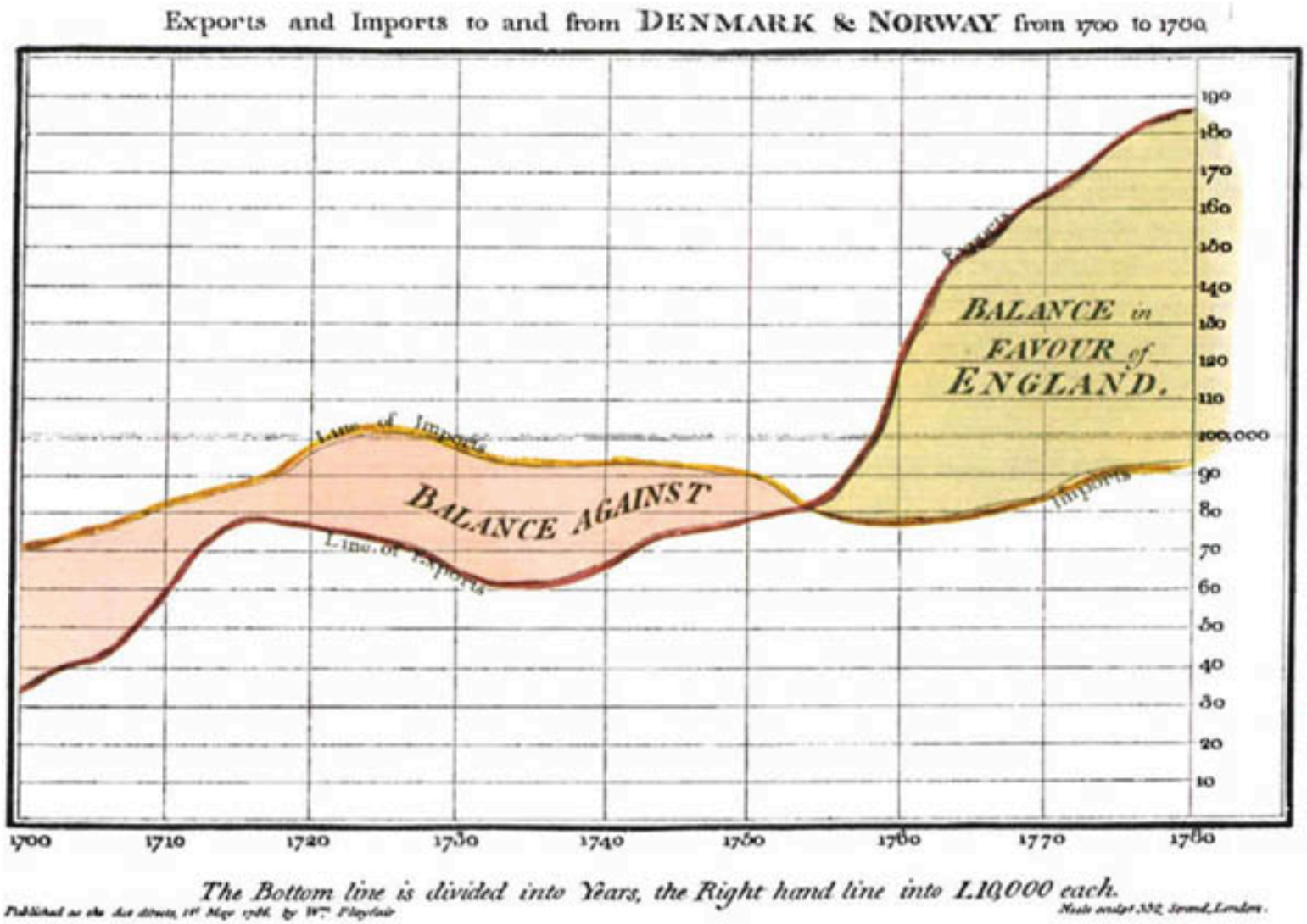
# Sensemaking Tasks [Card et al.]

- Information foraging
  - Collect information of interest
- Search for schema
  - Identify relevant dimensions of data
- Instantiate schema (with data)
  - Schema == knowledge representation
  - Organize / codify information
- Analysis (problem solving)
  - Analyze and filter data, answer questions
  - Refine schema as needed
- Record / communicate
  - Make a decision, take action, or communicate results

# Interactive Tasks [Shneiderman]

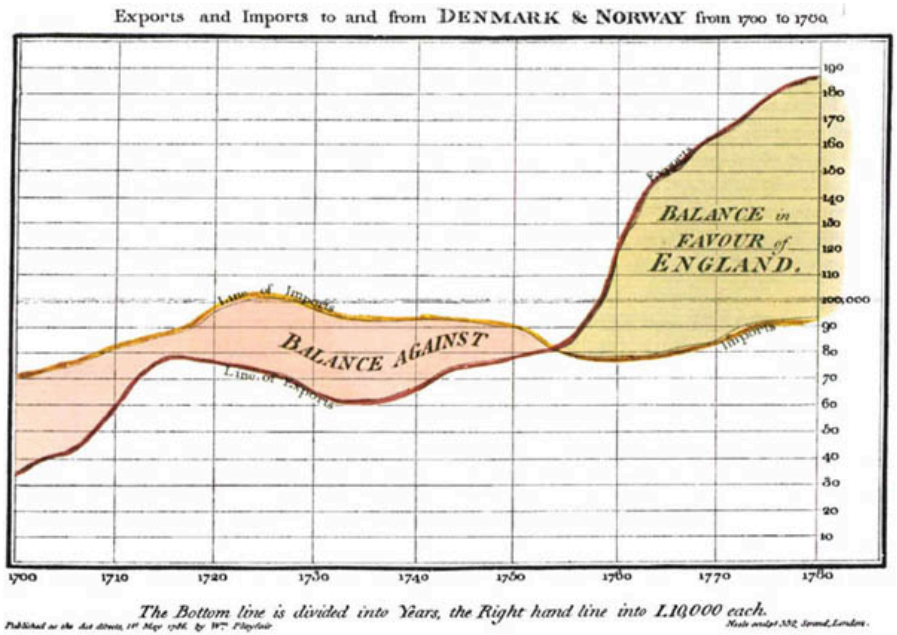
- Overview
  - Get an overview of the collection
- Zoom
  - Zoom in on items of interest
- Filter
  - Remove uninteresting items
- Details on demand
  - Select items and get details
- Relate
  - View relationships between items
- History
  - Keep a history of actions for undo, replay, refinement
- Extract
  - Make subcollections

# Data Graphics (Playfair, ca.1780)

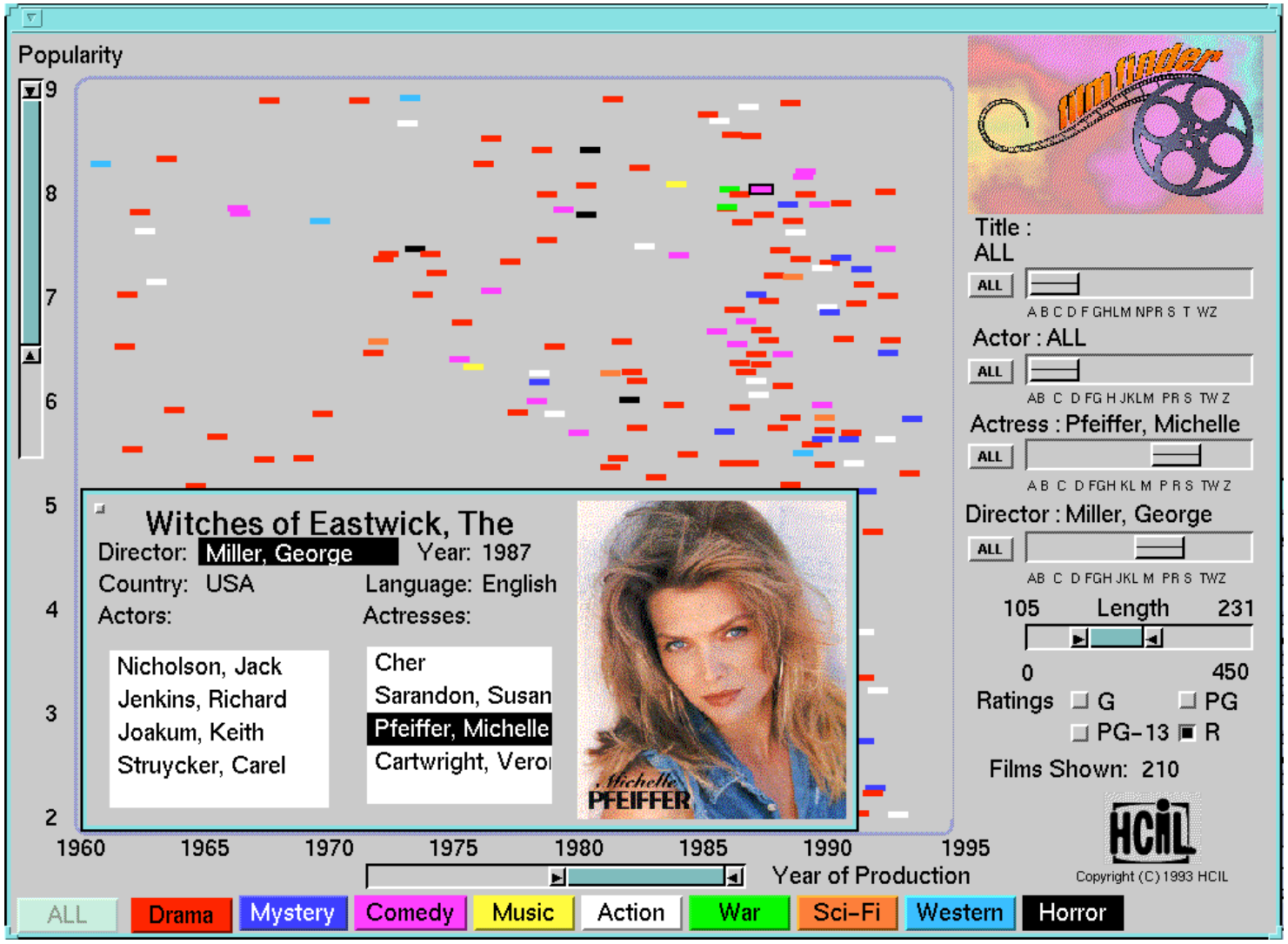


# Characterizing the Visualization

- x-axis: year (quantitative)
- y-axis: currency (quantitative)
- color: imports/exports (nominal)
- color: positive/negative (nominal/ordinal)

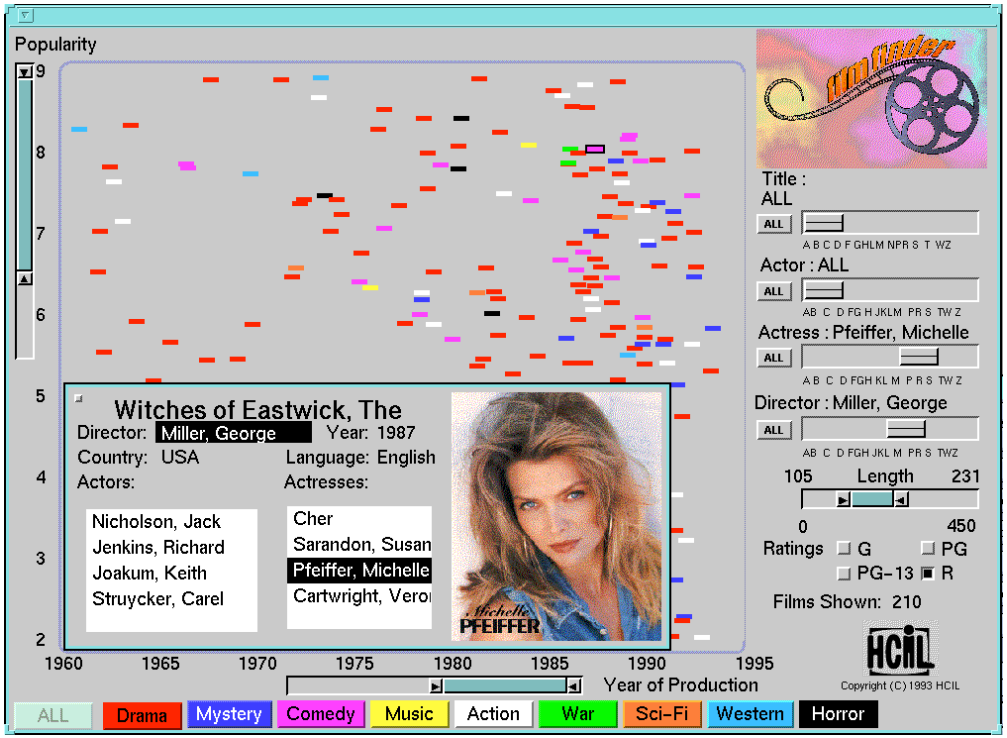


# Starfield Displays (spotfire)



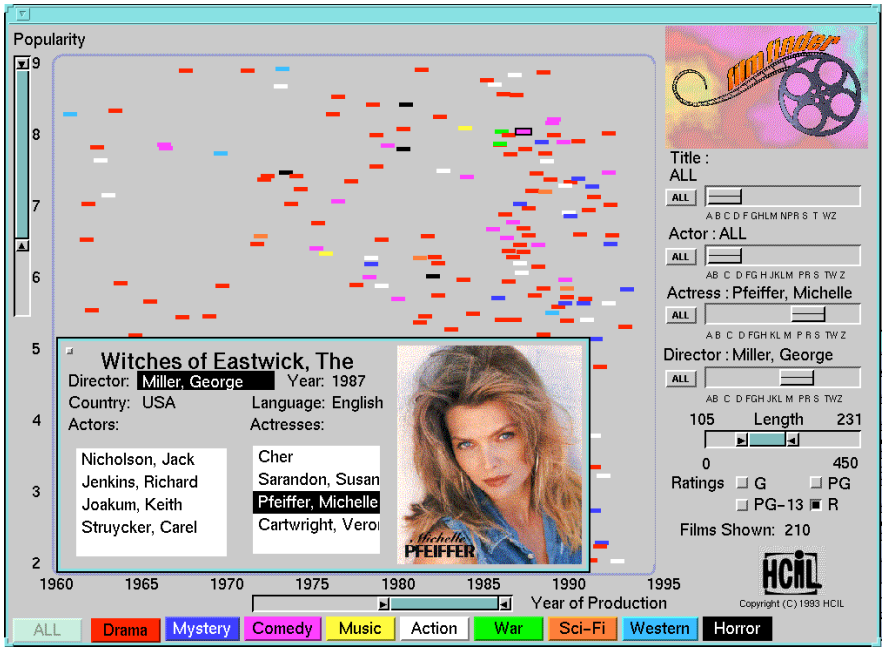
# Characterizing the Visualization

- x-axis: year of release (quantitative)
- y-axis: popularity (quantitative)
- color: genre (nominal)
- dynamic query filters
  - title (nominal)
  - actor (nominal)
  - actress (nominal)
  - director (nominal)
  - length (quantitative)
  - rating (ordinal)



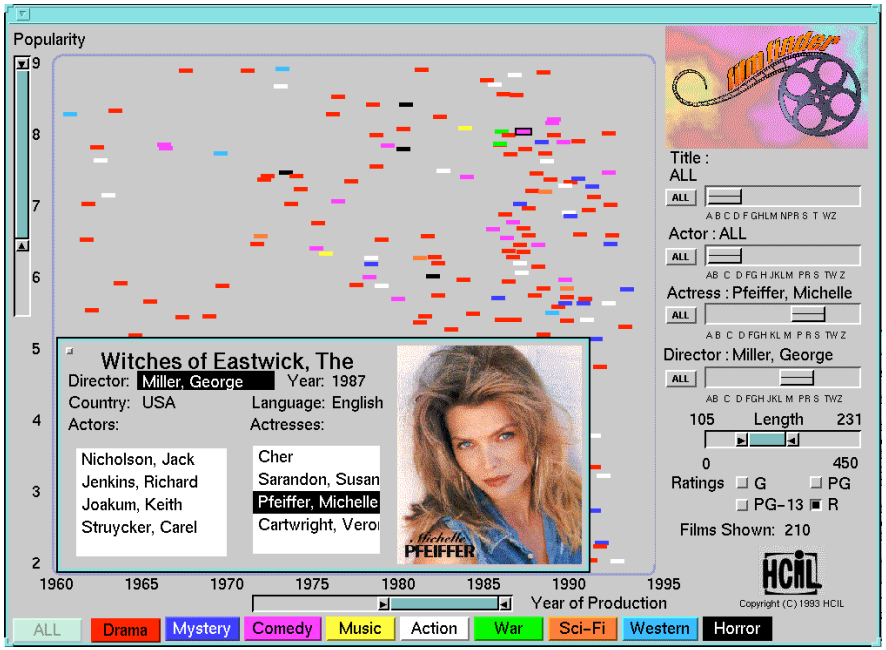
# Principle: Interactivity

- Turn visual analysis into a real-time iterative process
- Explore various hypotheses or interests
- Filter to hone in on data of interest
- Get details on demand

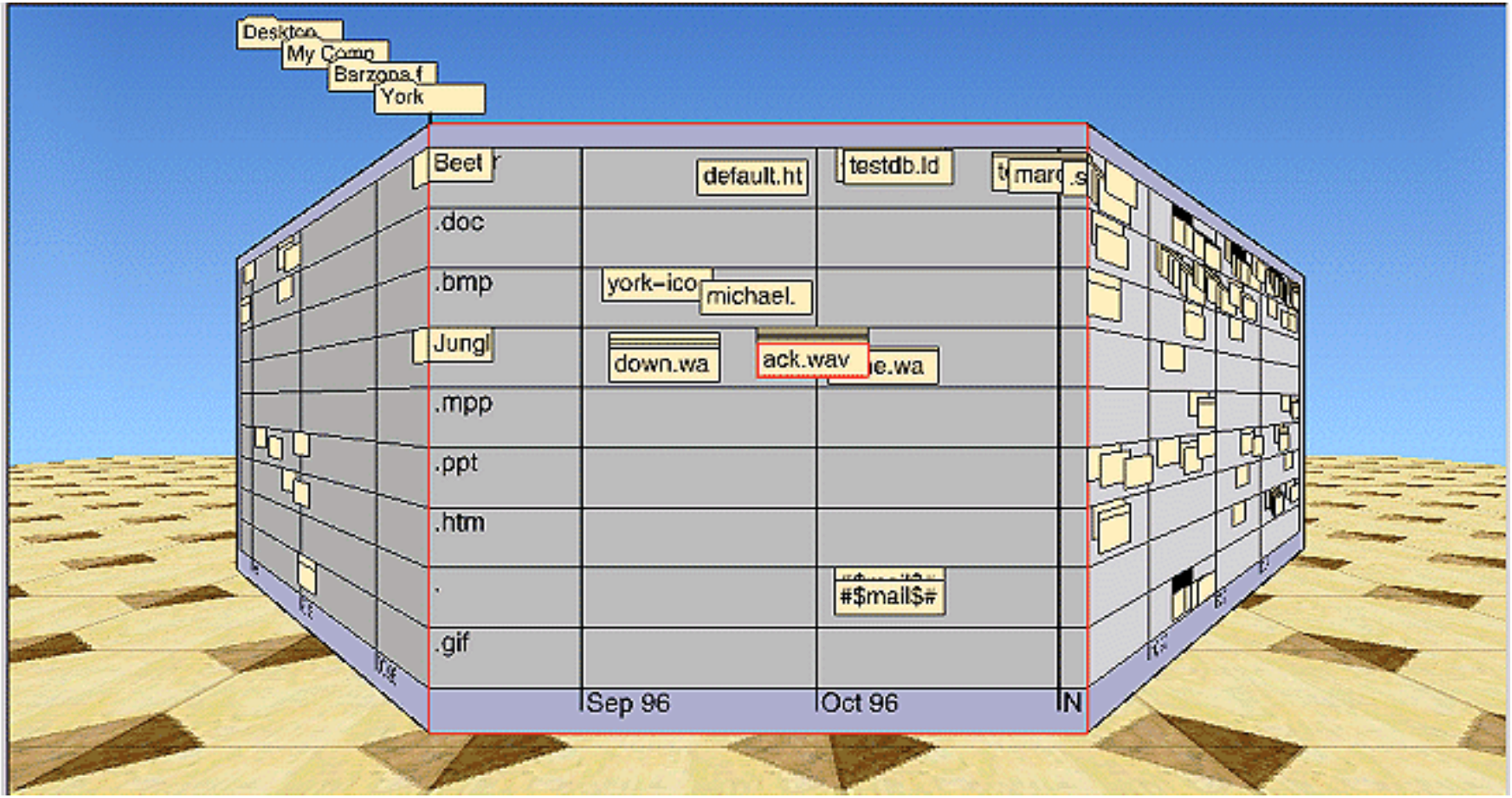


# Issue: Multi-Dimensional Data

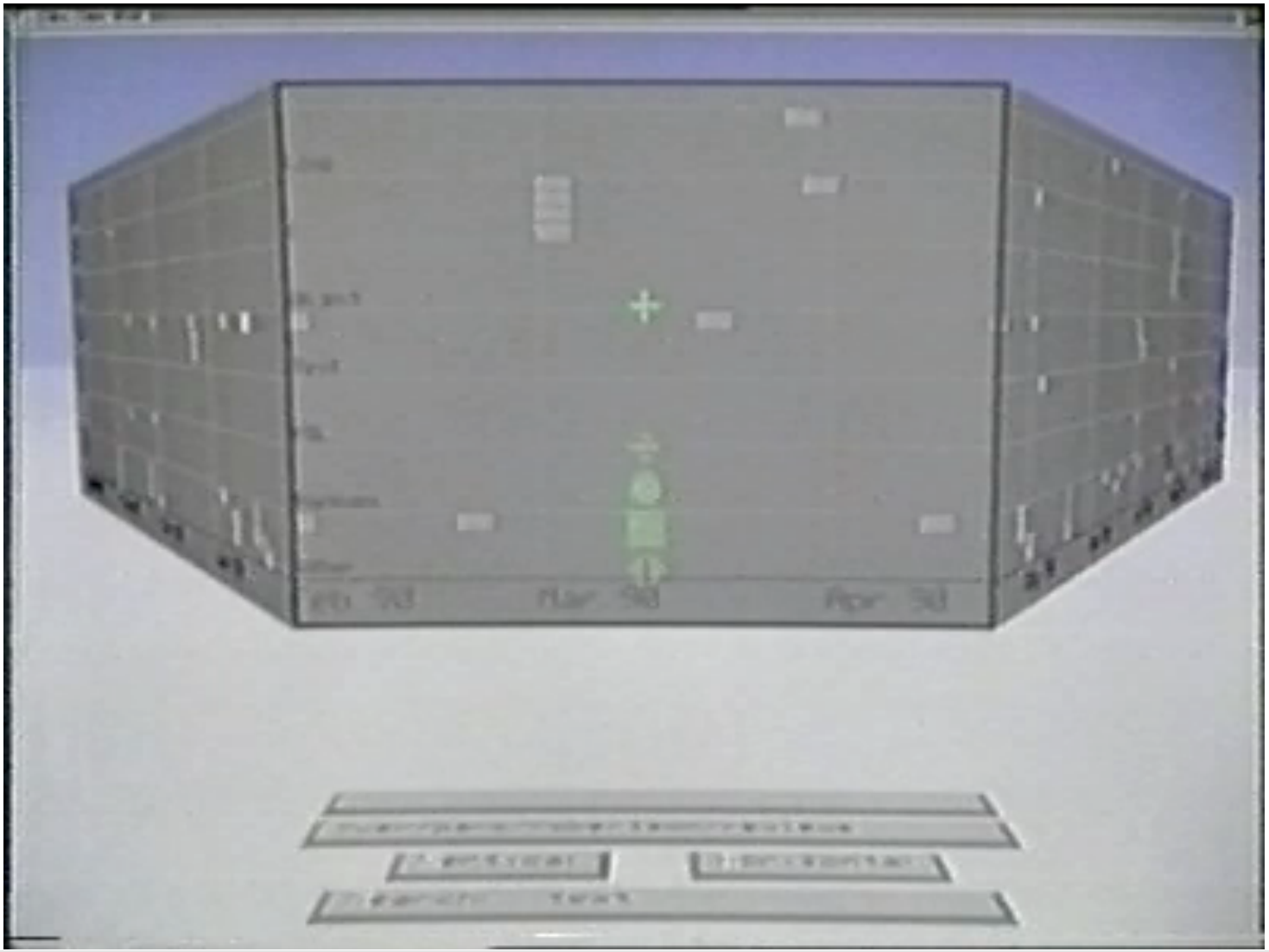
- FilmFinder visualizes 3 dimensions at a time, using 2 spatial dimensions and color
- Can we effectively see more dimensions simultaneously?



# Perspective Wall

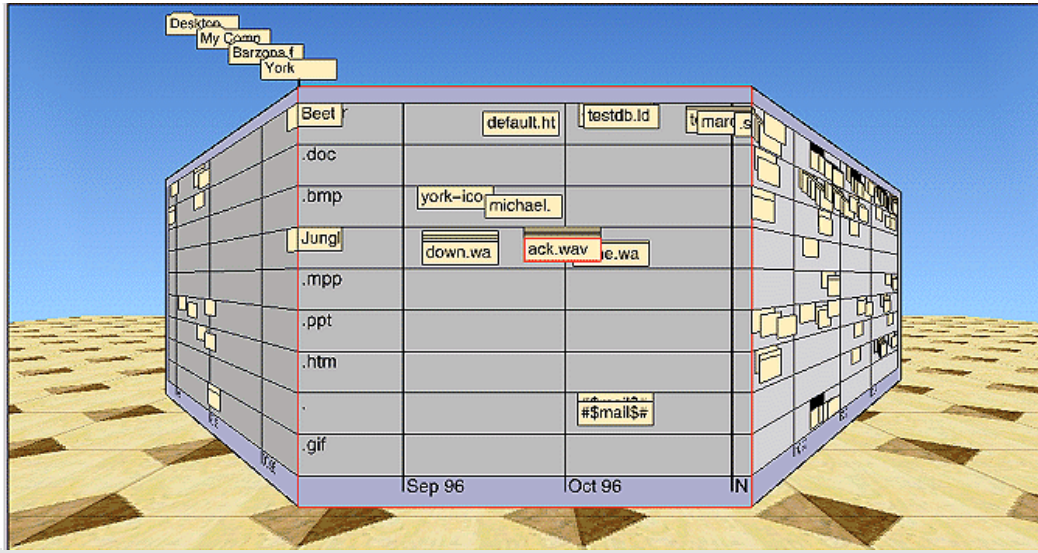


# Perspective Wall



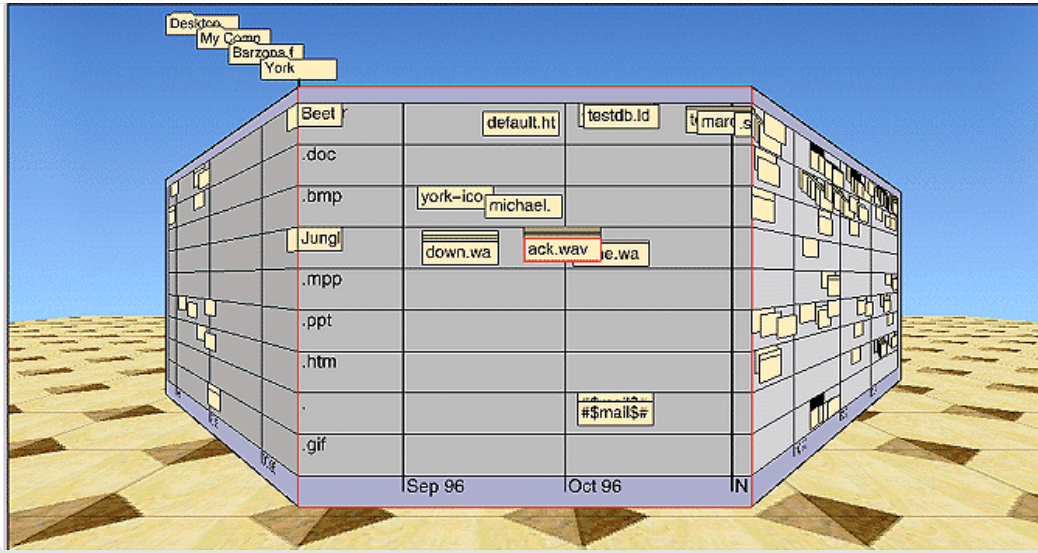
# Characterizing the Visualization

- x-axis: time of file access (quantitative)
- y-axis: file type (nominal)
- use of 3D perspective to
  - fit more data in the display
  - de-emphasize peripheral data

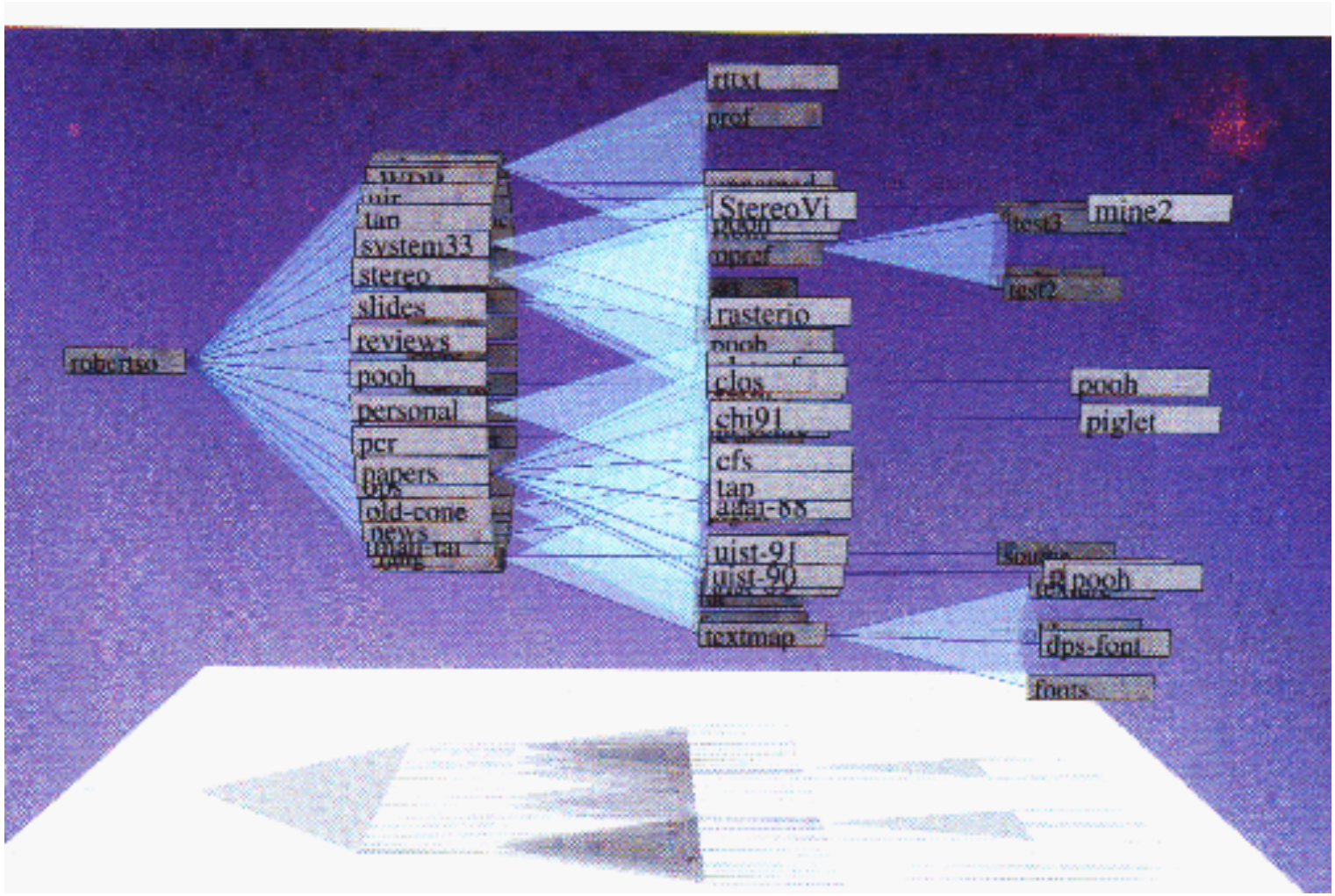


# Principle: Focus+Context

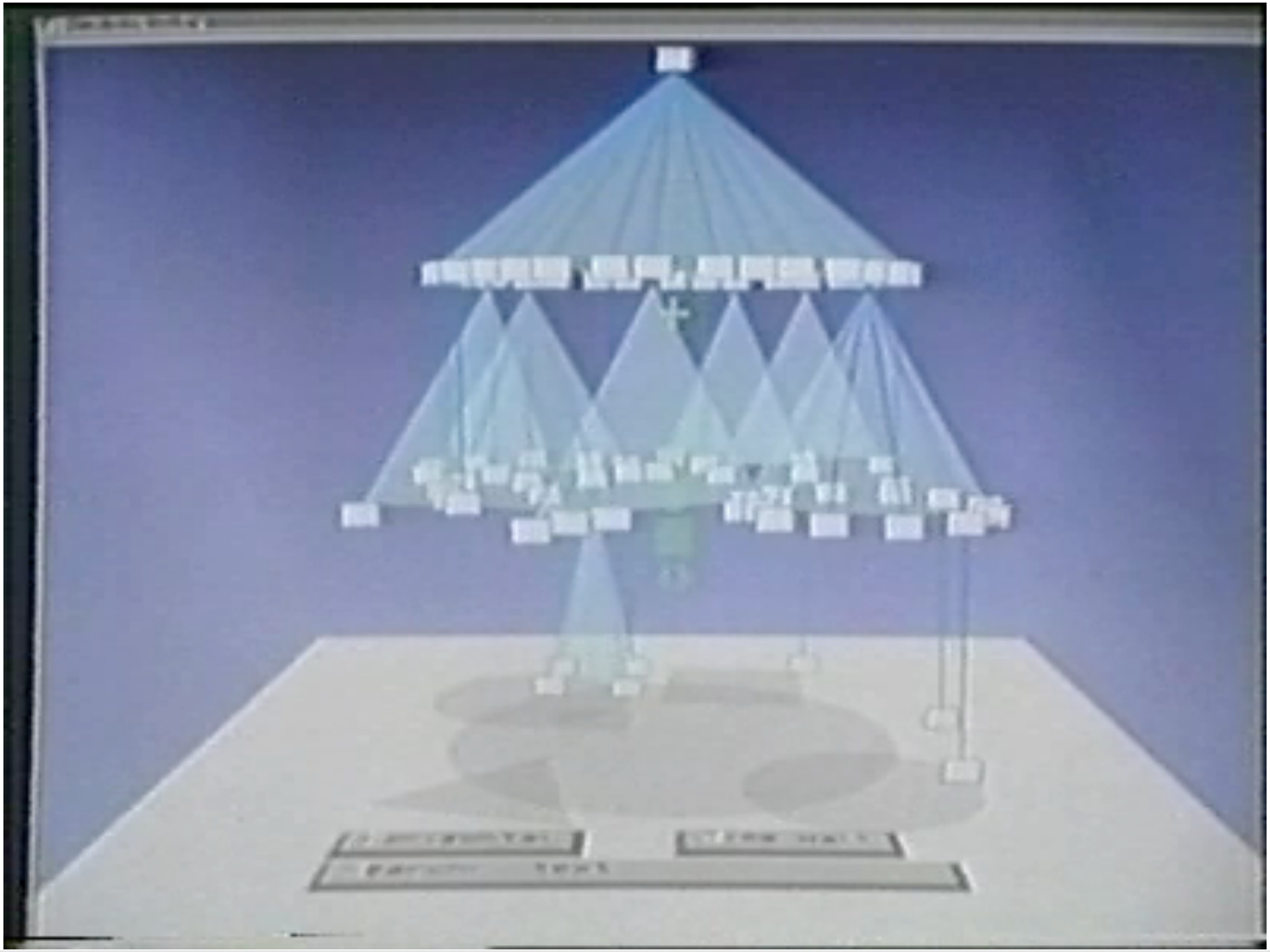
- Keep all the data in view
- Show data of interest in high detail
- Show peripheral data in lower detail
- Often achieved through perspective or visual distortion



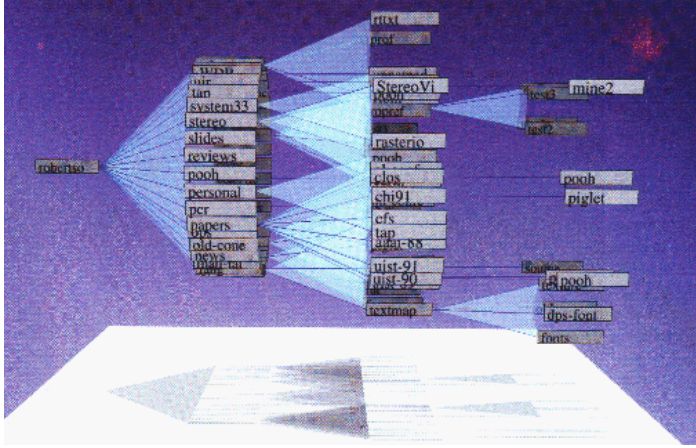
# Cone Trees


roberts0
system33
stereo
slides
reviews
pooh
personal
papers
old-cone
StereoVi
rasterio
clos
chi91
cfs
uist-91
uist-90
textmap
mine2
pooh
piglet
pooh
dps-font
fonts

# Cone Trees

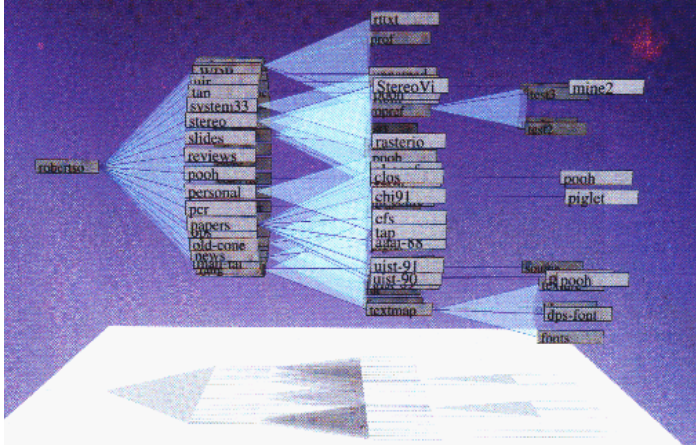


# Characterizing the Visualization



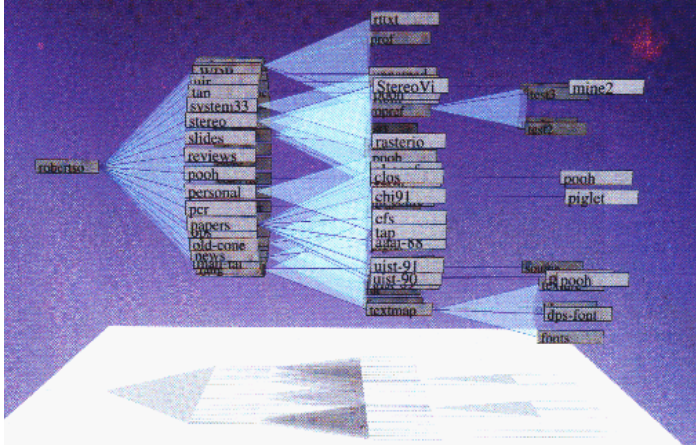

- x-axis: tree depth (hierarchical)
- y-axis / z-axis: arrangement of sibling / cousin nodes (hierarchical)
- connectivity: parent-child relationships (hierarchical)
- animation: perform view transition
- lighting: shadow provides flattened 2D view of structure

# Principle: Animation




- Depicts change over time
- Invaluable for view transitions
- Can communicate change, even on periphery of vision (eyes are very sensitive to motion)
- Existing debate about the efficacy of animation (depends on usage)

# Principle: 3D




- 2D or not 2D? Actually quite controversial!
- Though "cool", 3D can present problems with occlusion and navigation
- Most visualizations stay in the 2D or 2.5D
  - Perspective Wall: 3D perspective, 2D interaction

# A Re-Design: Degree-of-Interest (DOI) Trees

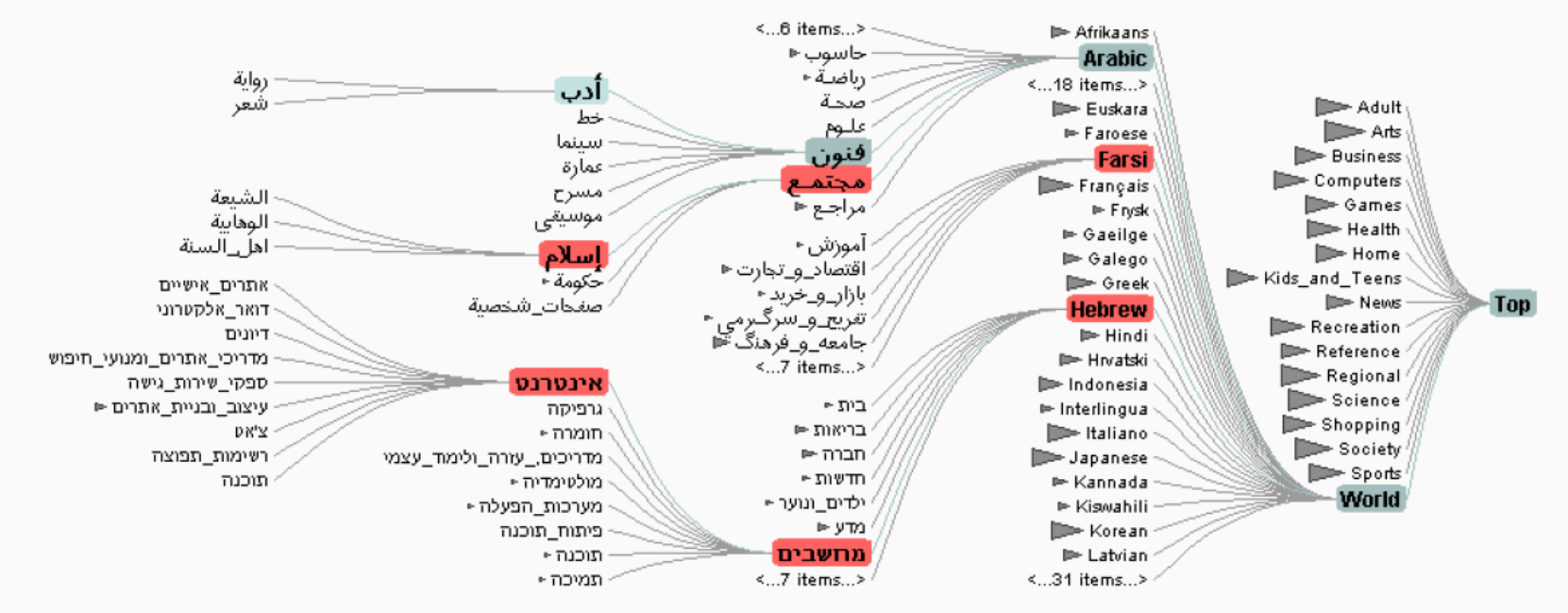
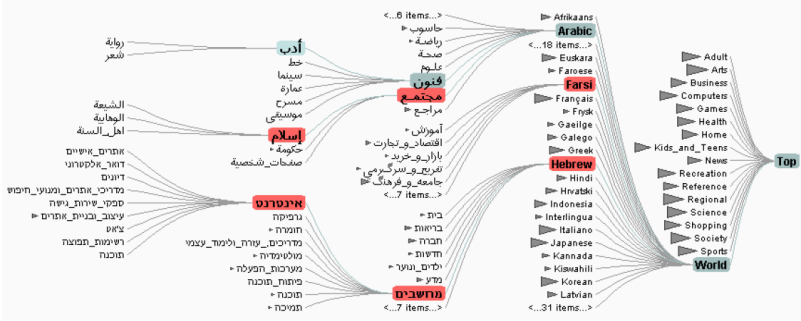



**Figure 1 DOITree visualization of the Open Directory Project (http://dmoz.org). The tree contains over 600,000 nodes, laid out in a right-to-left orientation. Multiple foci have been selected and the various expanded branches are allocated as much space as possible given the display constraints.**

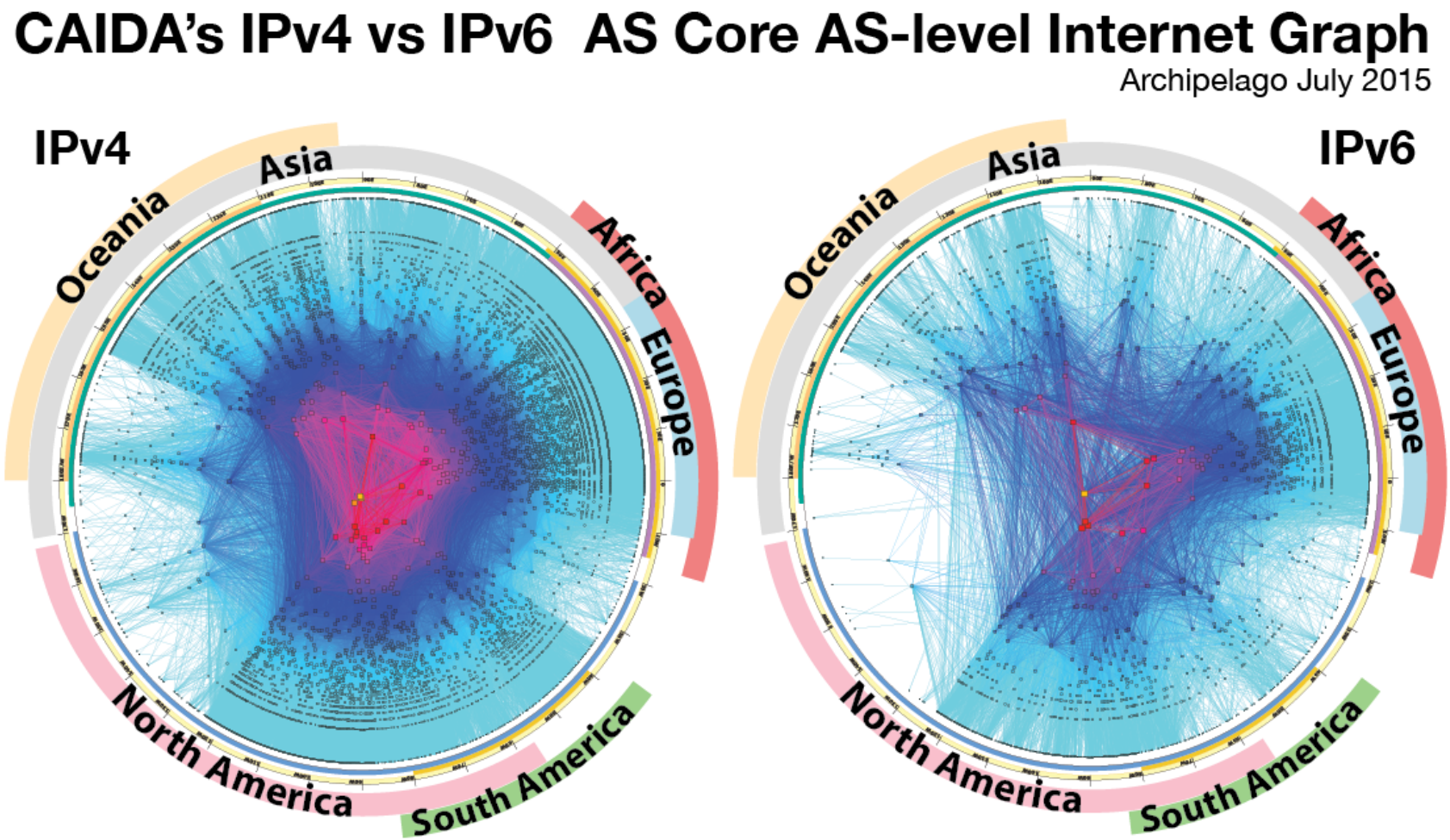
Heer, Card: DOITrees Revisited: Scalable, Space-Constrained Visualization of Hierarchical Data. AVI 2004.

# Characterizing the Visualization



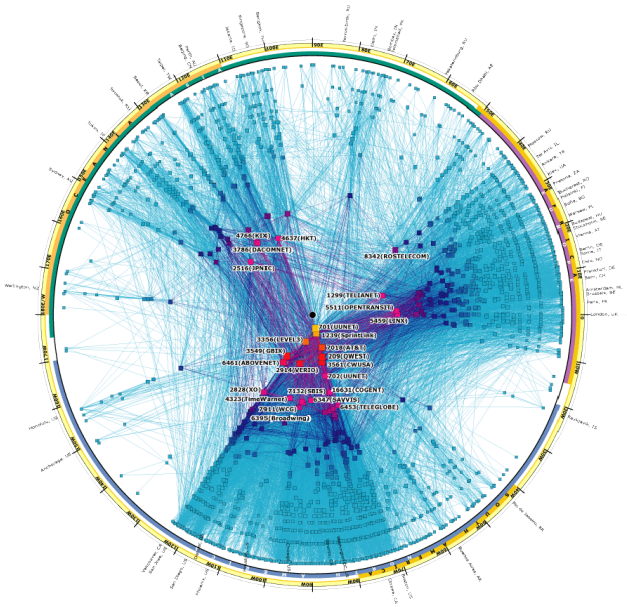

- Similar to cone-tree, but flattened
- Color: selection/focus status of nodes (nominal)
- Increased information density [Tufte]
- Curved edges create funnel effect
  - Allows greater y-separation of parents and children
- More focus+context
  - Only show selected, expanded subtrees
  - Collapsed subtrees replaced with a graphic, roughly indicating subtree size
  - If too many siblings, aggregate to keep legible

# Network Visualization



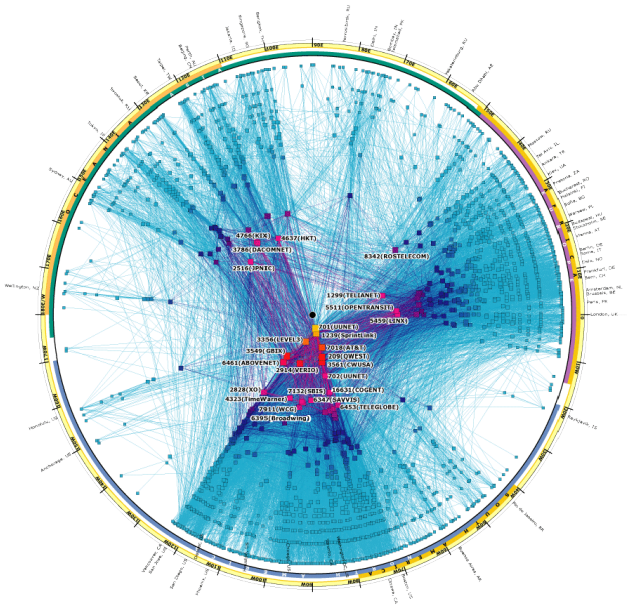
# Characterizing the Visualization

- Angle: longitude (quantitative)
- Radius: number of connections (quantitative)
- Color: number of connections (quantitative)
  - Color spectrum moving from cool to hot colors
- Color: continents (nominal/ordinal)
  - Category colors along periphery

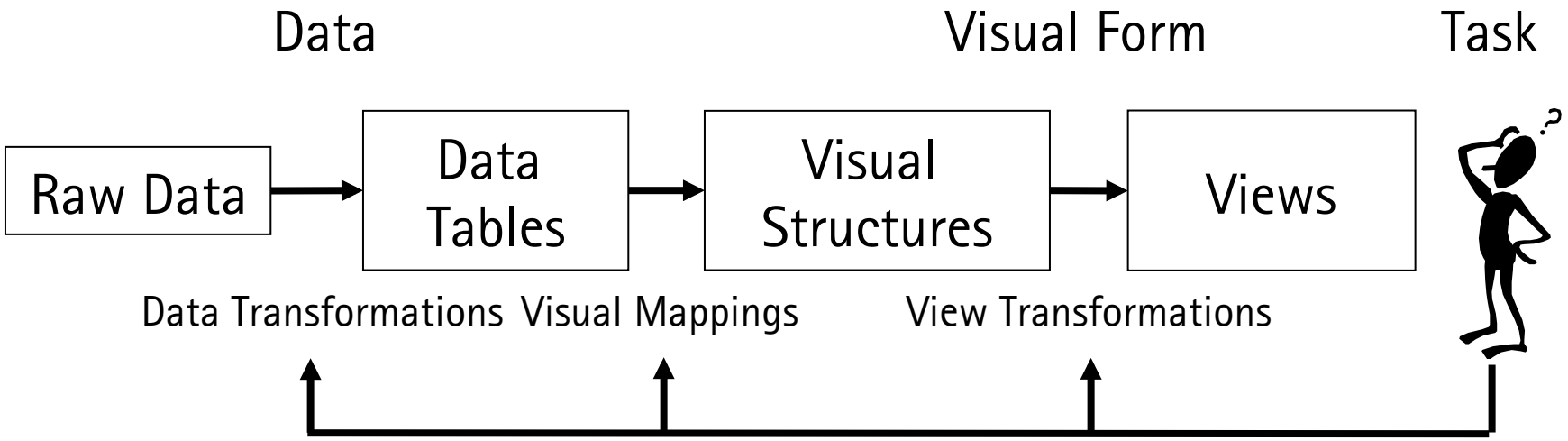


# Principles

- Redundant coding
  - In this case radius and color
  - Reinforce data of interest
- Design decision can obscure data
  - Network sparsity in Africa is masked by European networks

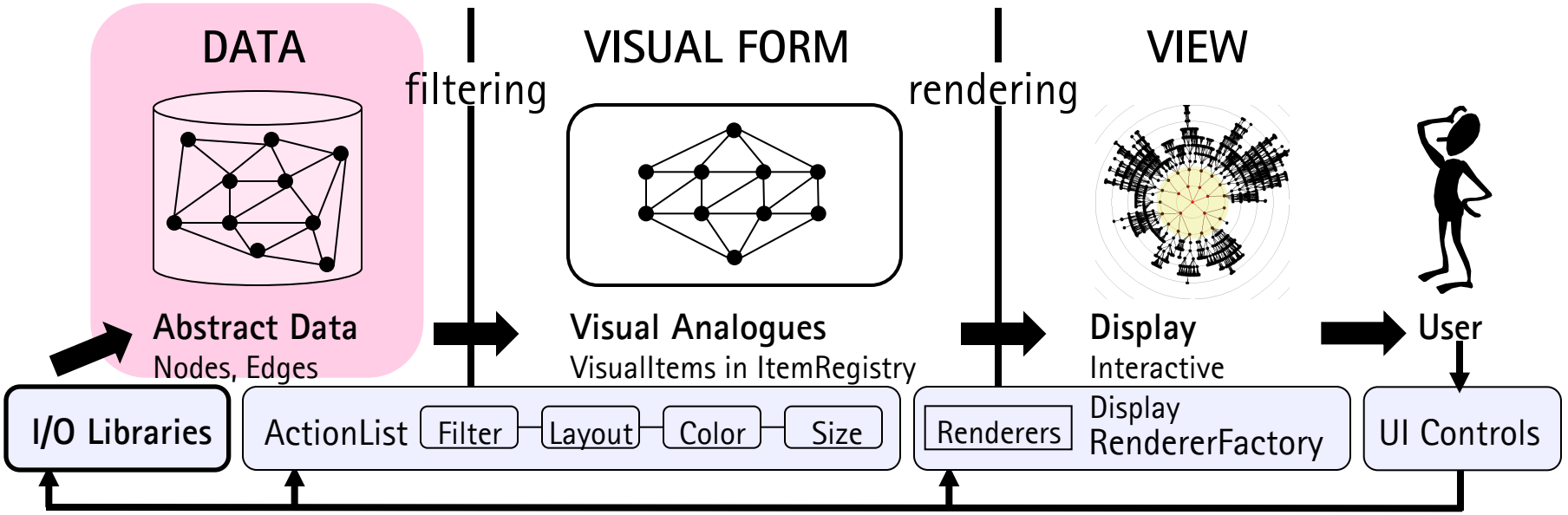


# Information Visualization Reference Model




- Data Transformations
  - Mapping raw data into an organization fit for visualization
- Visual Mappings
  - Encoding abstract data into a visual representation
- View Transformations
  - Changing the view or perspective onto the visual representation
- User interaction can feed back into any level

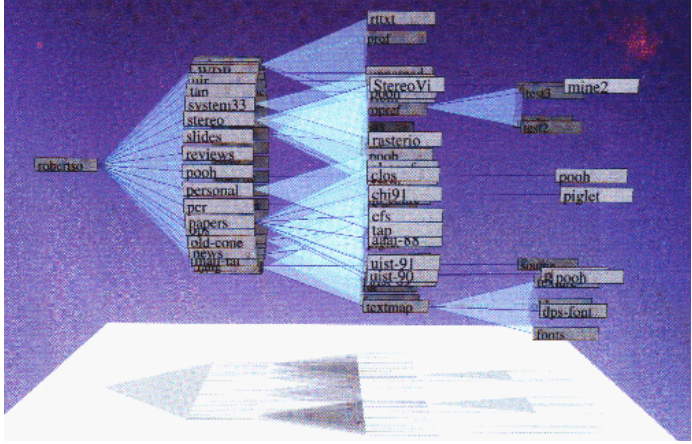
# Software Architectures and Toolkits



# Reference Model Examples

- Visual mappings
  - Layout (assigning x, y position)
  - Size, Shape, Color, Font, etc…
- View transformations
  - Navigation: Panning and Zooming
  - Animation
  - Visual Distortion (e.g., fisheye lens)

# Apply the Model: Cone Trees

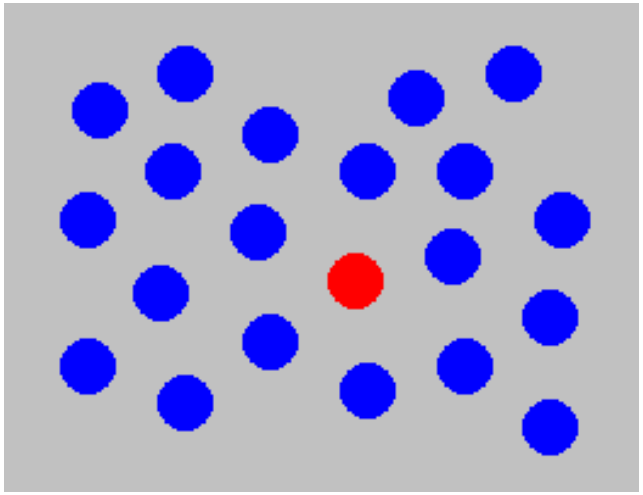


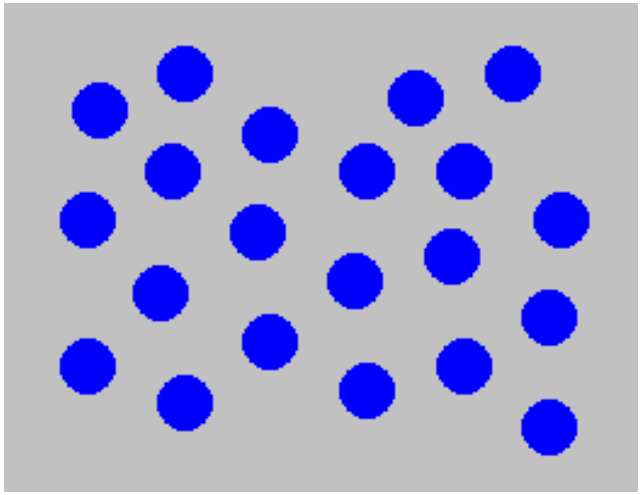

- Raw Data: File system directories
  - Data Transformations: Traverse file system subtree
- Data Tables: Parsed/extracted directory tree
  - Visual Mappings: Assign 3D coordinates to tree elements (layout), assign colors, fonts. Set lighting.
- Visual Structures: 3D model of tree
  - View Transformations: Camera placement; animation between tree configurations
- View: Rendered, interactive visualization
- Interaction: Selection of new focus node

# Preattentive Processing

- A limited set of visual properties are processed preattentively
  - (without need for focusing attention)
- This is important for design of visualizations
  - What can be perceived immediately?
  - Which properties are good discriminators?
  - What can mislead viewers?

# Example: Color Selection

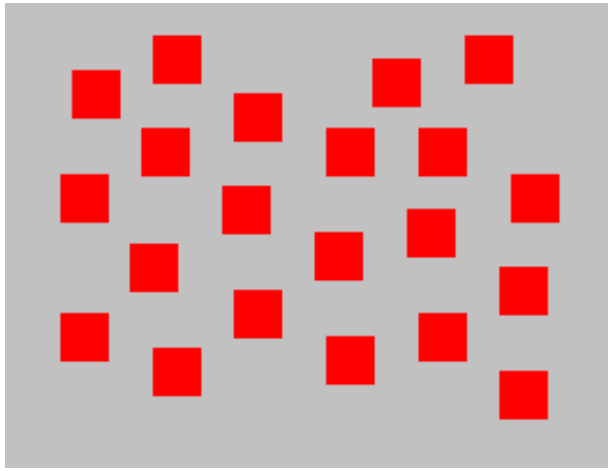


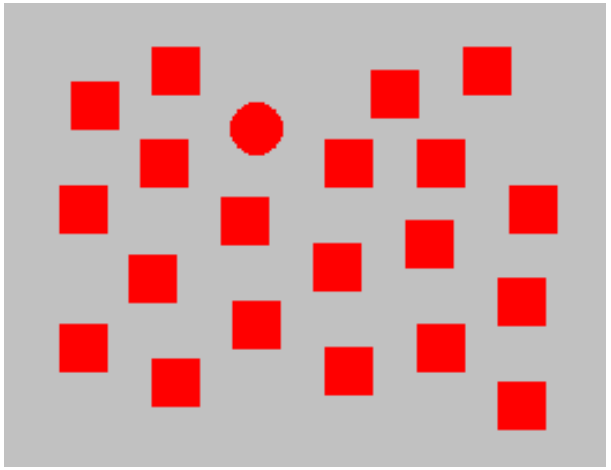


Viewer can rapidly and accurately determine whether the target (red circle) is present or absent. Difference detected in color.

From Healey 97
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

# Example: Shape Selection





Viewer can rapidly and accurately determine whether the target (red circle) is present or absent.
Difference detected in form (curvature)

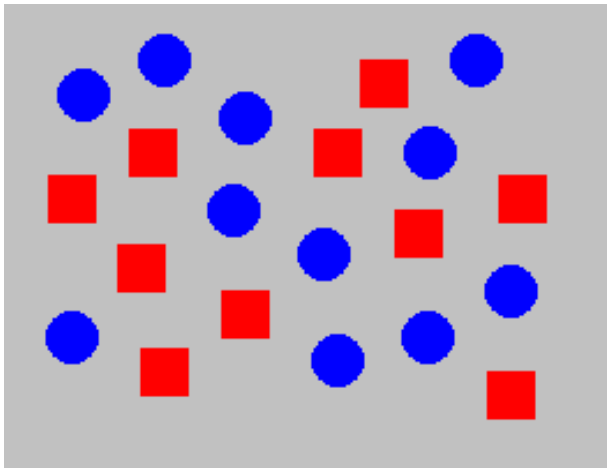
From Healey 97
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

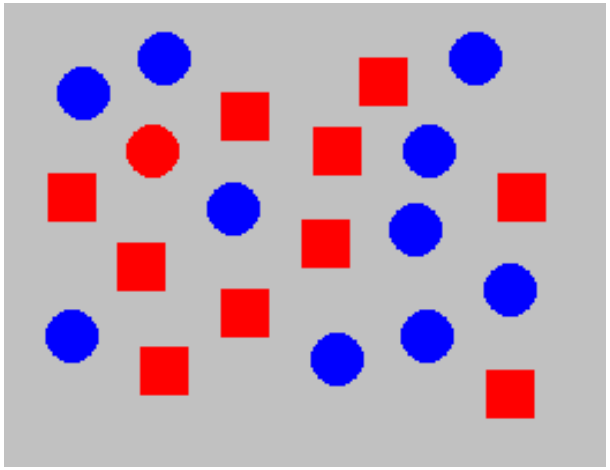
# Pre-Attentive Processing

- Less than 200-250 ms qualifies as pre-attentive
  - Eye movements take at least 200 ms
  - Yet certain processing can be done very quickly, implying low-level processing in parallel

- If a decision takes a fixed amount of time regardless of the number of distractors, it is considered to be preattentive.

# Example: Conjunction of Features

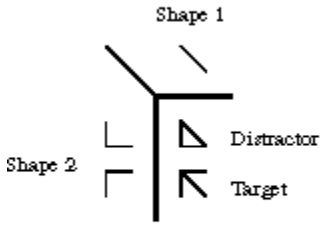


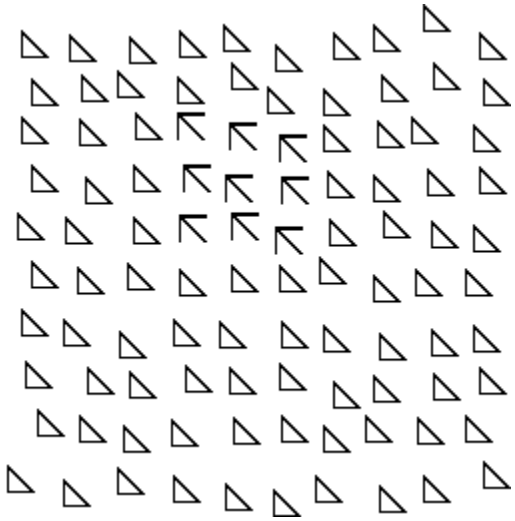


Viewer cannot rapidly and accurately determine whether the target (red circle) is present or absent when target has two or more features, each of which are present in the distractors. Viewer must search sequentially.

From Healey 97
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

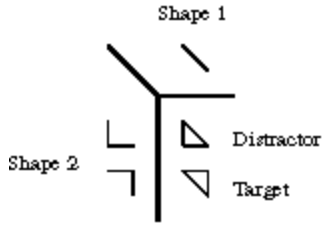
# Example: Emergent Features

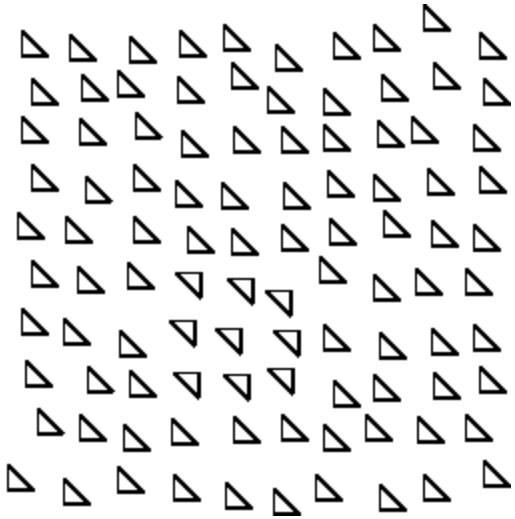


Target has a unique feature with respect to distractors (open sides) and so the group can be detected preattentively.

# Example: Emergent Features

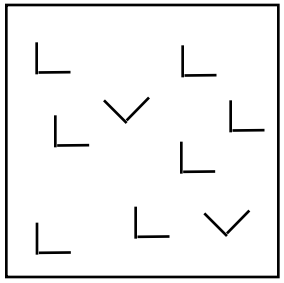


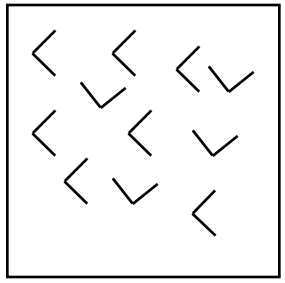



Target does not have a unique feature with respect to distractors and so the group cannot be detected preattentively.

# Asymmetric and Graded Preattentive Properties

- Some properties are asymmetric
  - A sloped line among vertical lines is preattentive
  - A vertical line among sloped lines is not
- Some properties have a gradation
  - Some more easily discriminated among than others





https://www.csc.ncsu.edu/faculty/healey/PP/

# Text is not Preattentive

SUBJECT PUNCHED QUICKLY OXIDIZED TCEJBUS DEHCNUP YLKCIUQ DEZIDIXO
CERTAIN QUICKLY PUNCHED METHODS NIATREC YLKCIUQ DEHCNUP SDOHTEM
SCIENCE ENGLISH RECORDS COLUMNS ECNEICS HSILGNE SDROCER SNMULOC
GOVERNS PRECISE EXAMPLE MERCURY SNREVOG ESICERP ELPMAXE YRUCREM
CERTAIN QUICKLY PUNCHED METHODS NIATREC YLKCIUQ DEHCNUP SDOHTEM
GOVERNS PRECISE EXAMPLE MERCURY SNREVOG ESICERP ELPMAXE YRUCREM
SCIENCE ENGLISH RECORDS COLUMNS ECNEICS HSILGNE SDROCER SNMULOC
SUBJECT PUNCHED QUICKLY OXIDIZED TCEJBUS DEHCNUP YLKCIUQ DEZIDIXO
CERTAIN QUICKLY PUNCHED METHODS NIATREC YLKCIUQ DEHCNUP SDOHTEM
SCIENCE ENGLISH RECORDS COLUMNS ECNEICS HSILGNE SDROCER SNMULOC

# Preattentive Visual Properties (Healey 97)

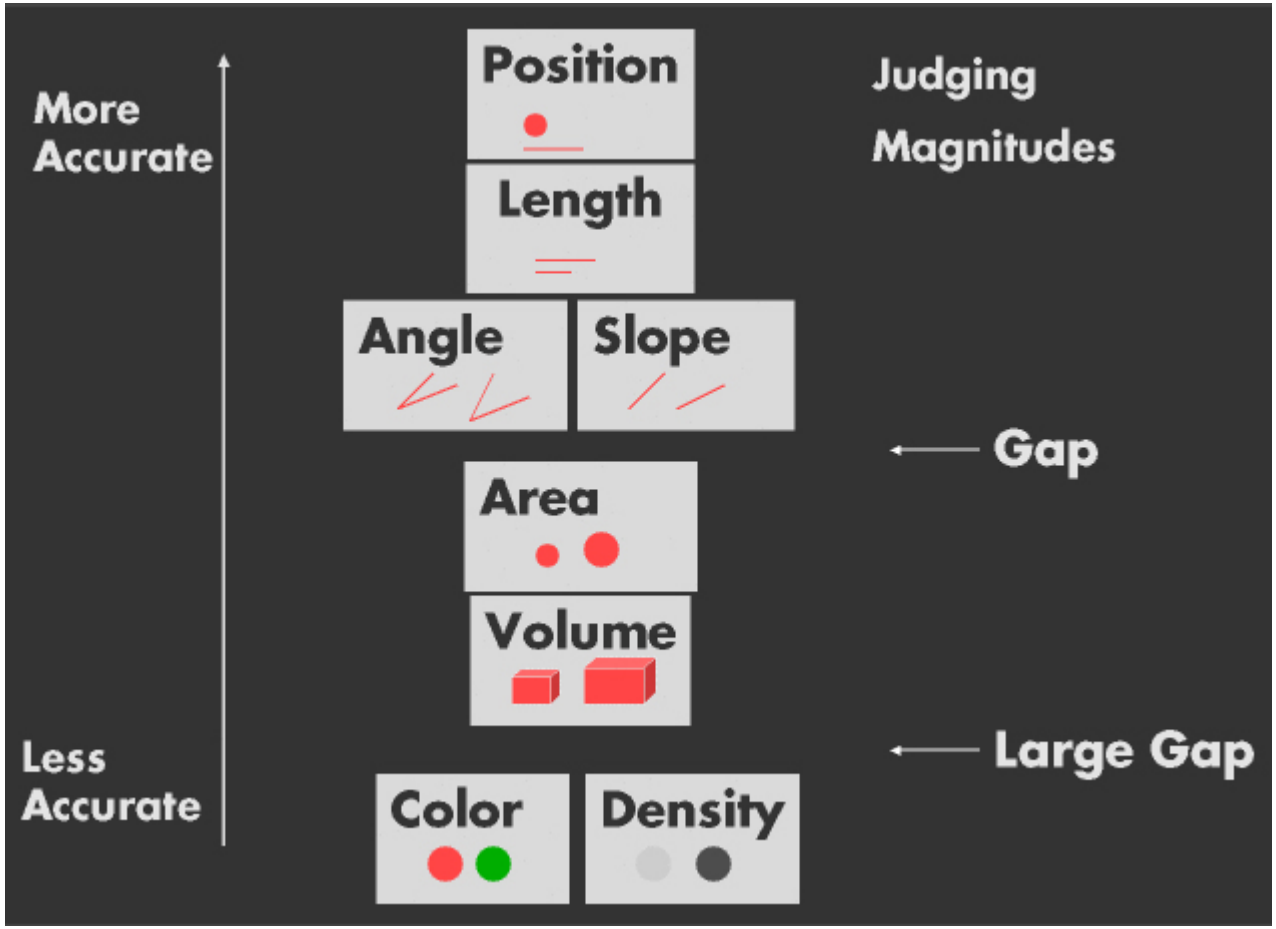
| | |
|---|---|
| length | Triesman & Gormican [1988] |
| width | Julesz [1985] |
| size | Triesman & Gelade [1980] |
| curvature | Triesman & Gormican [1988] |
| intersection | Julesz & Bergen [1983] |
| closure | Enns [1986]; Triesman & Souther [1985] |
| color (hue) | Nagy & Sanchez [1990, 1992]; D'Zmura [1991] |
| intensity | Beck et al. [1983]; Triesman & Gormican [1988] |
| flicker | Julesz [1971] |
| direction of motion | Nakayama & Silverman [1986]; Driver & McLeod [1992] |
| stereoscopic depth | Nakayama & Silverman [1986] |
| 3-D depth cues | Enns [1990] |
| lighting direction | Enns [1990] |

https://www.csc.ncsu.edu/faculty/healey/PP/

# Interpretations of Visual Properties

- Some properties can be discriminated accurately but don't have intrinsic meaning (Senay & Ingatious 97, Kosslyn, others)
- Density (Greyscale)
  - Darker -> More
- Size / Length / Area
  - Larger -> More
- Position
  - Leftmost -> first, Topmost -> first
- Hue
  - no intrinsic meaning
- Slope
  - no intrinsic meaning

# Accuracy Ranking of Quantitative Perceptual Tasks Estimated (Mackinlay 88 from Cleveland & McGill)



# Which properties used for what?

Stephen Few's Table:

(Stephen Few: Show Me The Numbers. Analytics Press, 2012.)

| Attribute | Quantitative | Qualitative |
|---|---|---|
| Line length | ● | |
| 2-D position | ● | |
| Orientation | | ● |
| Line width | | ● |
| Size | | ● |
| Shape | | ● |
| Curvature | | ● |
| Added marks | | ● |
| Enclosure | | ● |
| Hue | | ● |
| Intensity | | ● |

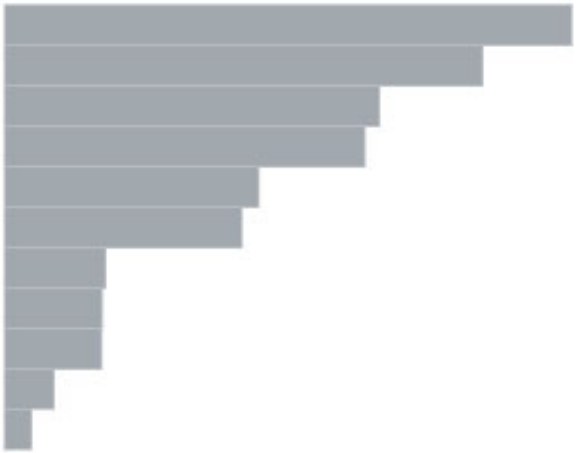
# Steve Few's Designs

**Sector Allocation of Holding**

| | | | |
|---|---|---|---|
| FINANCIALS | 21.45% | NON-CYCLICAL CONSUMER GOODS | 18.09% |
| CYCLICAL SERVICES | 14.17% | INFORMATION TECHNOLOGY | 13.61% |
| RESOURCES | 9.61% | GENERAL INDUSTRIES | 8.99% |
| UTILITIES | 3.83% | BASIC INDUSTRIES | 3.70% |
| NON-CYCLICAL SERVICES | 3.67% | CYCLICAL CONSUMER GOODS | 1.87% |

**Sector Allocation of Holding**

| | |
|---|---|
| Financials | 21.45% |
| Non-Cyclical Consumer Goods | 18.09% |
| Cyclical Services | 14.17% |
| Information Technology | 13.61% |
| Resources | 9.61% |
| General Industries | 8.99% |
| Utilities | 3.83% |
| Basic Industries | 3.70% |
| Non-Cyclical Services | 3.67% |
| Cyclical Consumer Goods | 1.87% |
| Other | 1.01% |



Stephen Few, http://www.perceptualedge.com

# Steve Few's Designs

**CONSERVATIVE ASSET ALLOCATION MODEL** Conservative investors tend to be more interested in safety of principal, liquidity and income, rather than in long-term growth or capital appreciation. These investors are willing to accept lower returns for the potential to reduce volatility.

6% International
2% Small Cap
2% Mid Cap
8% Large Cap
2% Real Estate Securities

5% High Yield Bonds
60% Bonds
15% Cash/Cash Equivalents

**MODERATELY CONSERVATIVE ASSET ALLOCATION MODEL** Moderately conservative investors are interested in safety of principal, liquidity, and income, but also seek modest growth in the value of their investments. These investors are willing to take on a little more risk to achieve that growth, with the understanding that it may increase volatility.

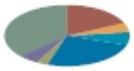
12% International
3% Small Cap
5% Mid Cap
17% Large Cap
3% Real Estate Securities

4% High Yield Bonds
56% Bonds

*An alternative would be to use a multi-asset choice, in all or in part, to achieve a similar risk profile.*

**BALANCED ASSET ALLOCATION MODEL** Balanced investors are equally interested in safety of principal and long-term growth. These investors generally want steady and sustained growth without the volatility that high-risk investments can bring.

18% International
5% Small Cap
7% Mid Cap
25% Large Cap
5% Real Estate Securities



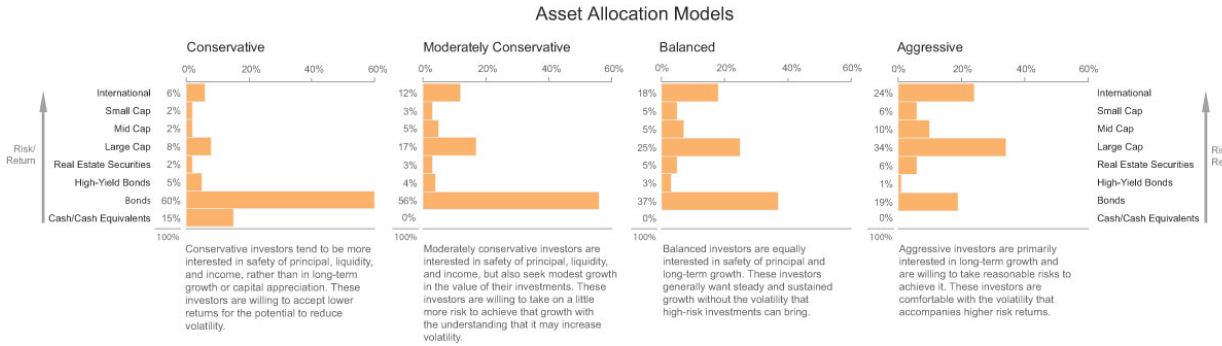
3% High Yield Bonds
37% Bonds

*An alternative would be to use a multi-asset choice, in all or in part, to achieve a similar risk profile.*

**AGGRESSIVE ASSET ALLOCATION MODEL** Aggressive investors are primarily interested in long-term growth and are willing to take reasonable risks to achieve it. These investors are comfortable with the volatility that accompanies higher risk investments.

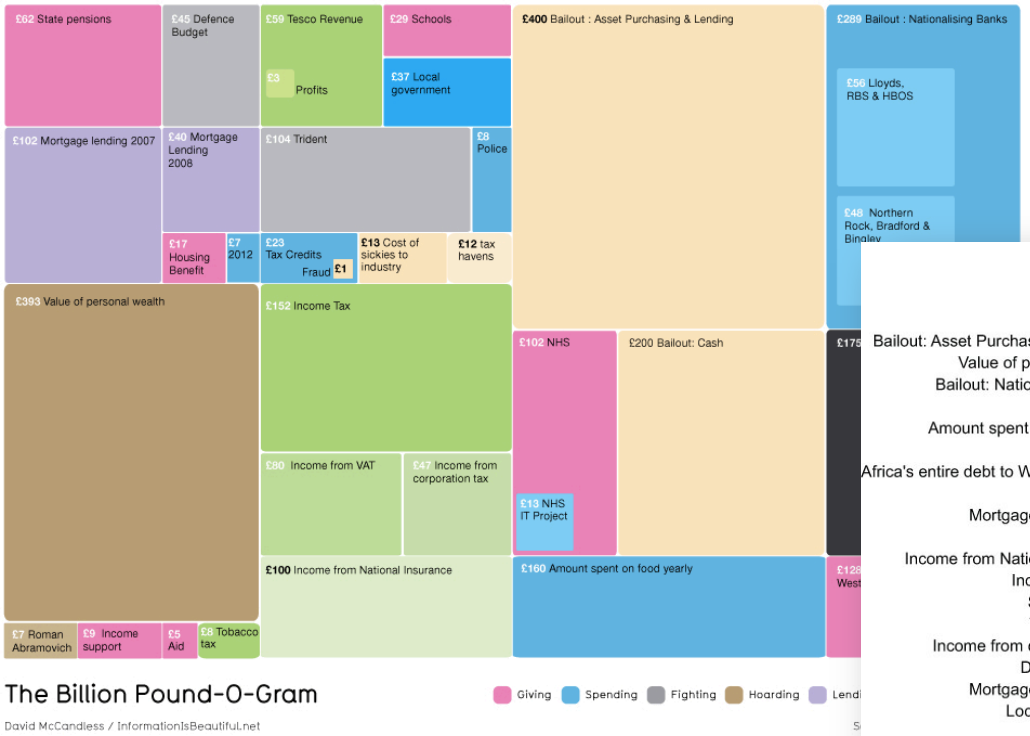
24% International
6% Small Cap
10% Mid Cap
34% Large Cap
6% Real Estate Securities

1% High Yield Bonds
19% Bonds

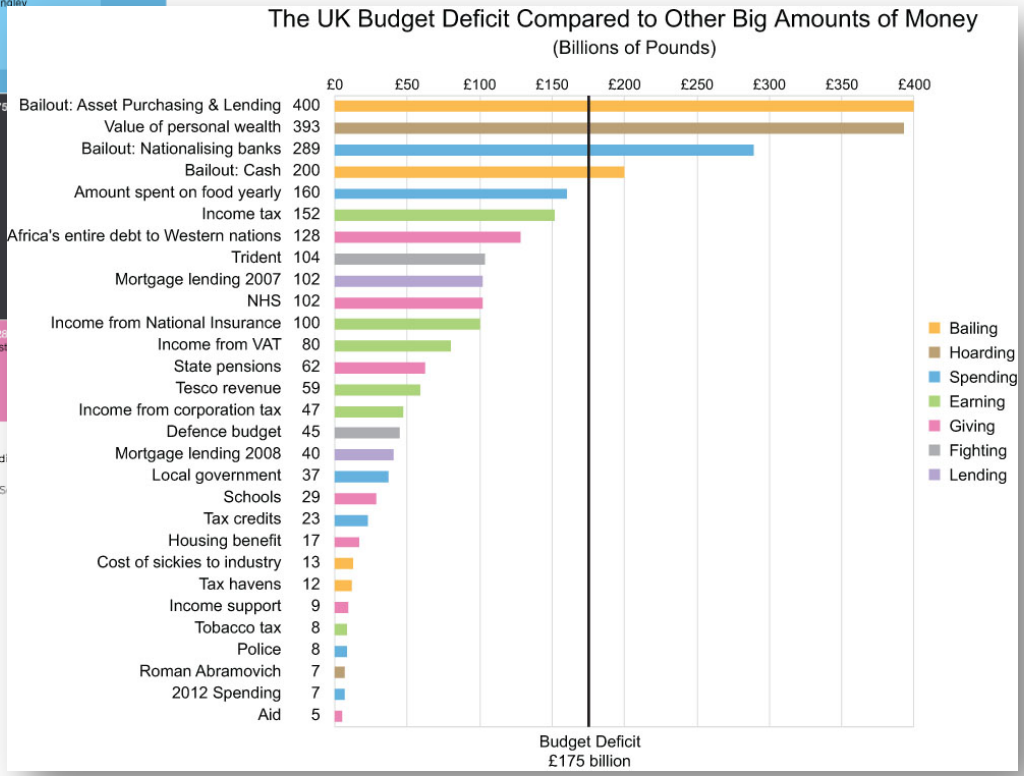



Stephen Few, http://www.perceptualedge.com

# Steve Few's Designs




Which is bigger: Income Support or Police?




Stephen Few, http://www.perceptualedge.com

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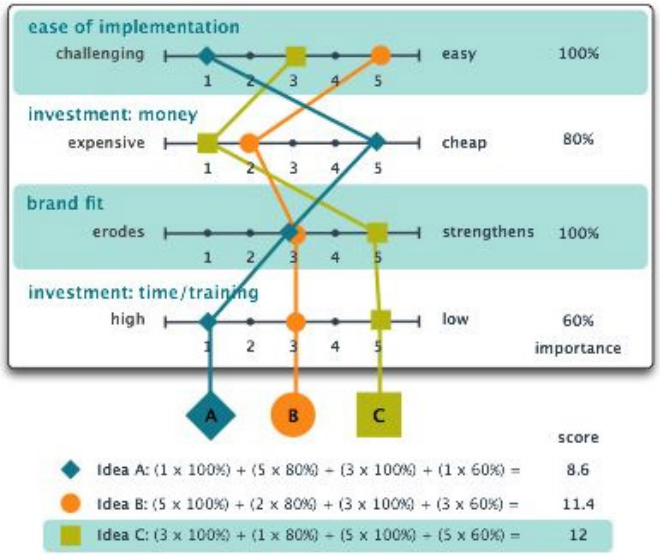
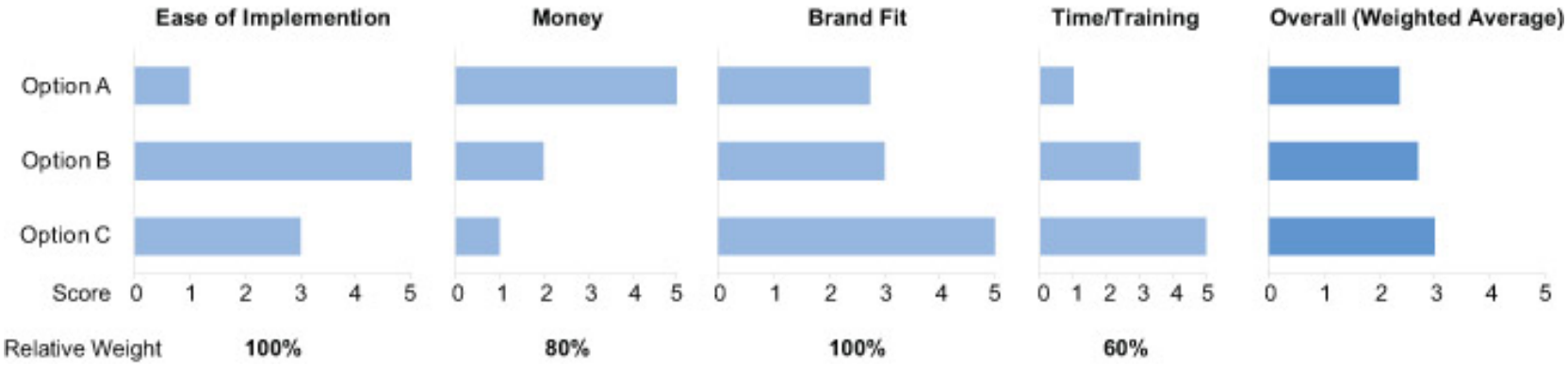
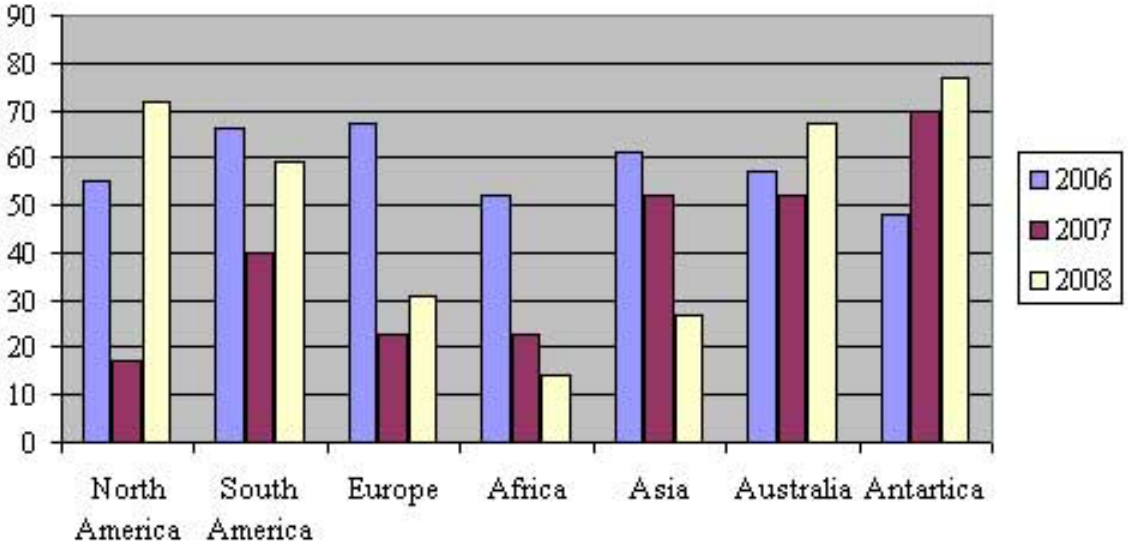


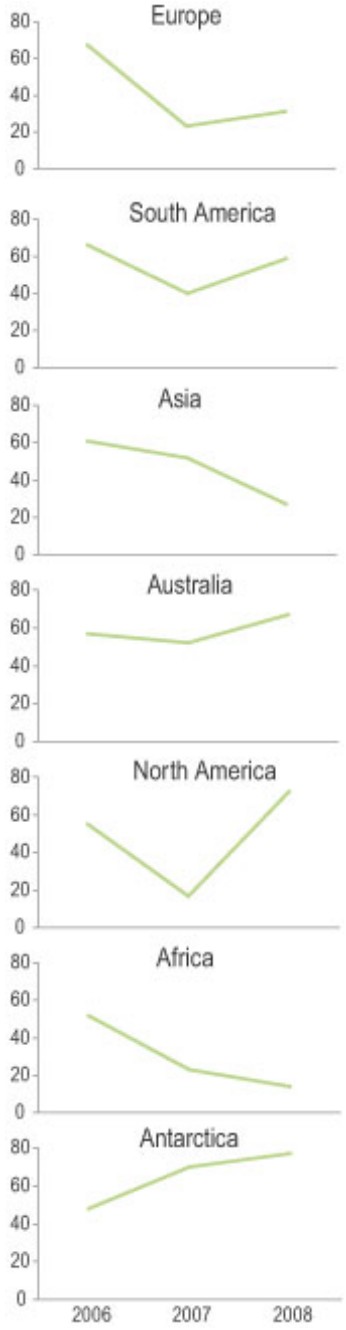

"Using this advanced method I was able to confirm that idea C would be our best bet."




Stephen Few, http://www.perceptualedge.com

# Steve Few's Designs




principle of "small multiples"

Stephen Few, http://www.perceptualedge.com

# Plotting Likert and Other Rating Scales

Percentages for Agreement that primary position is professionally challenging by demographics characteristics

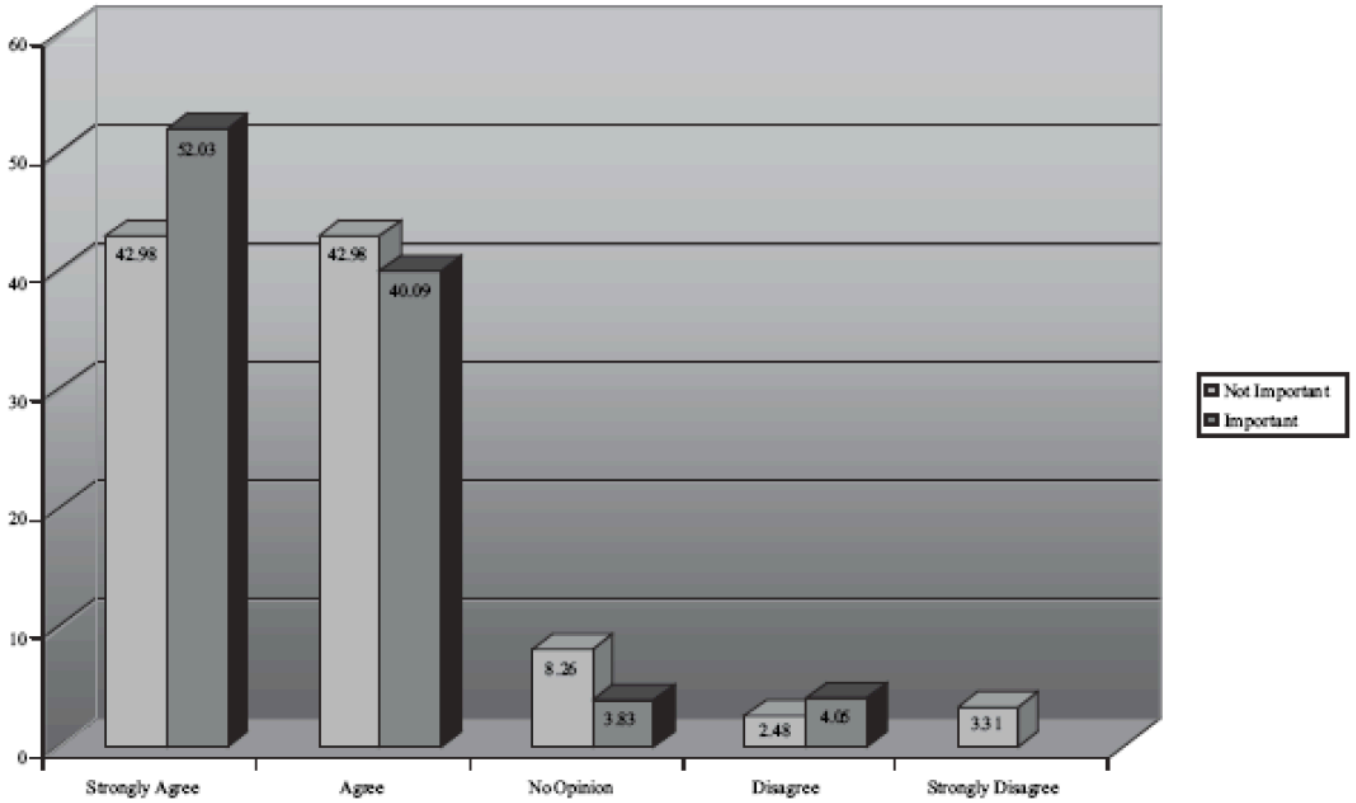
| | Total Count* | Strongly Agree | Agree | No Opinion | Disagree | Strongly Disagree | Total |
|---|---|---|---|---|---|---|---|
| *All Survey Responses* | *565* | *50.1* | *40.7* | *4.8* | *3.7* | *0.7* | *100* |
| **Employment sector** | | | | | | | |
| Academic (nonstudent) | 253 | 64.0 | 30.8 | 3.2 | 2.0 | 0.0 | 100 |
| Business and industry | 176 | 40.6 | 50.0 | 2.8 | 6.3 | 0.0 | 100 |
| Federal, state, and local government | 71 | 38.0 | 47.9 | 7.0 | 4.2 | 2.8 | 100 |
| Private consultant/self-employed | 28 | 39.3 | 53.6 | 7.1 | 0.0 | 0.0 | 100 |
| Other (including retired, students, not employed, etc.) | 34 | 29.4 | 44.1 | 14.7 | 5.9 | 5.9 | 100 |
| **Race** | | | | | | | |
| White | 400 | 50.0 | 41.8 | 4.5 | 2.8 | 1.0 | 100 |
| Asian | 122 | 53.3 | 40.2 | 3.3 | 3.3 | 0.0 | 100 |
| Black or African American | 10 | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 | 100 |
| Other | 17 | 47.1 | 35.3 | 5.9 | 11.8 | 0.0 | 100 |
| **Education** | | | | | | | |
| Associate's and Bachelor's | 175 | 37.1 | 49.1 | 5.7 | 6.9 | 1.1 | 100 |
| Master's and Above | 388 | 55.9 | 36.9 | 4.4 | 2.3 | 0.5 | 100 |
| **Gender** | | | | | | | |
| Male | 356 | 50.6 | 41.0 | 4.2 | 3.4 | 0.8 | 100 |
| Female | 200 | 51.0 | 39.0 | 6.0 | 3.5 | 0.5 | 100 |

# General Note: Due to a small number of respondents in some cells, we combined some of the response categories.
* The total count does not include nonrespondents.

Robbins, Heiberger: Plotting Likert and Other Rating Scales, JSM 2011.

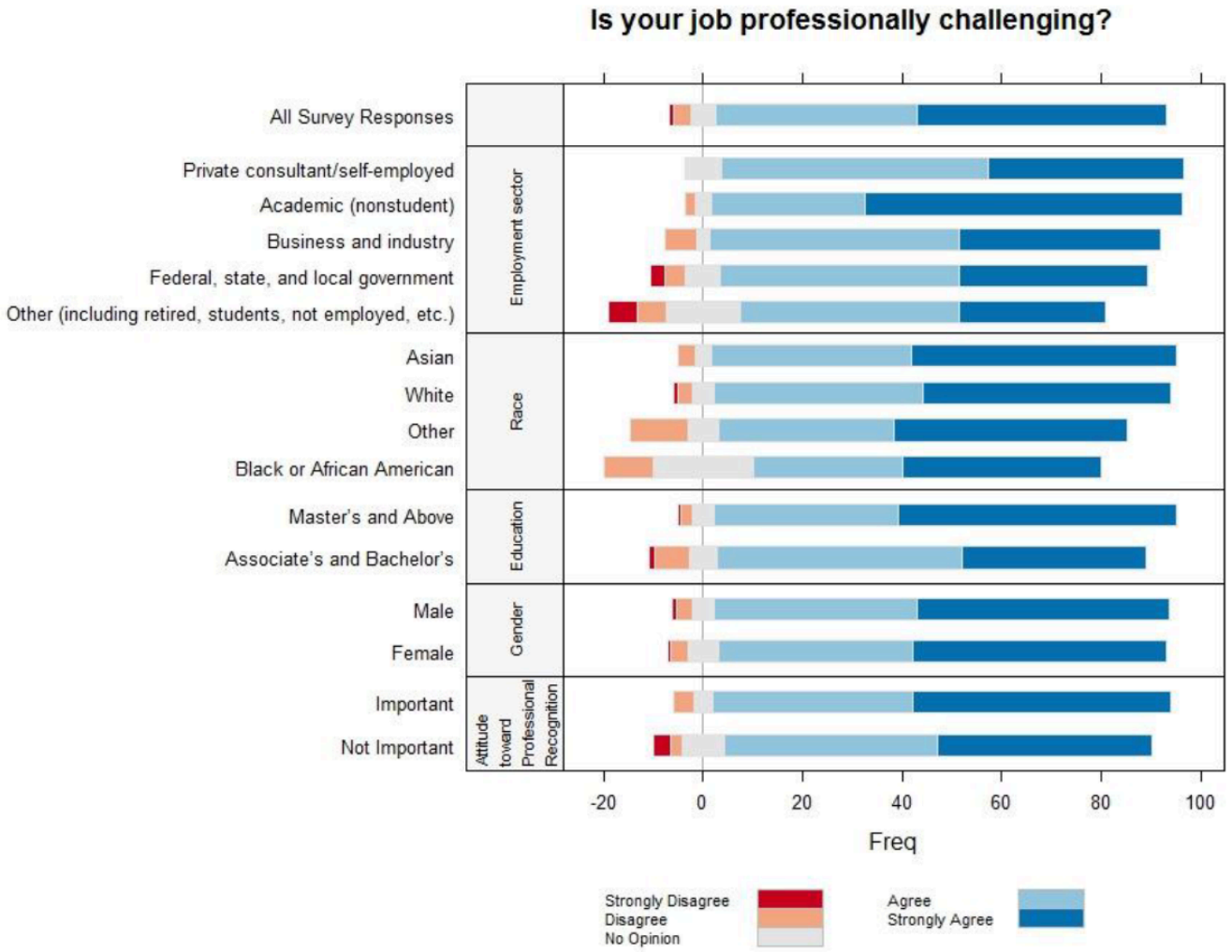
# Plotting Likert and Other Rating Scales

Percentages for Agreement that primary position is professionally challenging by demographics characteristics



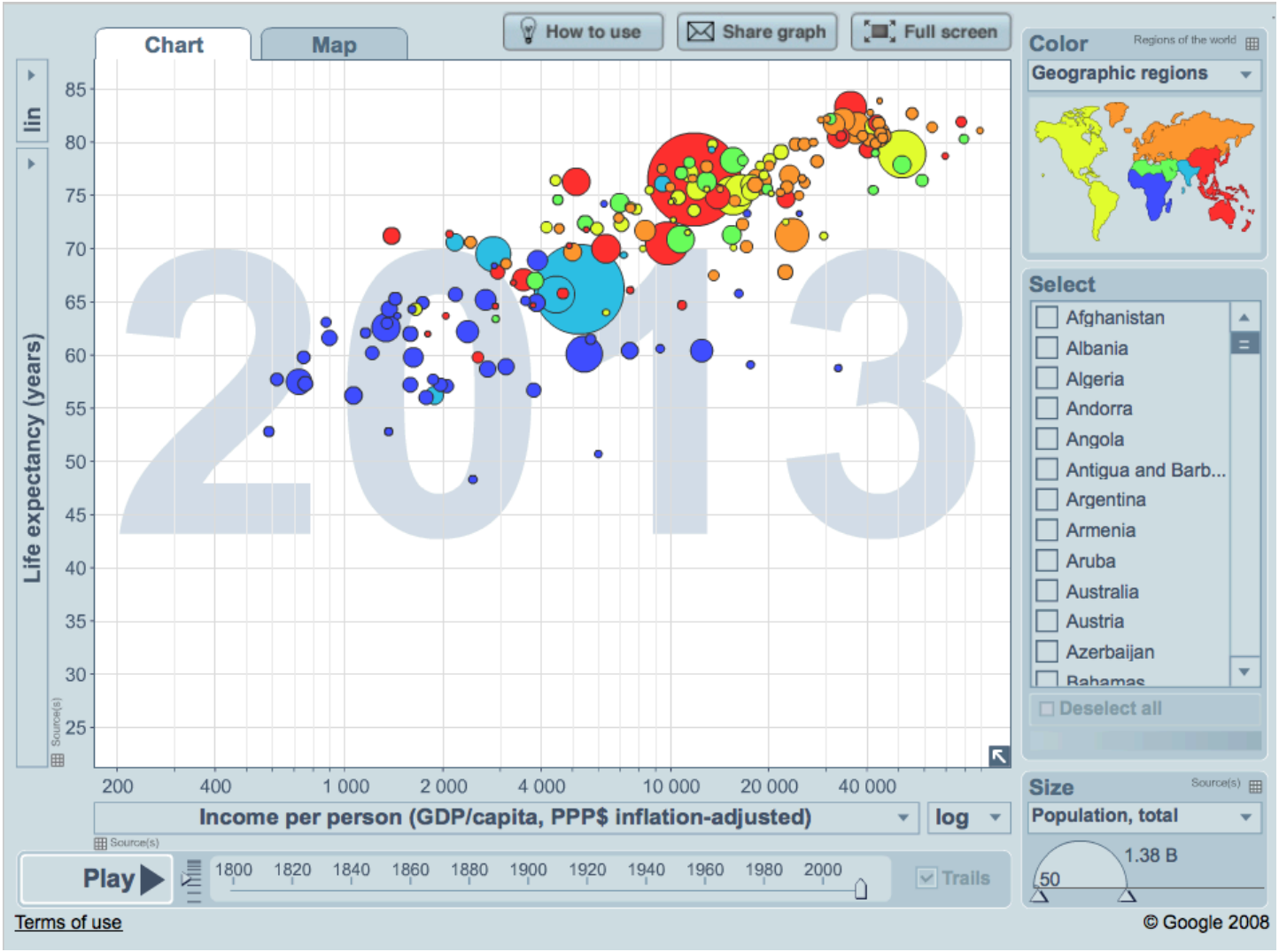

Robbins, Heiberger: Plotting Likert and Other Rating Scales, JSM 2011.

# Plotting Likert and Other Rating Scales




Robbins, Heiberger: Plotting Likert and Other Rating Scales, JSM 2011.

# Interactive Data Exploration




https://www.gapminder.org/world/

# TED Talk by Hans Rosling

- https://www.youtube.com/watch?v=hVimVzgtD6w