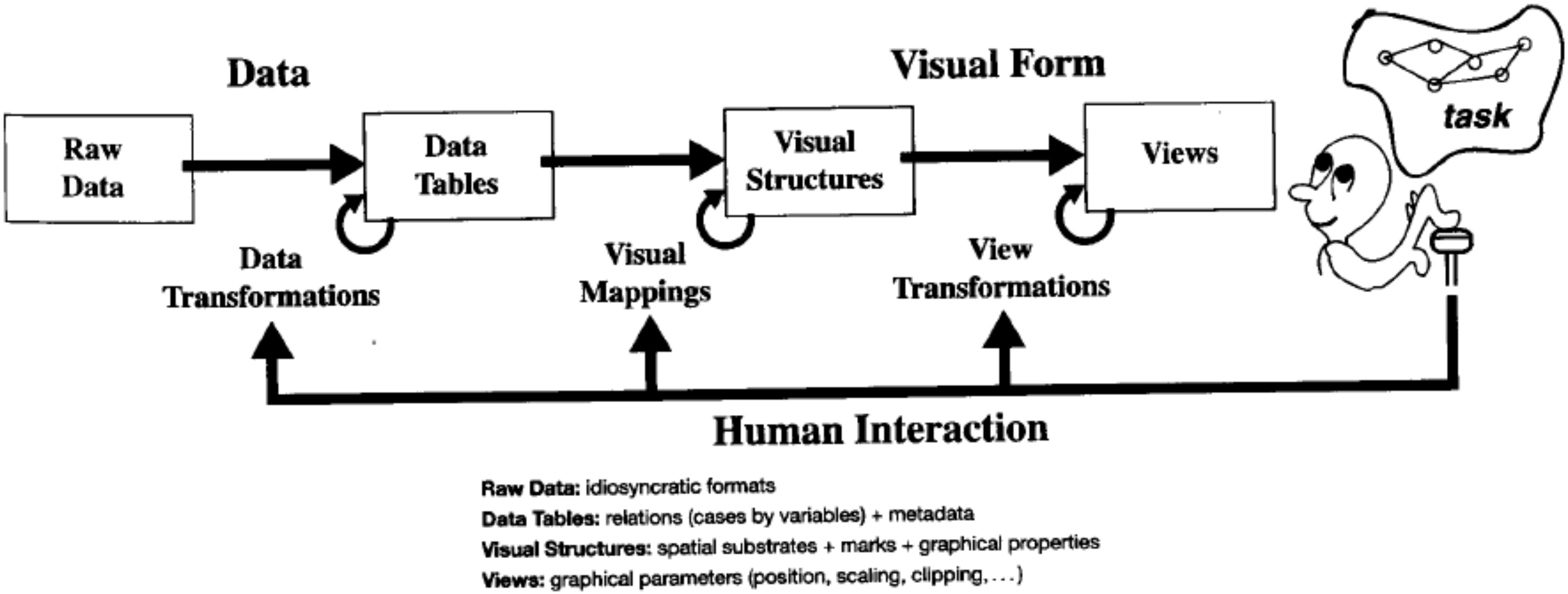
3 Information Visualization

Literature:

- E. Tufte: The Visual Display of Quantitative Information,2nd ed., B&T 2001
- Marti Hearst
  - http://bailando.sims.berkeley.edu/talks/chi03-tutorial.ppt
- Margret-Anne Storey
  - http://www.cs.uvic.ca/~mstorey/teaching/infovis/course_notes/introduction.pdf

Visualization Reference Model



- Raw Data → Data Table
  filtering
- Data Table → Visual Structure
  pick mappings
- Visual Structure → Views
  probes, viewpoints, distortions

(Storey, 2004)

Types of Data

- Entities
  - Objects of interest
- Relationships
  - Form structures that relate entities
  - Many kinds of relationships exist
    - Is-part-of, is-kind-of, is-xyx-to, …
- Attributes of entities or relationships
  - Attribute vs. Independent information (entity)
  - Attribute is variable of a certain value type
- Operations
  - Actions can also be considered as data
- Metadata
  - Data about data

Basic Attribute Value Types

- Nominal (qualitative)
  - No inherent order (but can be tested for equality =)
  - Examples: City names, types of diseases, kind of fruit, ...
- Ordinal (qualitative)
  - Ordered (can be tested for <, >), but not at measurable intervals
  - Sequencing things, ranking
  - Examples: first, second, third, …; cold, warm, hot
- Nominal/Interval (quantitative)
  - Integer or real numbers
  - Ordered (can be tested for <, >)
  - Arithmetical operations, ratios are possible
  - Interval data: Derivation of gaps (e.g. time between departure and arrival)
  - Examples: Size and population of countries, schedule times, numeric grades

Hearst, 2003

Attribute Dimensions

- All kinds of *tensors* may appear as attribute values
- Tensor rank 0: Scalar
  - E.g. mass, temperature, length, price
- Tensor rank 1: Vector
  - E.g. force, momentum, location, direction
- Tensor rank 2: Matrix
  - E.g. linear transformation
- …

Mapping to Visual Structures

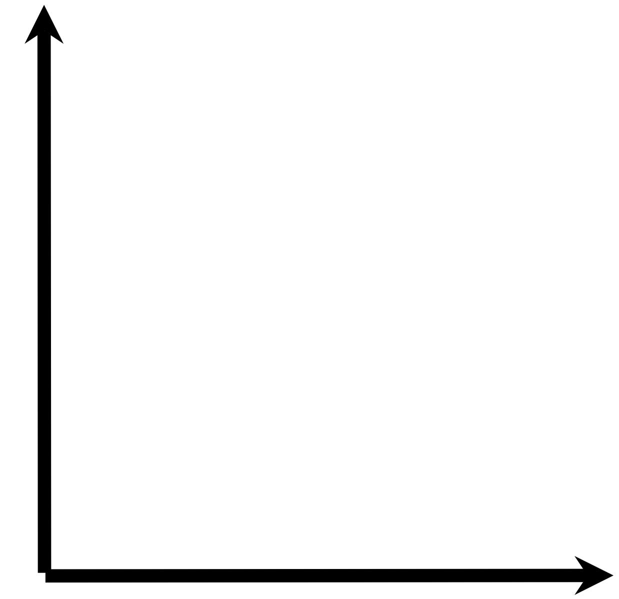
- Mapping from data tables to visual structures is
  - *expressive*

    if all data in the table (and only this information) are presented in the structure
  - *efficient*

    if the visual representation is easier to interpret for humans, can convey more distinctions or leads to fewer errors

(Storey, 2004)

Visual Structure

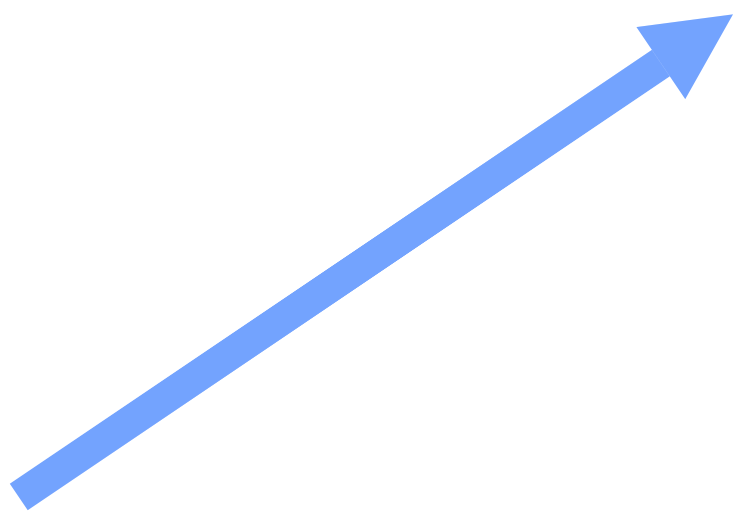


- Spatial substrate
  - –Fixed number of dimensions
  - –Inherently perceptual
- Axes
  - –Unstructured axis
  - –Nominal axis (division into subregions)
  - –Ordinal axis (order has meaning)
  - –Quantitative axis (metric associated with region)
- Graphical marks
  - –Visible things that occur in space

(based on Storey, 2004)

Graphical Marks

- Four elementary types:
  - Points (0D)
  - Lines (1D)
  - Areas (2D)
  - Volumes (3D)
- In practice, marks need more dimensions than in theory
  - E.g. Points can be seen only if painted as areas



(based on Storey, 2004)

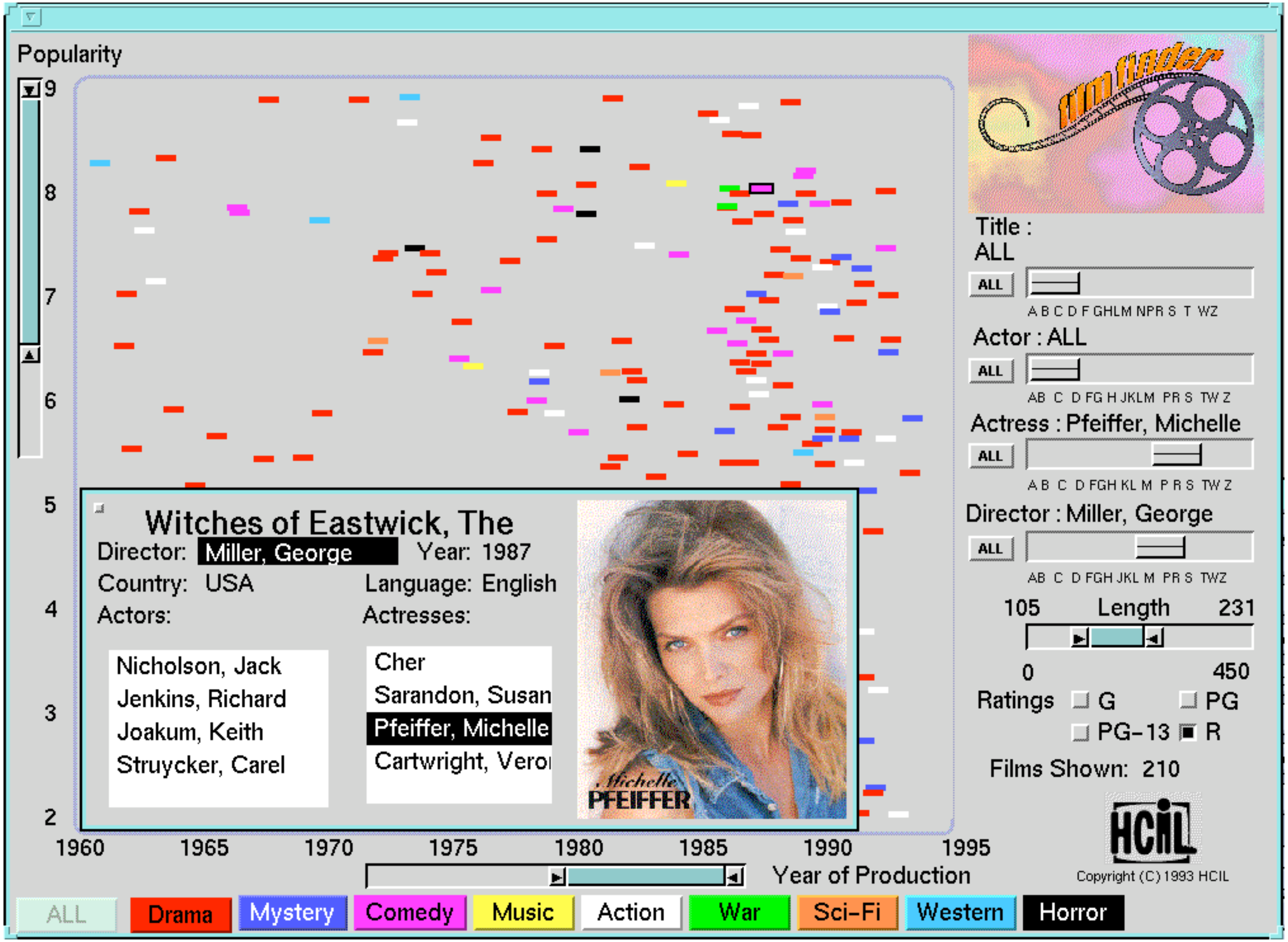
Mapping Examples

(assume 2-dimensional representations)

- Two scalars:
  - –Price vs. top speed of cars
- Ordinal and scalar:
  - –Max. price vs. brand of cars
- Ordinal and vector:
  - –Price range vs. brand of cars
- Vector and scalar:
  - –Location vs. average temperature
- Vector and vector:
  - –Location vs. temperature range

Example: FilmFinder

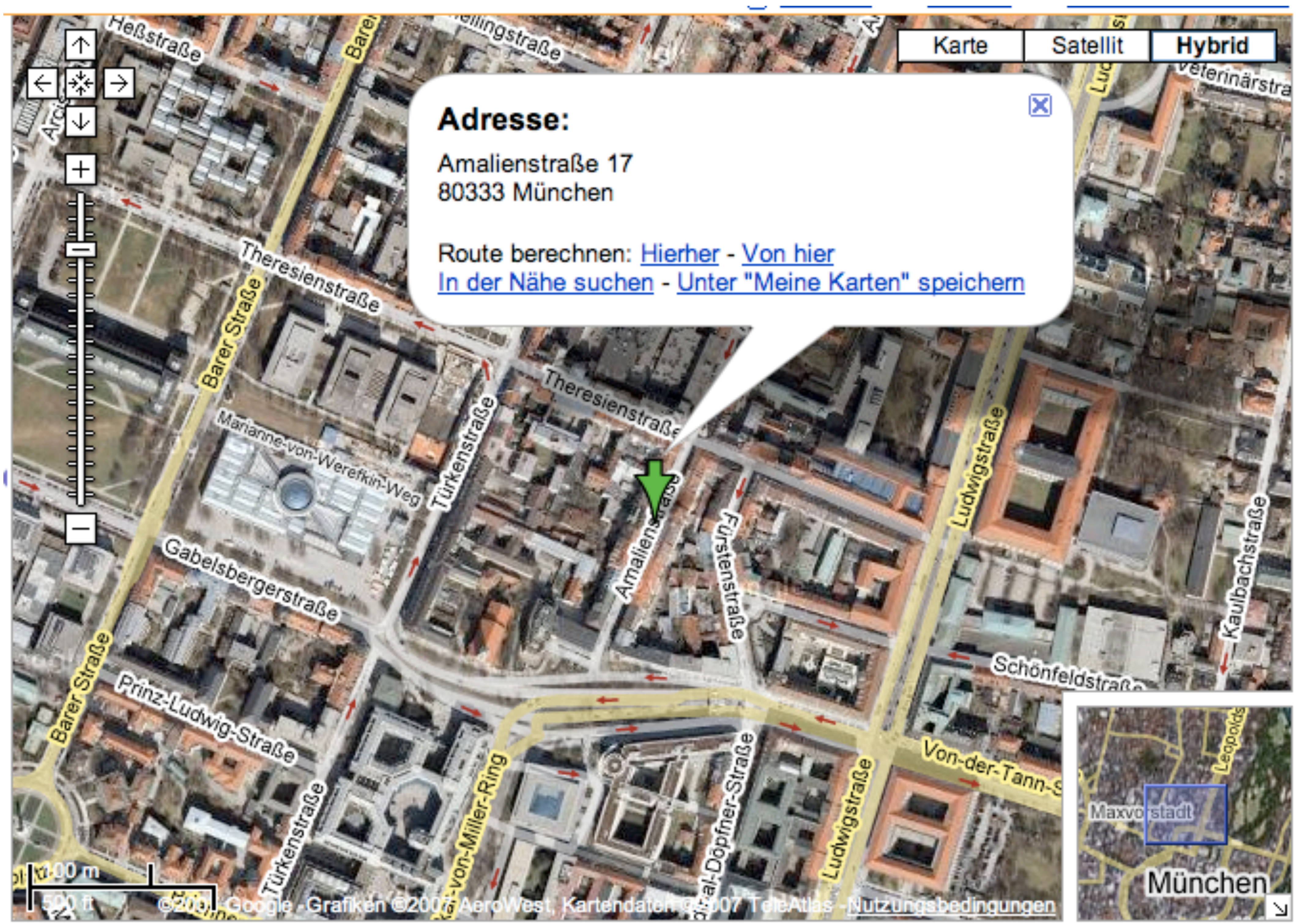
University of Maryland, HCIL



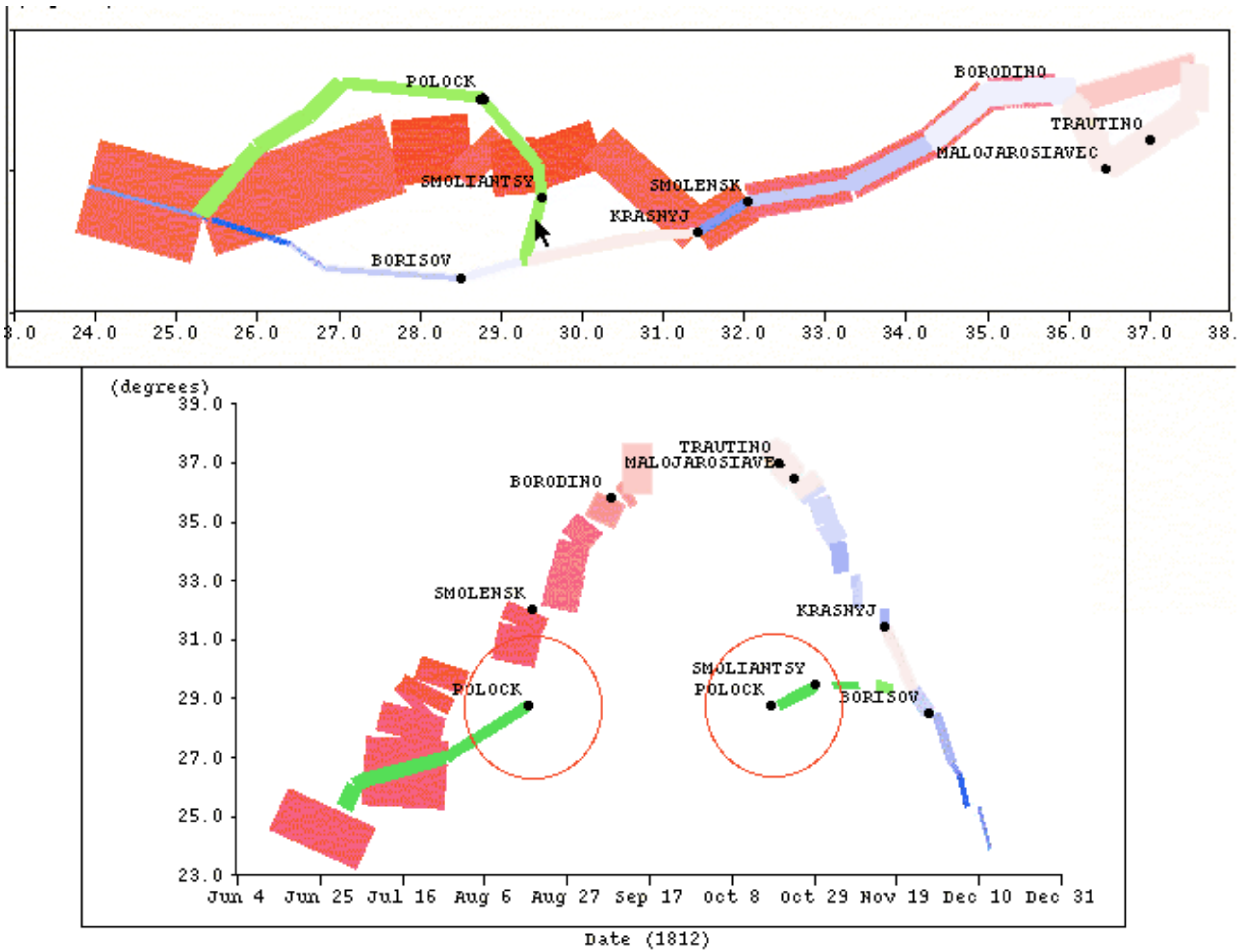
View Transformations

- Ability to interactively modify and augment visual Structures
  - Turning static presentations into visualizations
- Time is exploited to display more information
  - Dynamic Visualizations exist in space time
- Three common view transformations:
  1. Location probes: use location to reveal additional info
  2. Viewpoint controls: zoom, pan, clip the viewpoint
  3. Distortion: focus + context view

Example: View Transformations in Google Maps



Example: Interactive Graphs



http://www.cs.cmu.edu/~sage

Accuracy Ranking of Perceptual Tasks

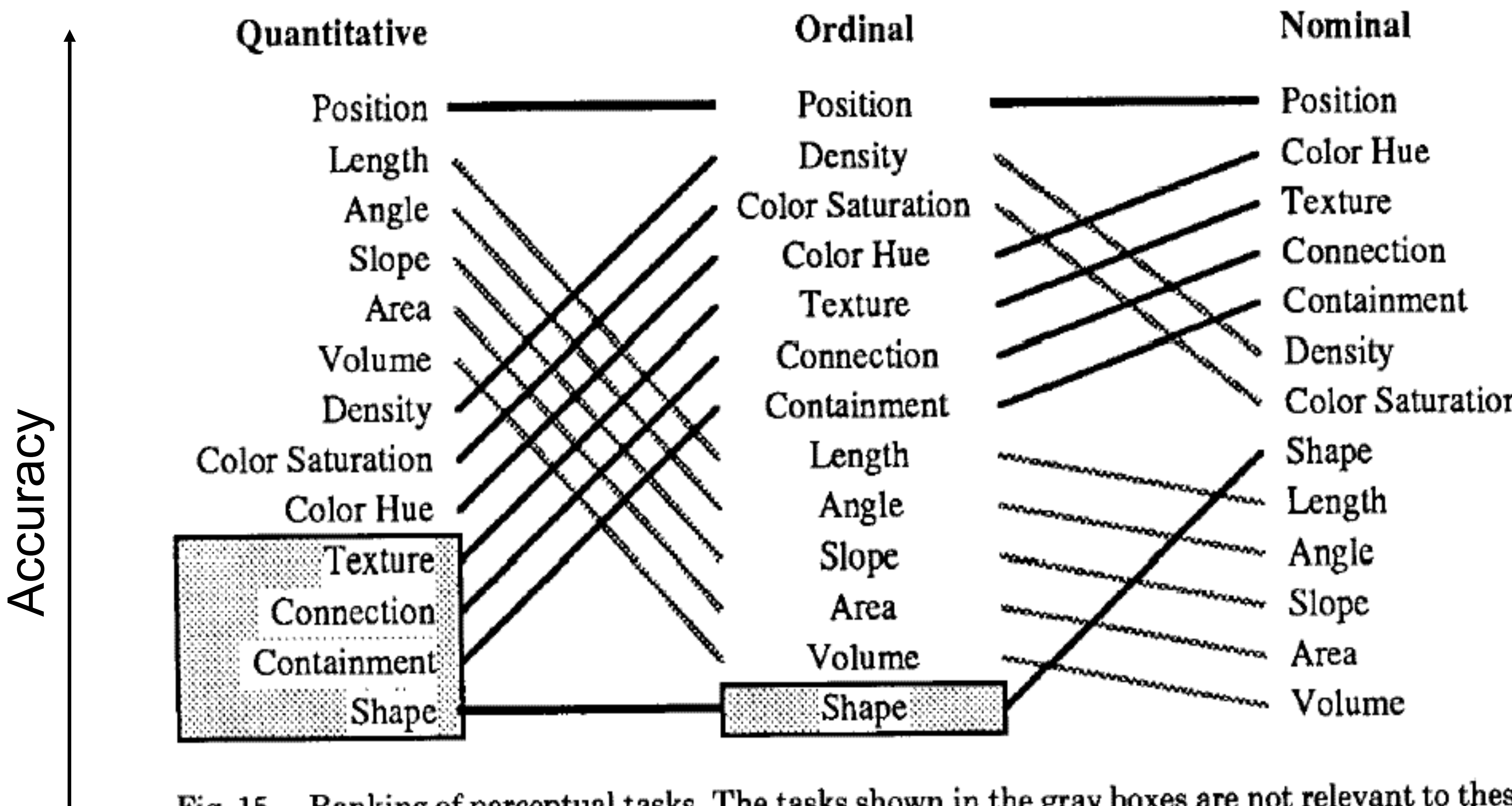


Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data.

Mackinlay 88

Interpretations of Visual Properties

- Some properties have intrinsic meaning
  (Senay & Ingatious 97, Kosslyn, others)
  - Density (Greyscale)

    Darker -> More
  - Size / Length / Area

    Larger -> More
  - Position

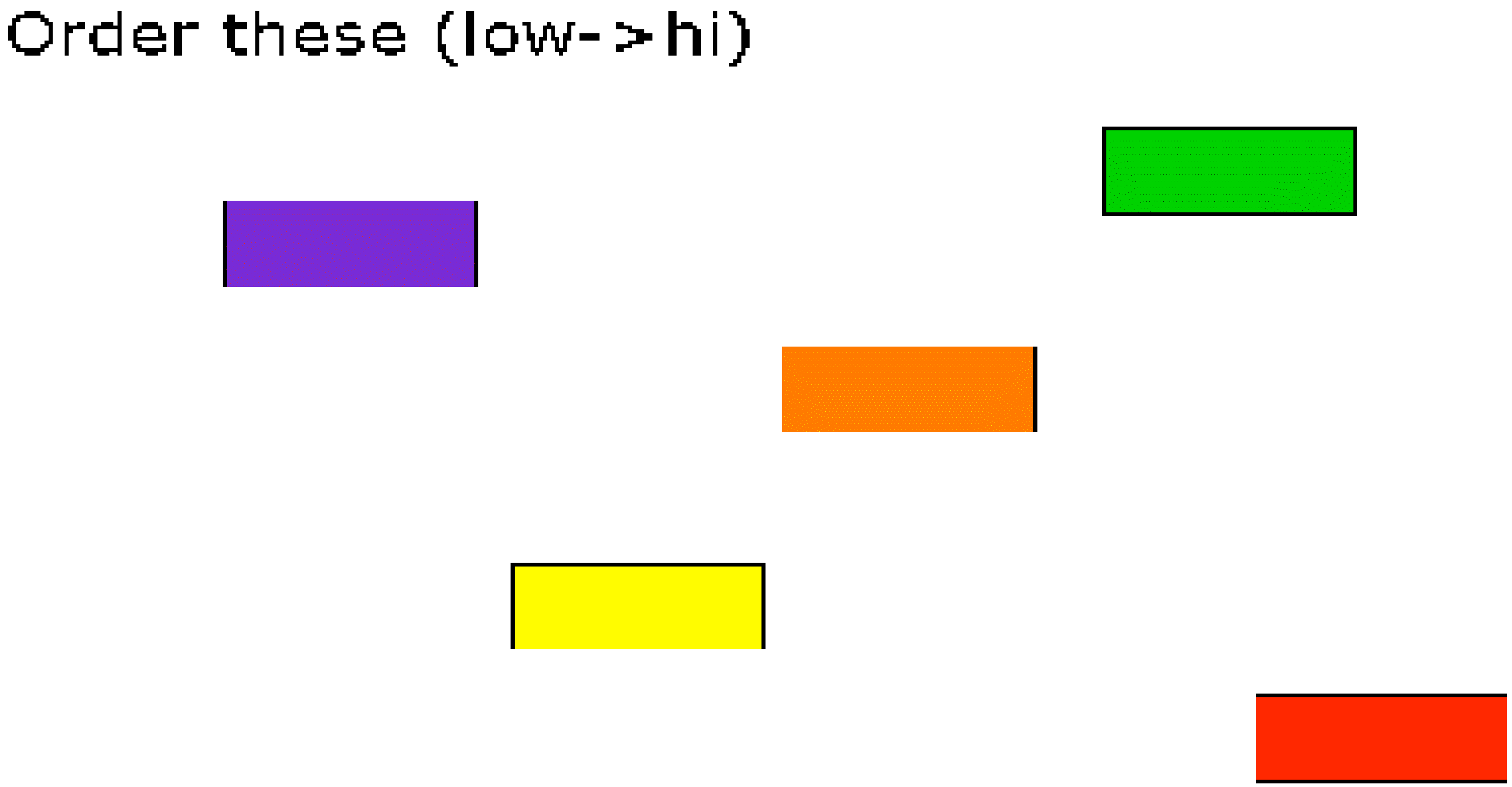
    Leftmost -> first, Topmost -> first
- Some properties do not have intrinsic meaning, even some perceived quite accurately
  - Hue

    ??? no intrinsic meaning
  - Slope

    ??? no intrinsic meaning

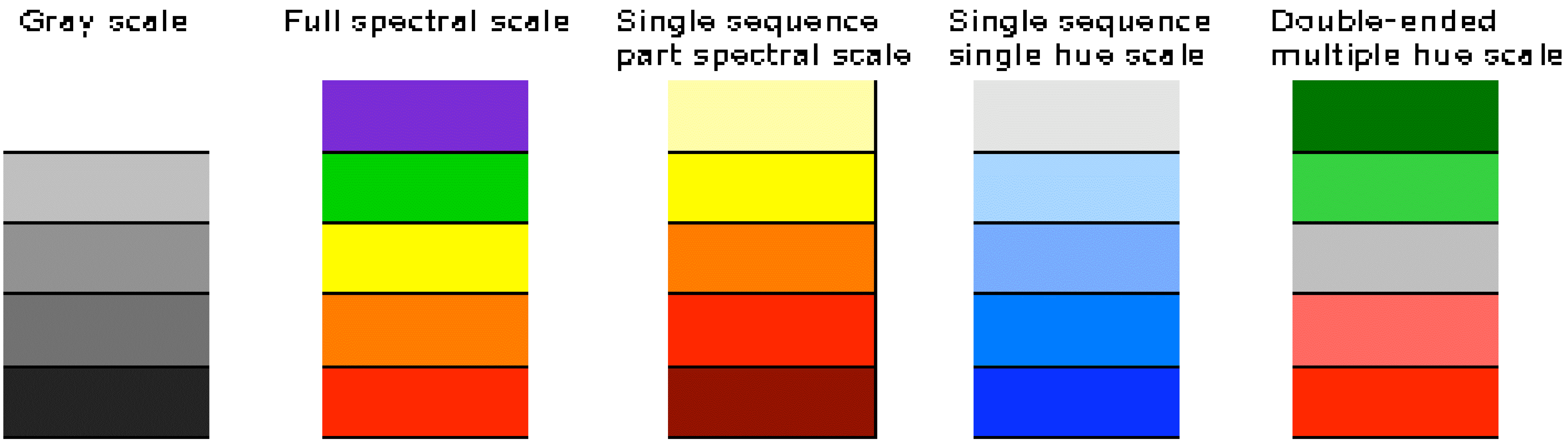
Hearst, 2003

Color Schemes (1)



Hearst, 2003

Color Schemes (2)



Hearst, 2003

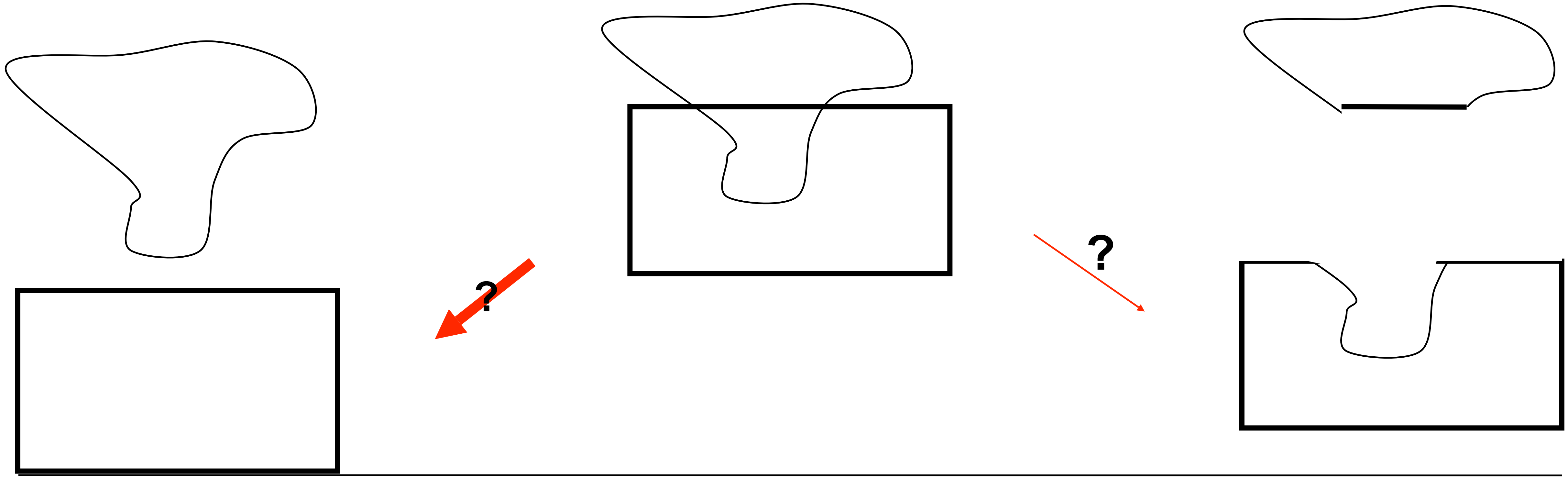
Using Color

- Call attention to specific items
- Distinguish between classes of items
  - Increases the number of dimensions for encoding
- Increase the appeal of the visualization
- Proceed with caution
  - Less is more
  - Representing magnitude is tricky
- Examples
  - Red-orange-yellow-white
    - Works for cost
  - Green-light green-light brown-dark brown-grey-white works for atlases
  - Grayscale is unambiguous but has limited range

Hearst, 2003

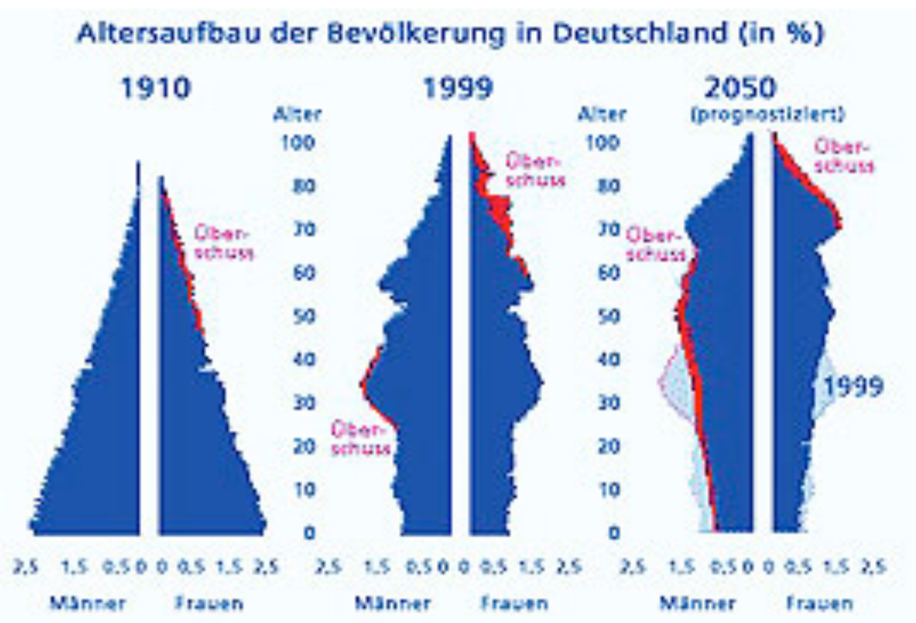
Continuity

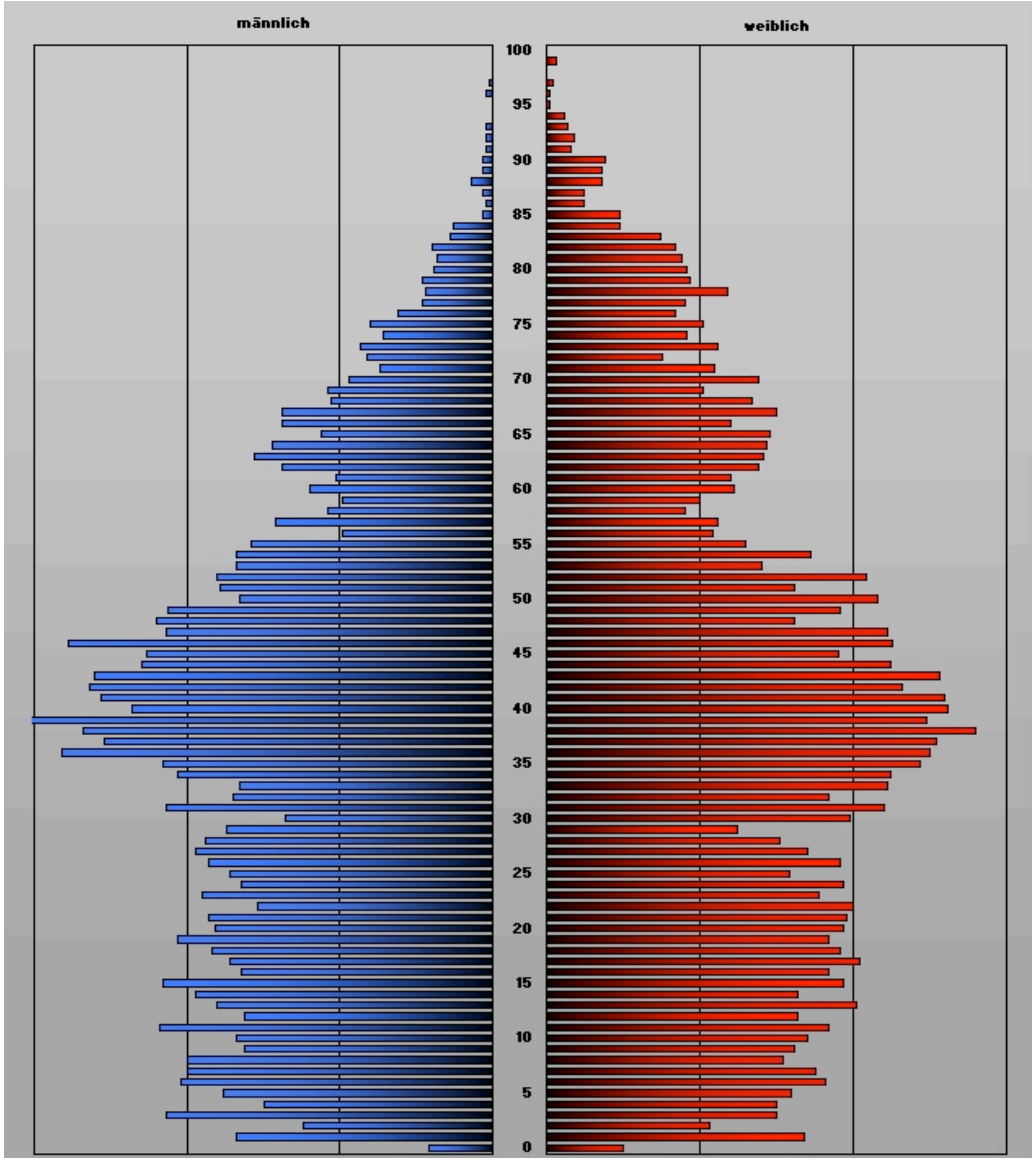
- Experience tells that visual elements are more likely to be continuous
- Implied connection
- connections are used to show relations



Symmetry

- Symmetrical to emphasize relationship

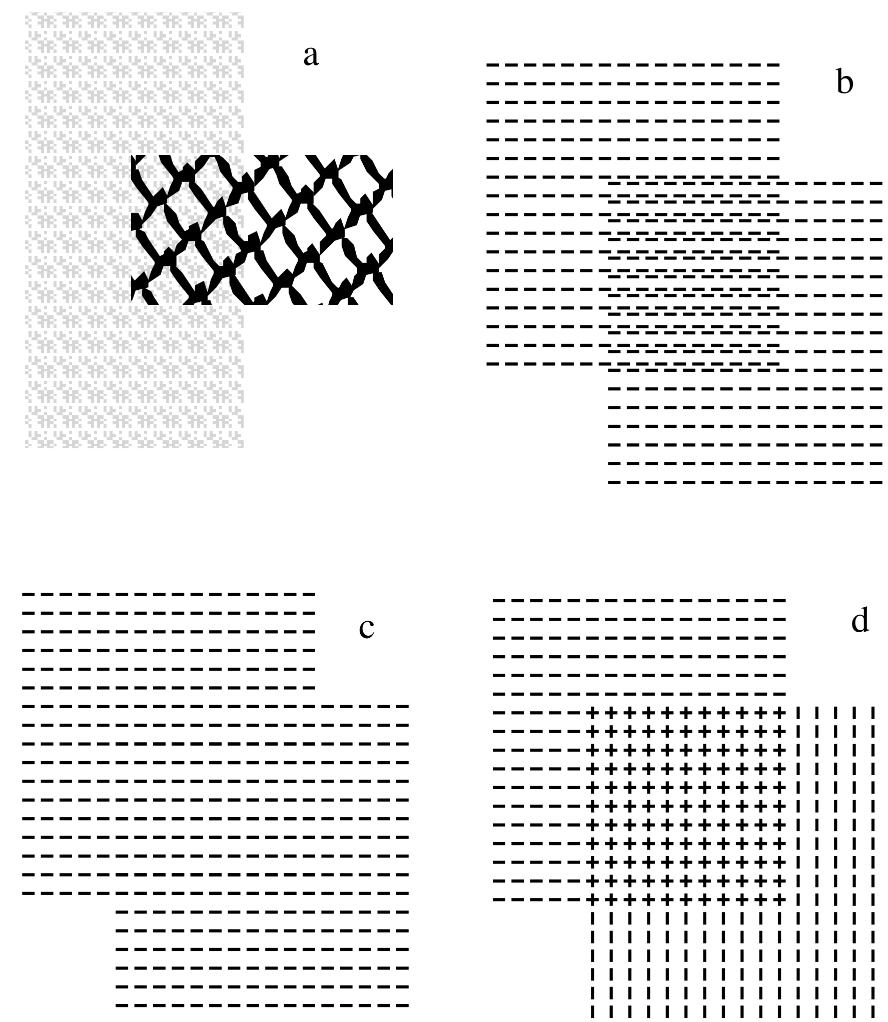




Figure, Background, Transparency, Overlap

- What is foreground and what is background?
- Transparency is perceived only when good continuity and color correspondence exists.
- Visual interference in overlapping textures

a



Principles of Graphical Excellence (E. Tufte)

- Graphical excellence
  - The well-designed presentation of interesting data – a matter of substance, of statistics, and of design
    - » consists of complex ideas communicated with clarity, precision and efficiency
    - » is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space
    - » **requires telling the truth about the data**.

Hearst, 2003

Tufte Principle

Data ink = ink used for representing data

Chart ink = ink used for extra elements different from data

Avoid “chart junk”! Maximize the data-ink ratio:

$$\text{Data-ink ratio} = \frac{\text{data ink}}{\text{total ink used in graphic}}$$

Hearst, 2003

Tufte's Graphical Integrity

- Some lapses intentional, some not

$$\text{Lie Factor} = \frac{\text{size of effect in graph}}{\text{size of effect in data}}$$

- Misleading uses of area
- Misleading uses of perspective
- Leaving out important context
- Lack of taste and aesthetics

Hearst, 2003

Lie factor

$$\textbf{lie factor} = \frac{\text{size of effect shown in graph}}{\text{size of effect in data}}$$

where

$$\textbf{size of effect} = \frac{|\text{second value - first value}|}{\text{first value}}$$

A lie factor that is either much higher or much lower than one is bad. A **high** lie factor **exaggerates** differences between values. A **low** lie factor **obscures** differences between values.

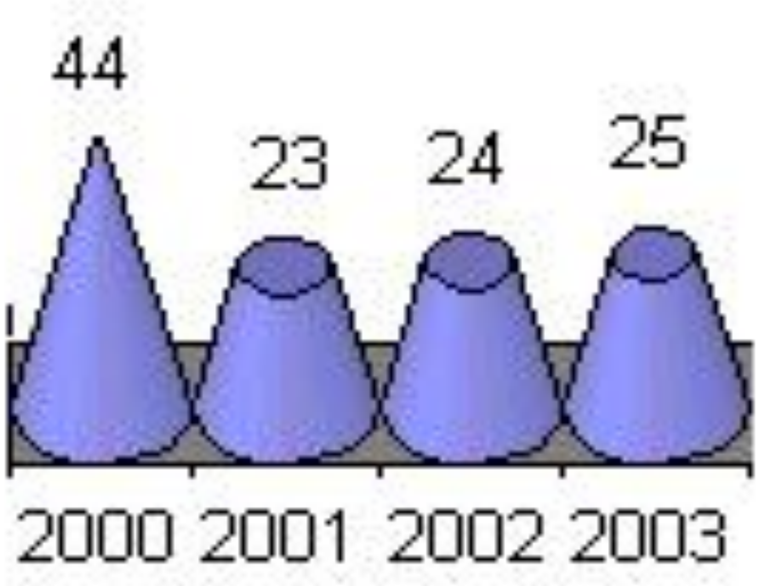
A common example of a **high** lie factor occurs when both dimensions of a two-dimensional figure are made proportional to the same data, so that the size of the figure is proportional to the square of the data; for instance,

Year	Books circulated
2001	100 
2002	141 
2003	200 

where the lie factor is about 2.4.

http://instruct.uwo.ca/fim-lis/504/504gra.htm

An example of a **low** lie factor can be seen in the "Cones" custom chart format in Microsoft Excel.

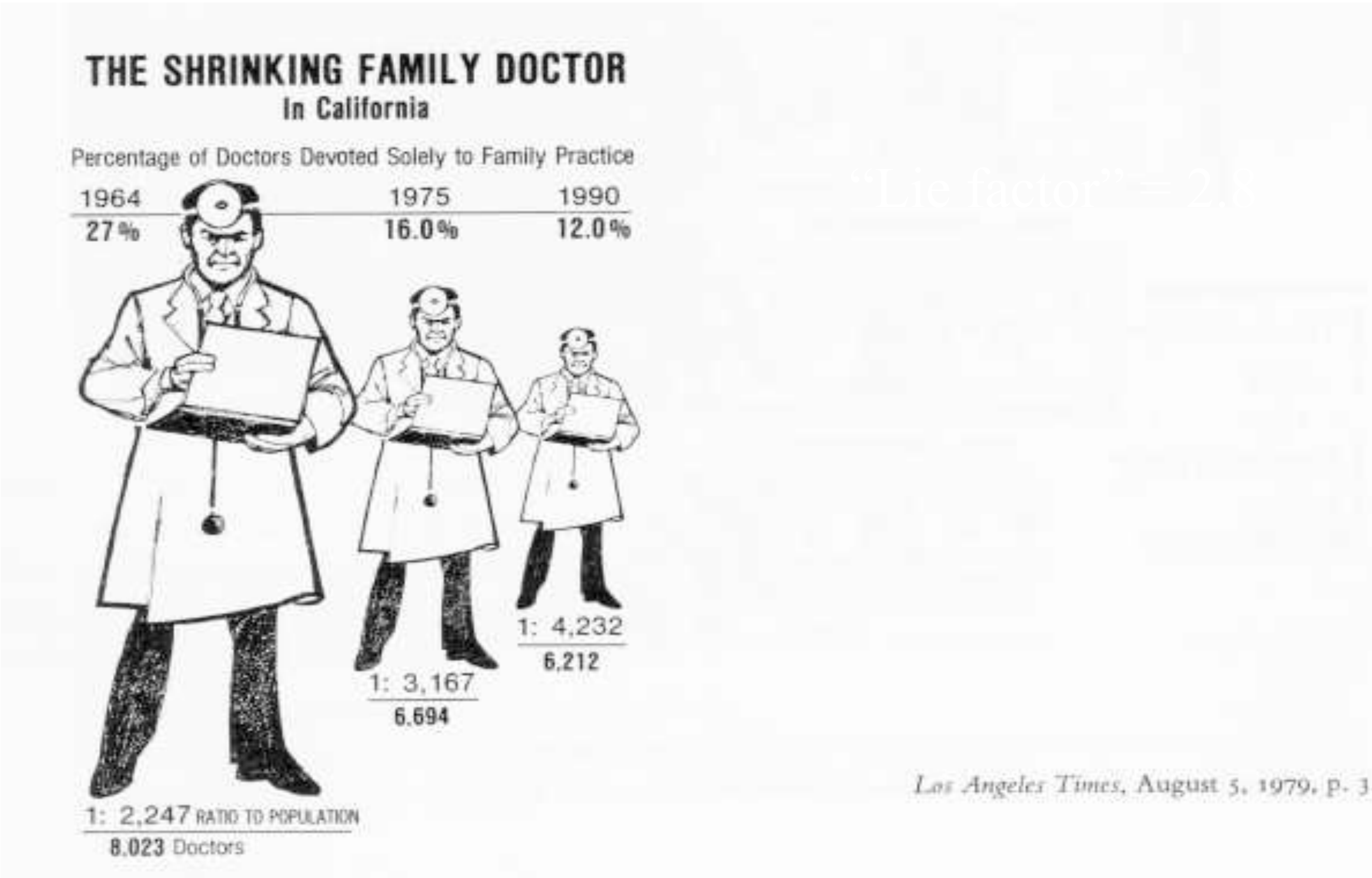


The heights of the (truncated) cones are proportional to the data, but their areas on the screen and their apparent volumes make the larger data values seem relatively small.

Charting on a **logarithmic** scale can also produce a low lie factor.

http://instruct.uwo.ca/fim-lis/504/504gra.htm

How to Exaggerate with Graphs
from Tufte ’83



Marti Hearst

How to Exaggerate with Graphs
from Tufte '83

Error: Shrinking along both dimensions

Washington Post, October 25, 1978, p. 1.

Marti Hearst

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Basic Types of Symbolic Displays
(Kosslyn 89)

- Graphs
- Charts
- Maps
- Diagrams

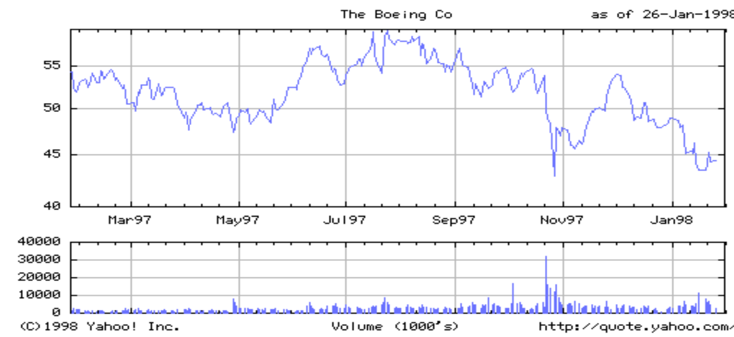
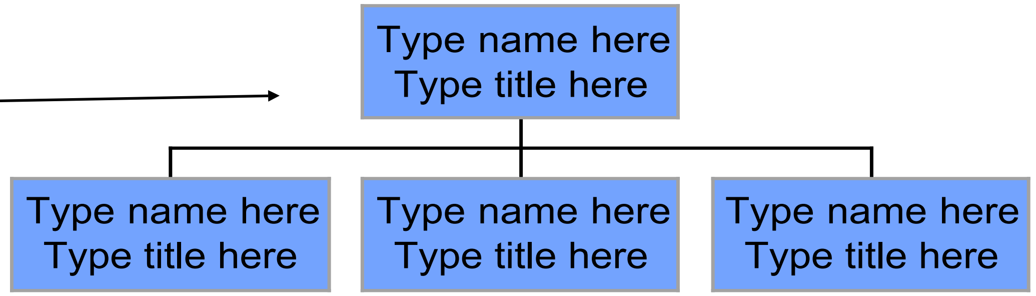
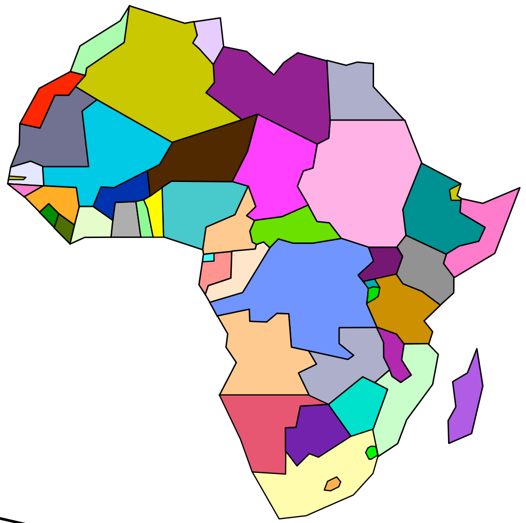
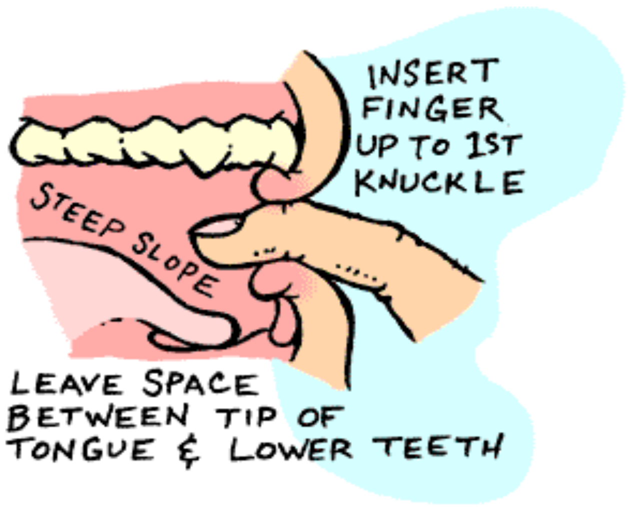


Chart Title



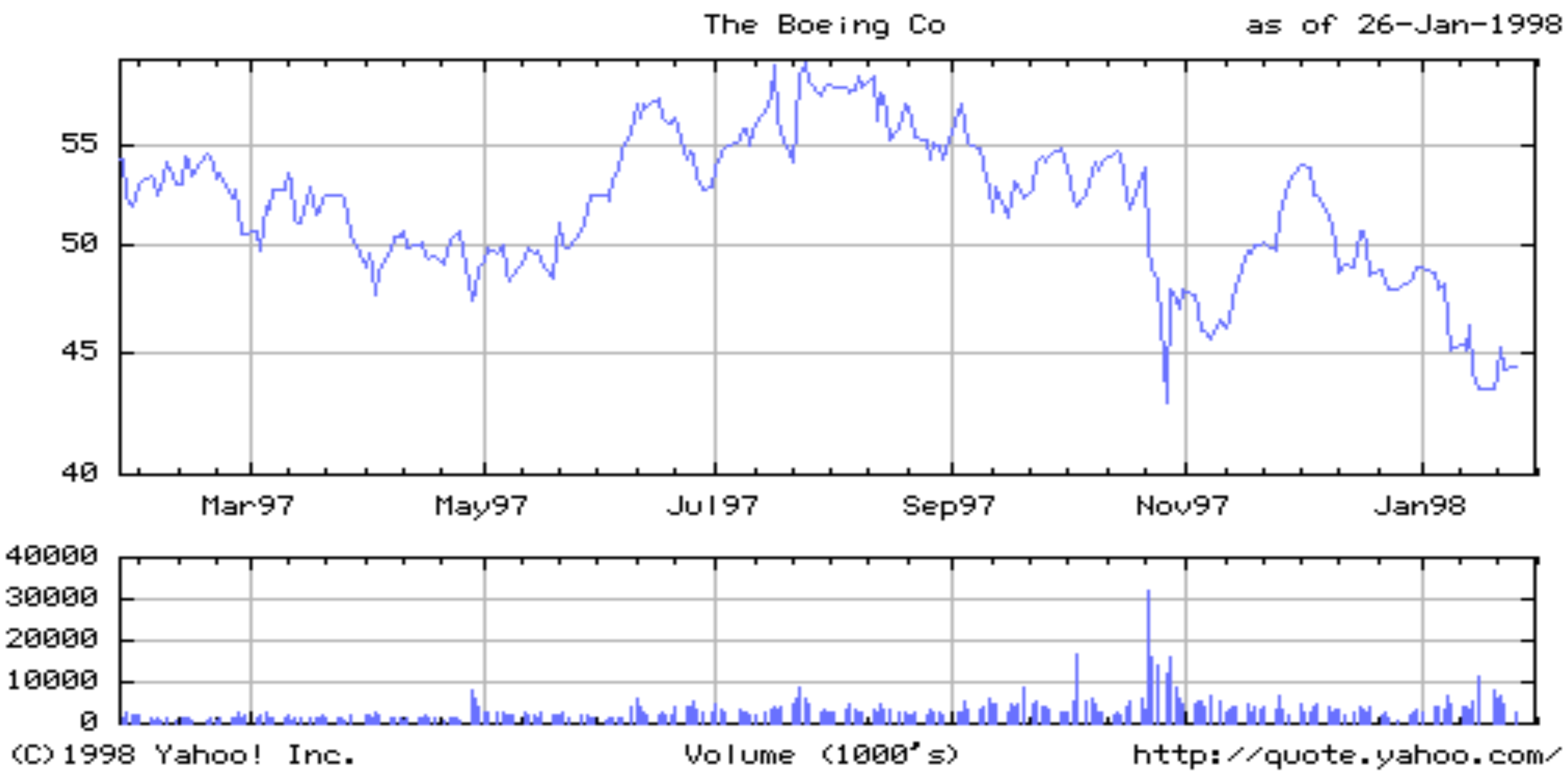




From Hearst, 2003

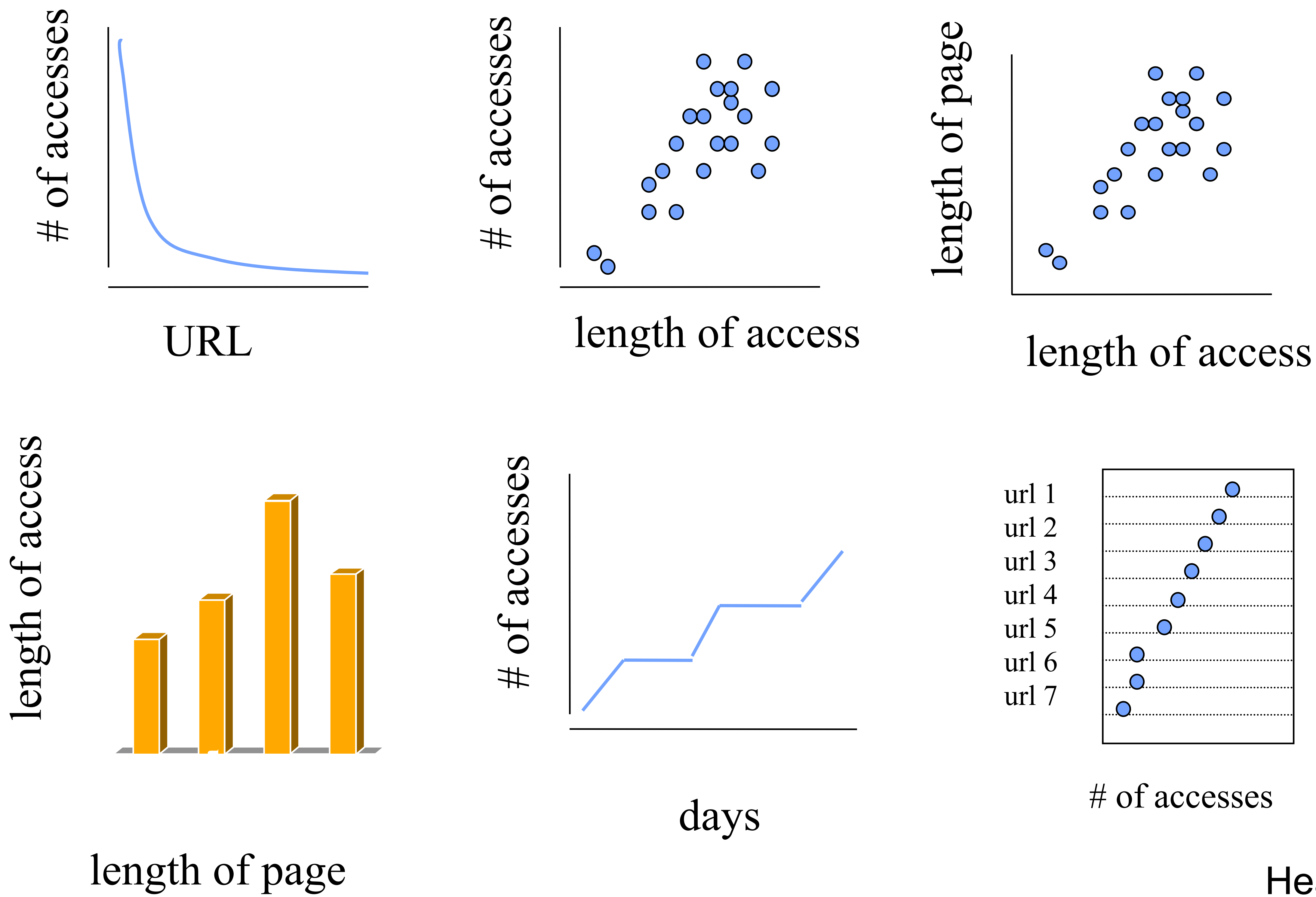
Graphs

- At least two scales required
- values associated by a symmetric “paired with” relation
  - Examples: scatter-plot, bar-chart, line graph



Hearst, 2003

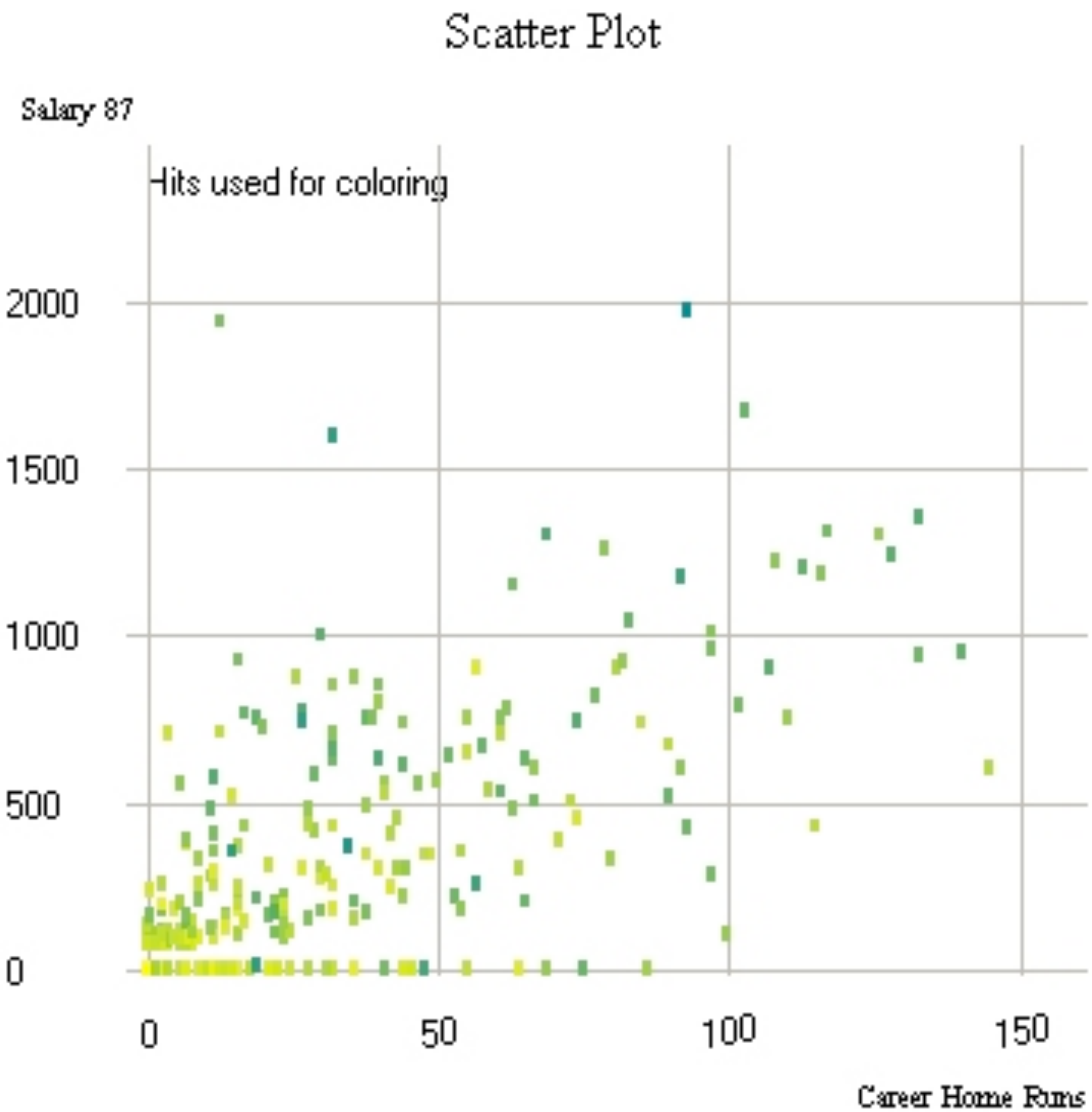
Common Graph Types



Hearst, 2003

Scatter Plots

- Qualitatively determine if variables
  - are highly correlated
    - » linear mapping between horizontal & vertical axes
  - have low correlation
    - » spherical, rectangular, or irregula distributions
  - have a nonlinear relationship
    - » a curvature in the pattern of plotted points
- Place points of interest in context
  - Color representing special entities



Hearst, 2003

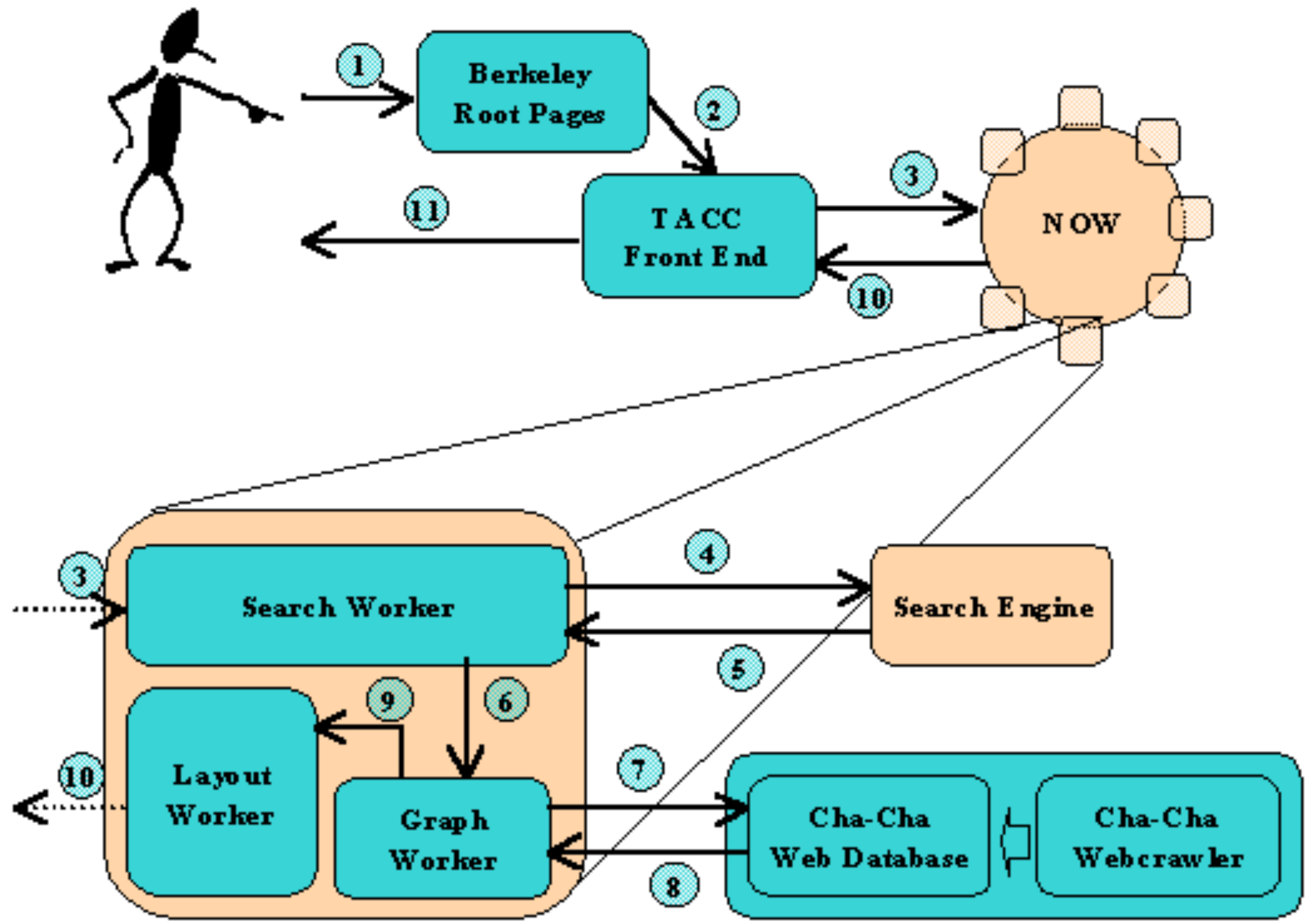
When to use which type?

- Line graph
  - x-axis requires quantitative variable
  - Variables have contiguous values
  - Familiar/conventional ordering among ordinals
- Bar graph
  - Comparison of relative point values
- Scatter plot
  - Convey overall impression of relationship between two variables
- Pie Chart?
  - Emphasizing differences in proportion among a few numbers

Hearst, 2003

Charts

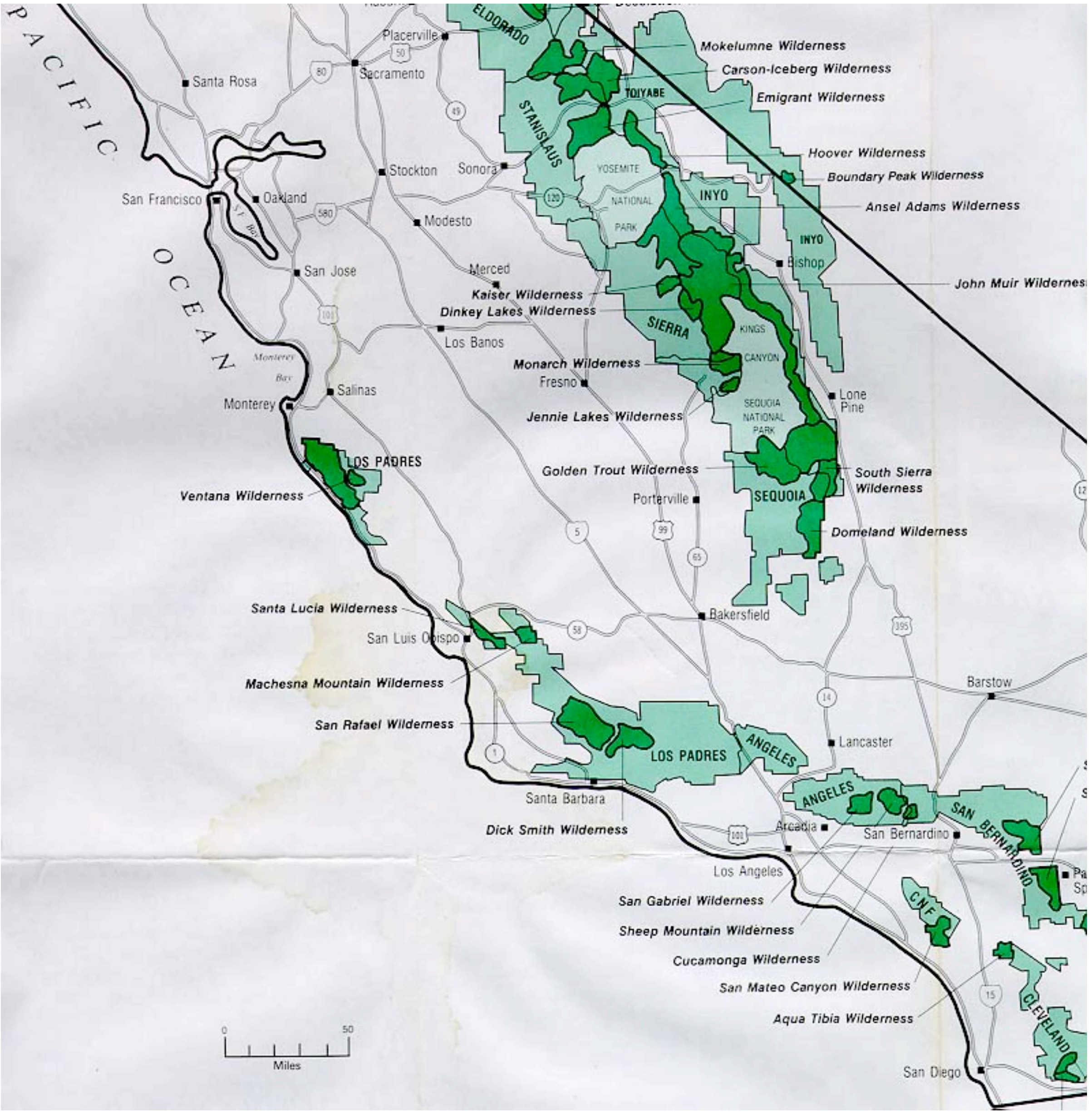
- Discrete relations among discrete entities
- Structure relates entities to one another
- Lines and relative position serve as links
- Examples: Family tree, flow chart



Hearst, 2003

Maps

- Internal relations determined (in part) by the spatial relations of what is pictured
- Labels paired with locations

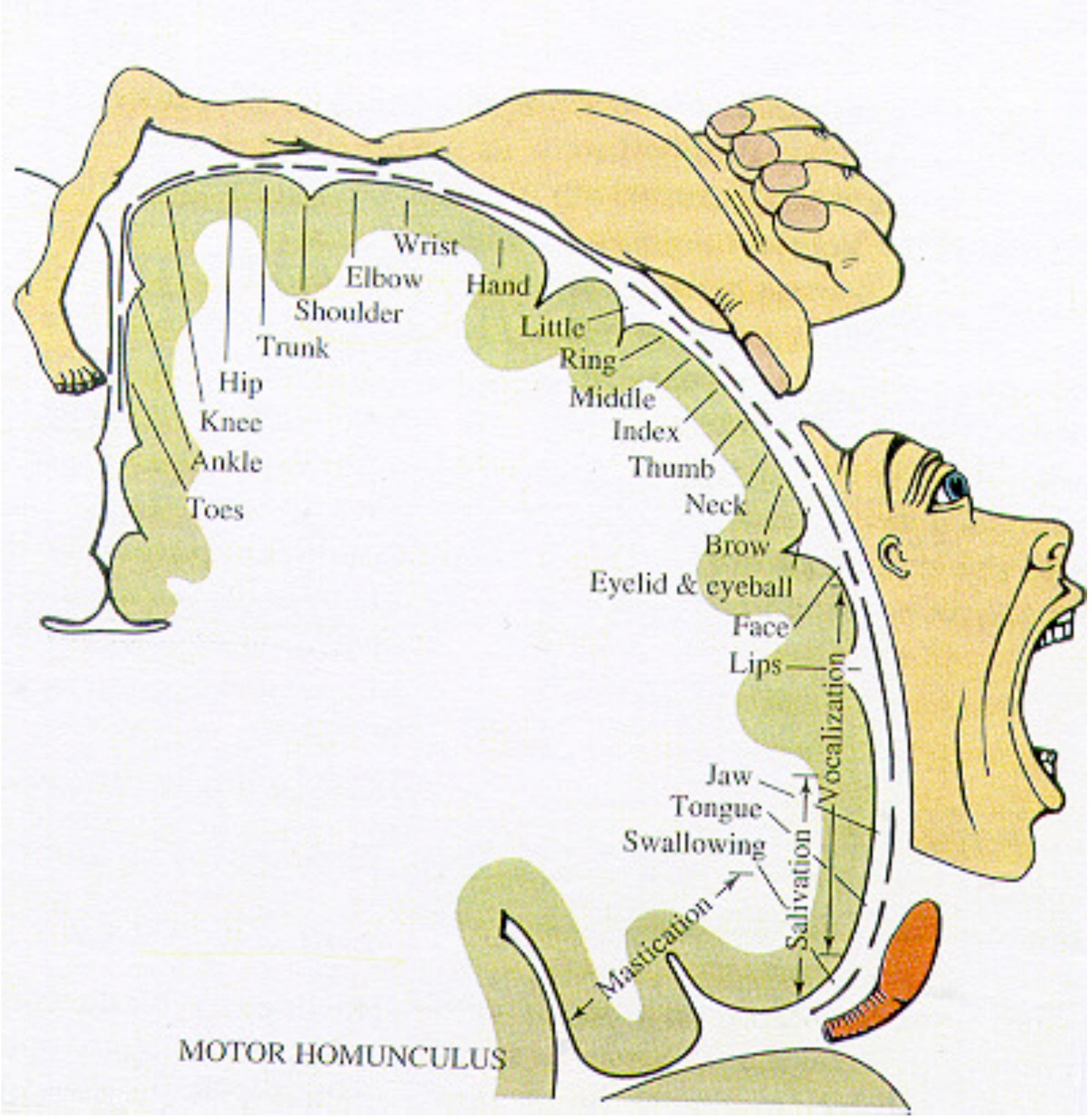


www.thehighsierra.com

Hearst, 2003

Diagrams

- Schematic pictures of objects or entities
- Parts are symbolic (unlike photographs)
  - How-to illustrations
  - Figures in a manual

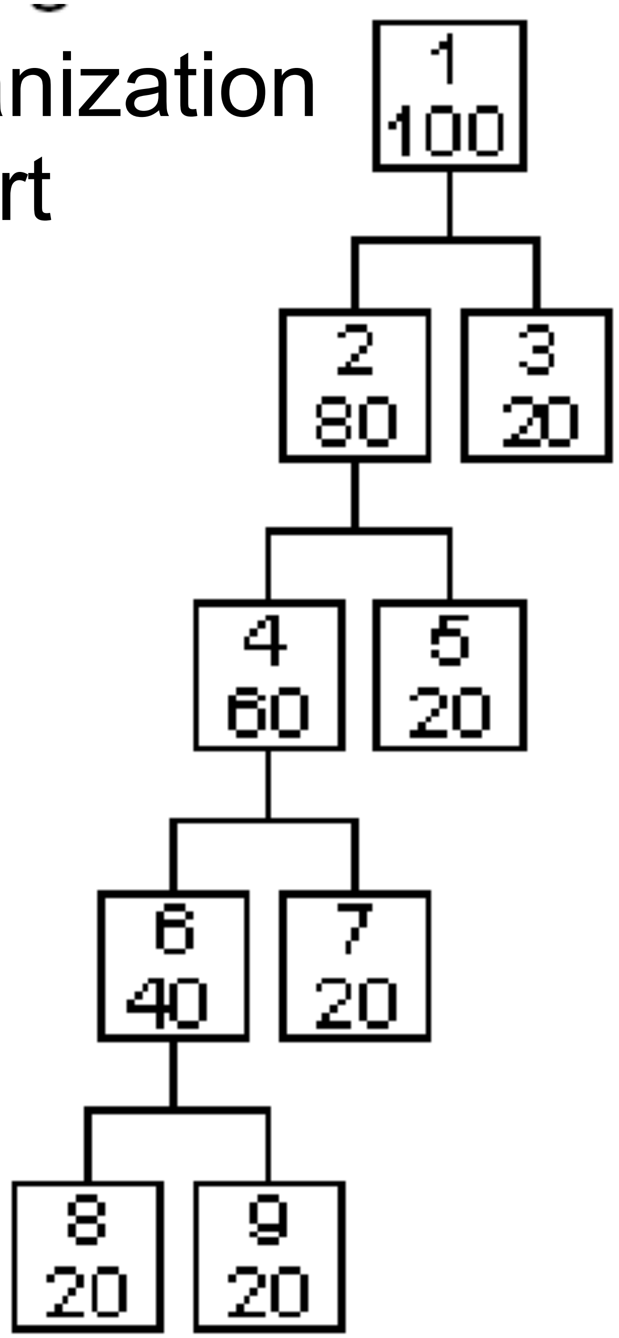


From Glietman, Henry. Psychology. W.W. Norton and Company, Inc. New York, 1995

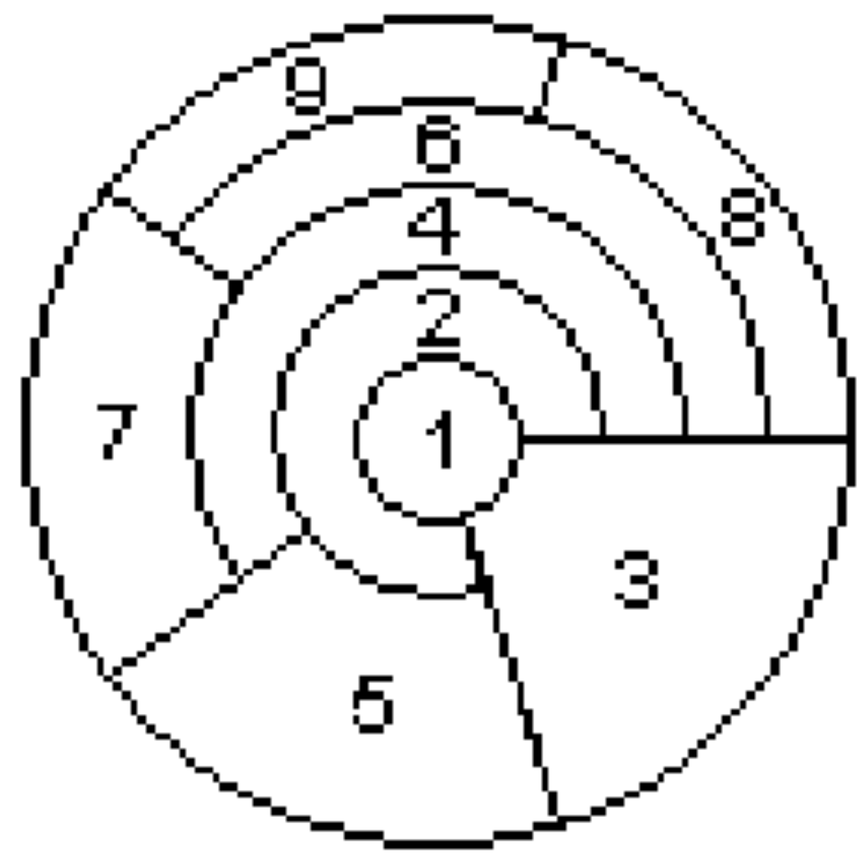
Hearst, 2003

Alternative Tree Visualizations (1)

Organization Chart

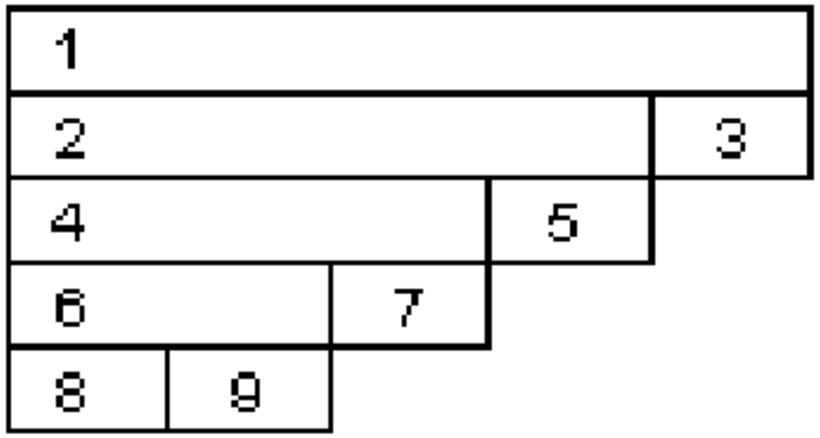


Tree Ring

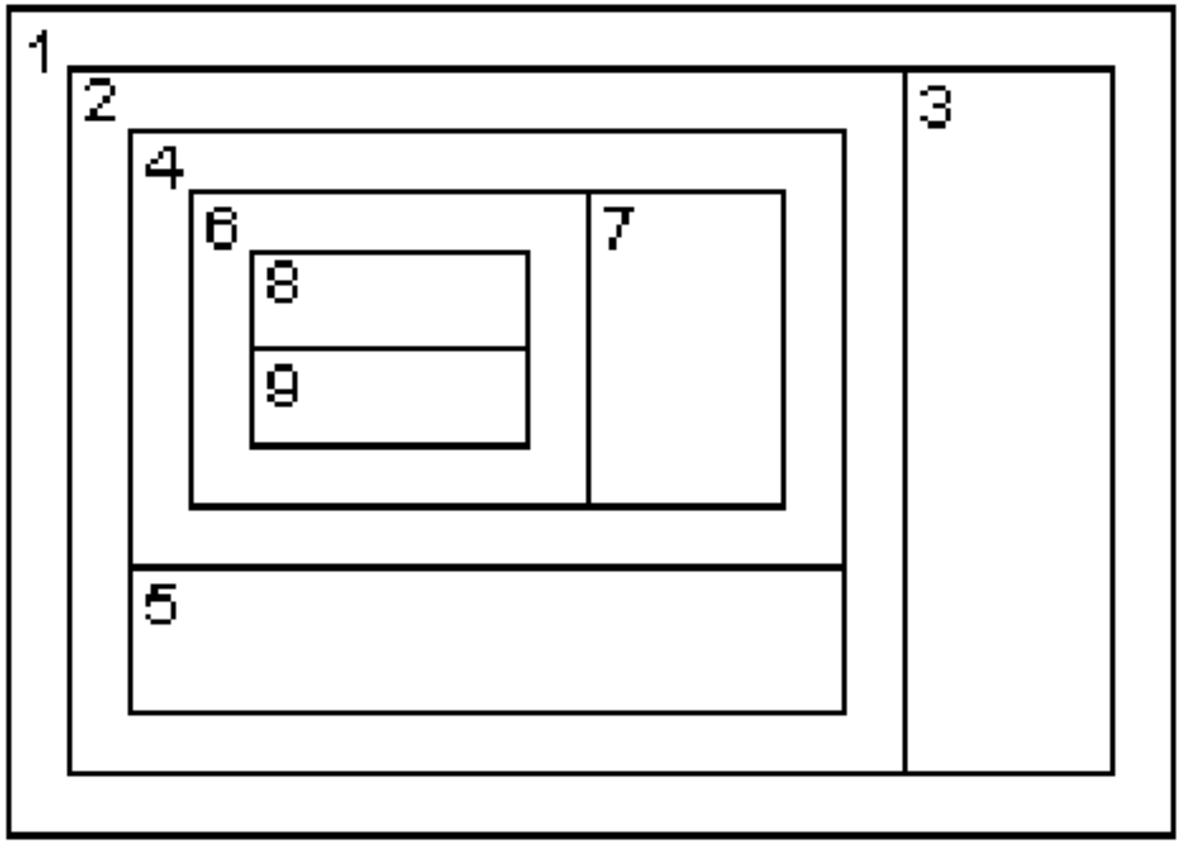


Alternative Tree Visualizations (2)

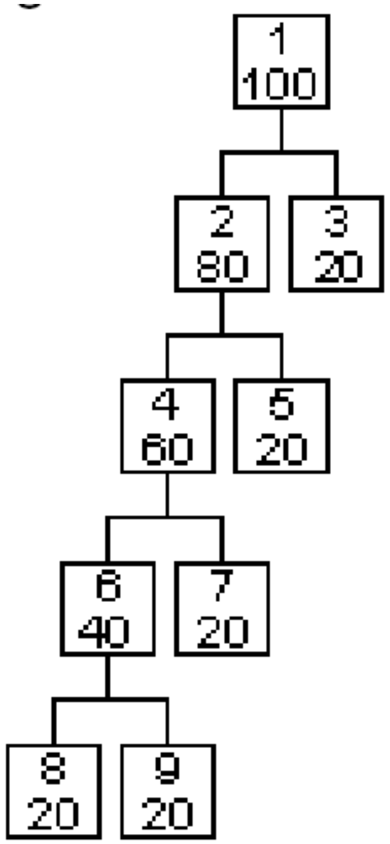
Icicle Plot

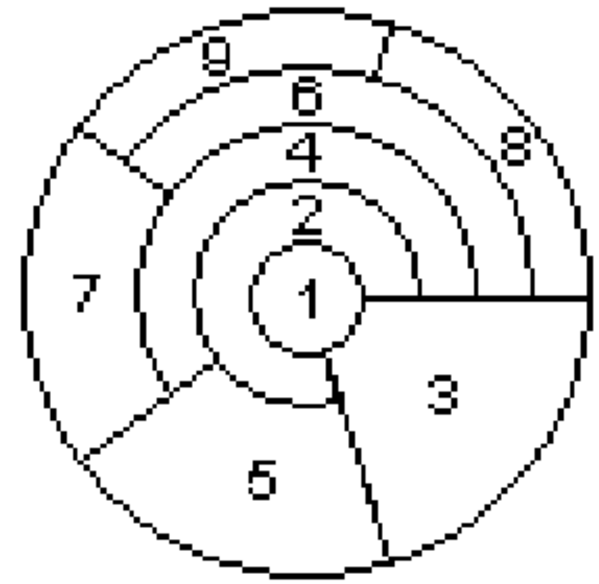


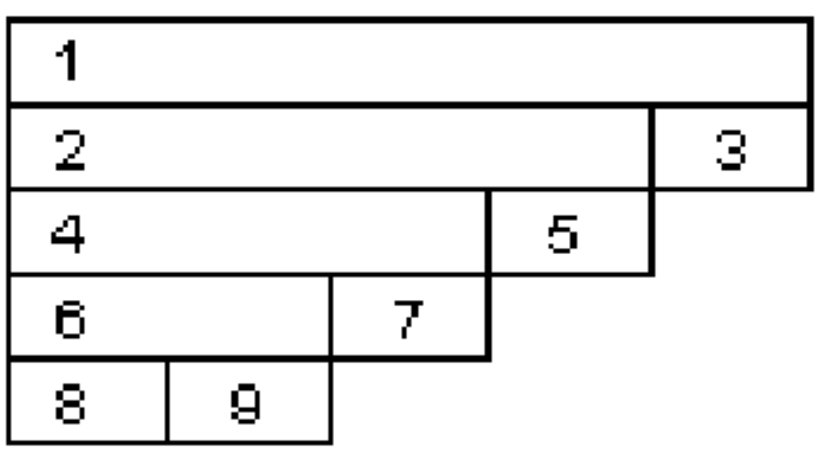
Tree Map

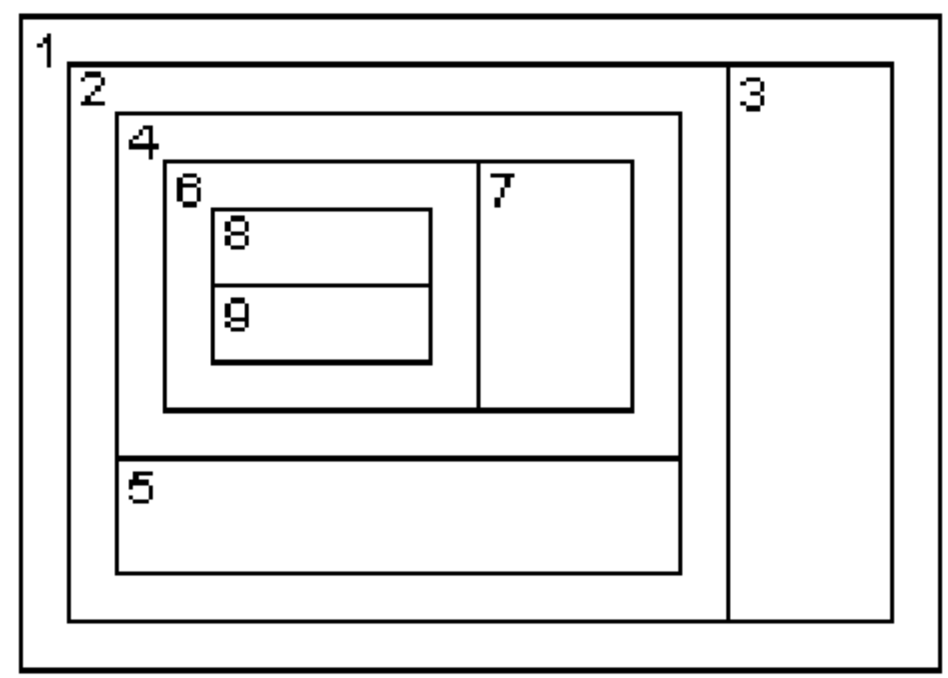


Comparing Tree Visualizations









Typical Tasks for Viewing Trees

- Determine the type of tree, e.g.
  - Binary
  - N-ary
  - Balanced
  - Unbalanced
- Find relations, e.g.
  - Deepest common ancestor
- Size of the tree, e.g.
  - How many levels
  - How many leaves
- Details about leaves, e.g.
  - Largest leaf

- Different representation may be better for a given task, e.g.
  - To find out if a tree is balanced or how many levels exist, the Icicle Plot is good

For more details see:

Barlow et al. "A Comparison of 2-D Visualizations of Hierarchies" INFOVIS'01
http://www.sims.berkeley.edu/courses/is247/s02/readings/barlow.pdf

Information Visualization Tasks

Tasks in interactive workflow using visualized information:

• **Overview**	Gain an overview of the entire collection
• **Zoom**	Zoom in on items of interest
• **Filter**	Filter out uninteresting items
• **Details-on-demand**	Select an item or group and get details when needed
• **Relate**	View relationships among items
• **History**	Keep a history of actions to support undo, replay, and progressive refinement
• **Extract**	Allow extraction of sub-collections and of the query parameters

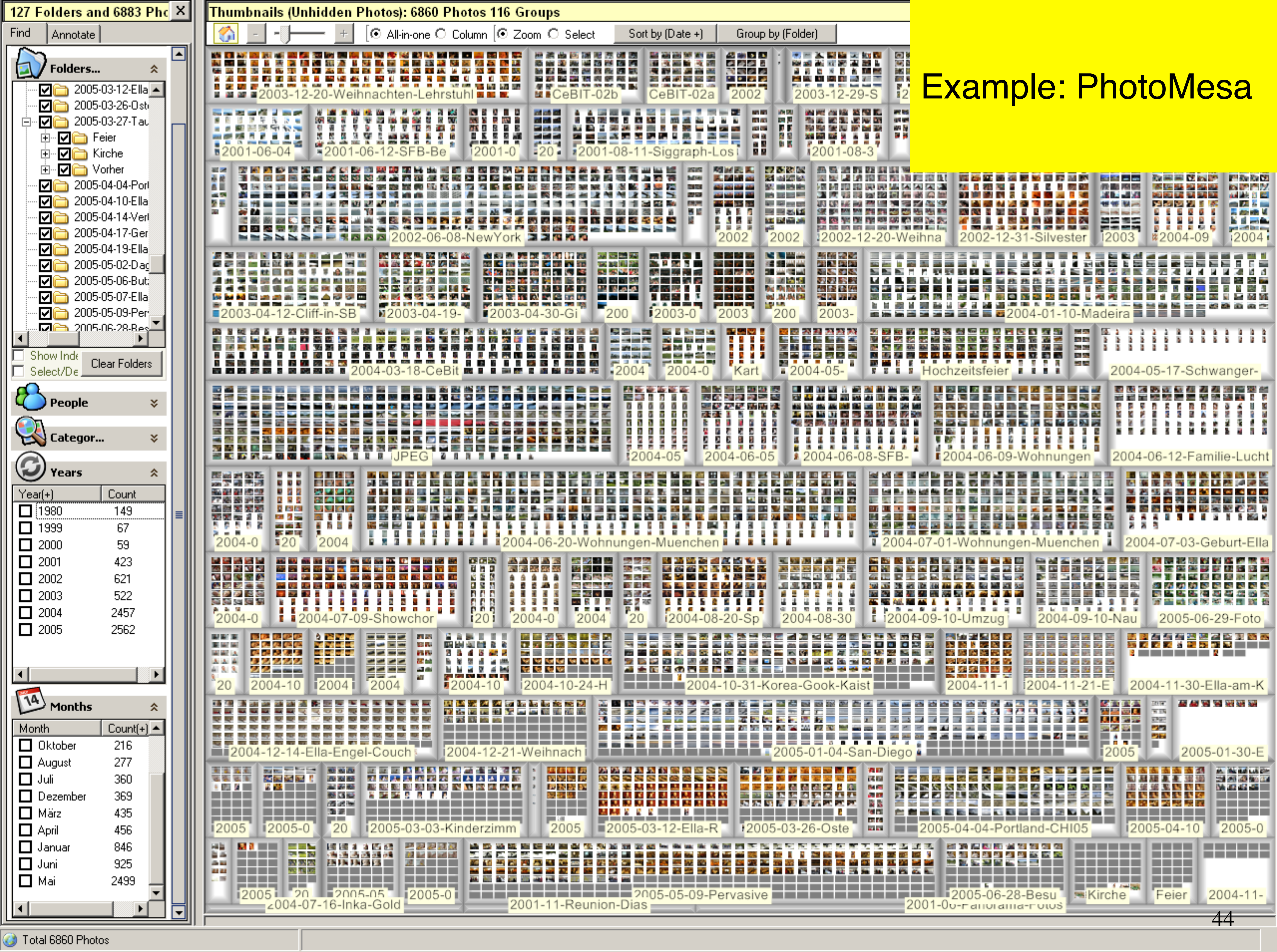
Shneiderman, 2003

Information Visualization Mantra

…
Overview, zoom & filter, details-on-demand
Overview, zoom & filter, details-on-demand
Overview, zoom & filter, details-on-demand
Overview, zoom & filter, details-on-demand
Overview, zoom & filter, details-on-demand
Overview, zoom & filter, details-on-demand
…

Shneiderman, 2003

Example: PhotoMesa



Visualization Techniques for View Transformations

- Focus & Context
- Zoom & Pan

Focus & Context: Background

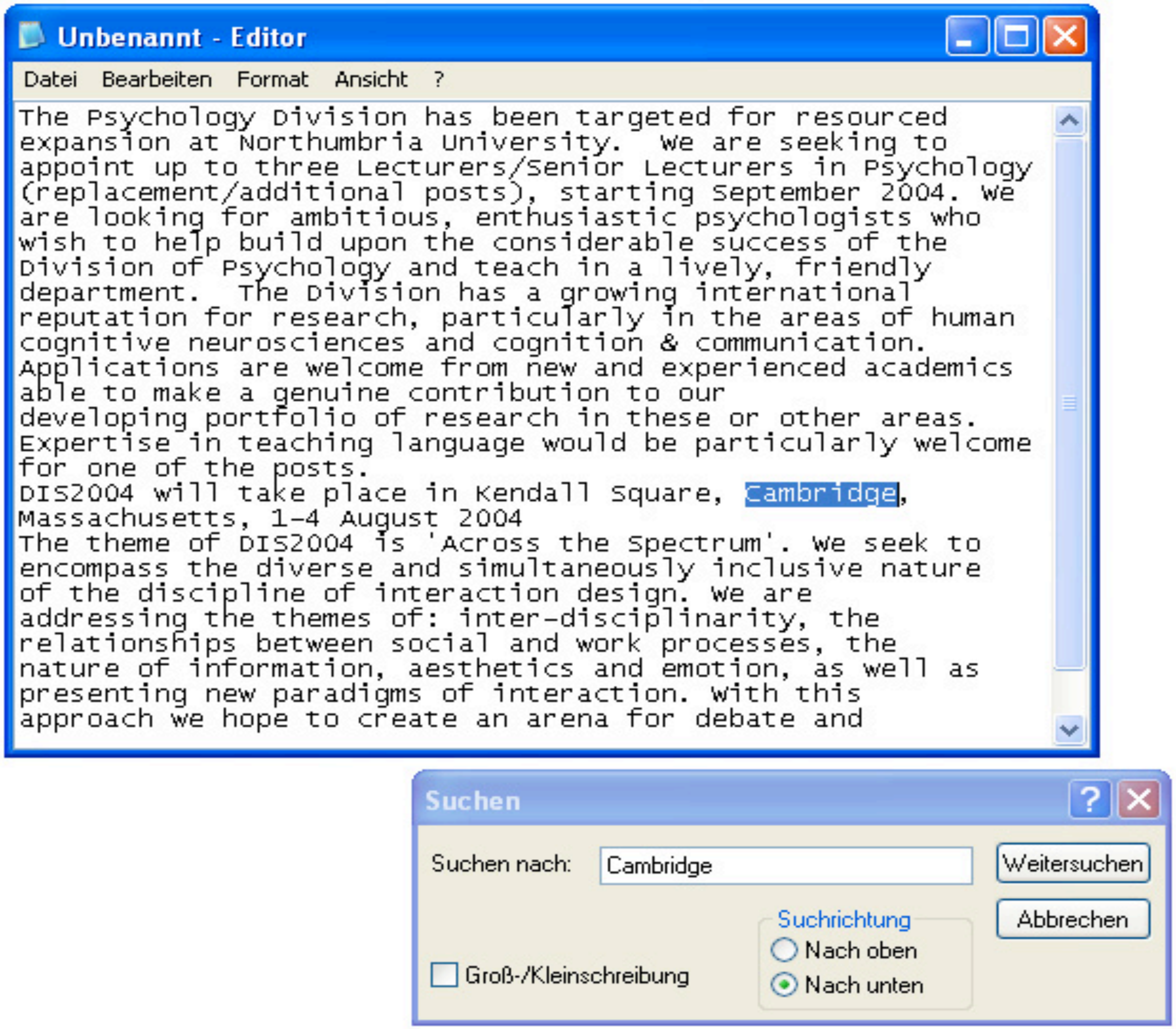
- Useful Field of View (UFOV)
  - Expands searchlight metaphor
  - Size of region from which we can rapidly take information
  - Maintains constant number of targets
- Tunnel Vision and Stress
  - UFOV narrows as cognitive load/stress goes up
- Role of Motion in Attracting Attention
  - UFOV larger for movement detection

Depth of Field

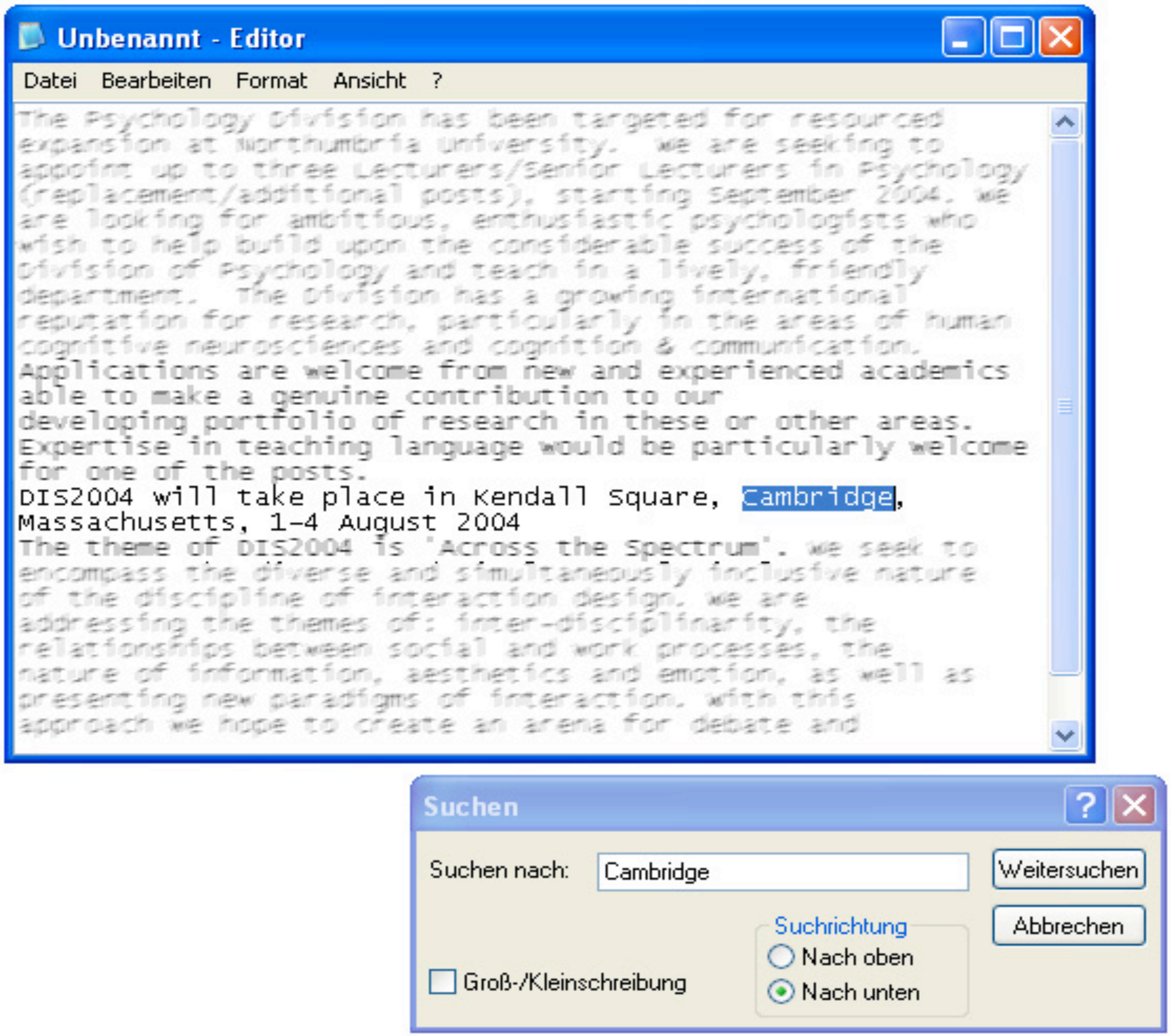
- Guiding user attention by blurring less relevant parts of an image
- Keeping the context

- Semantic Depth of field = blurring objects based on their relevance

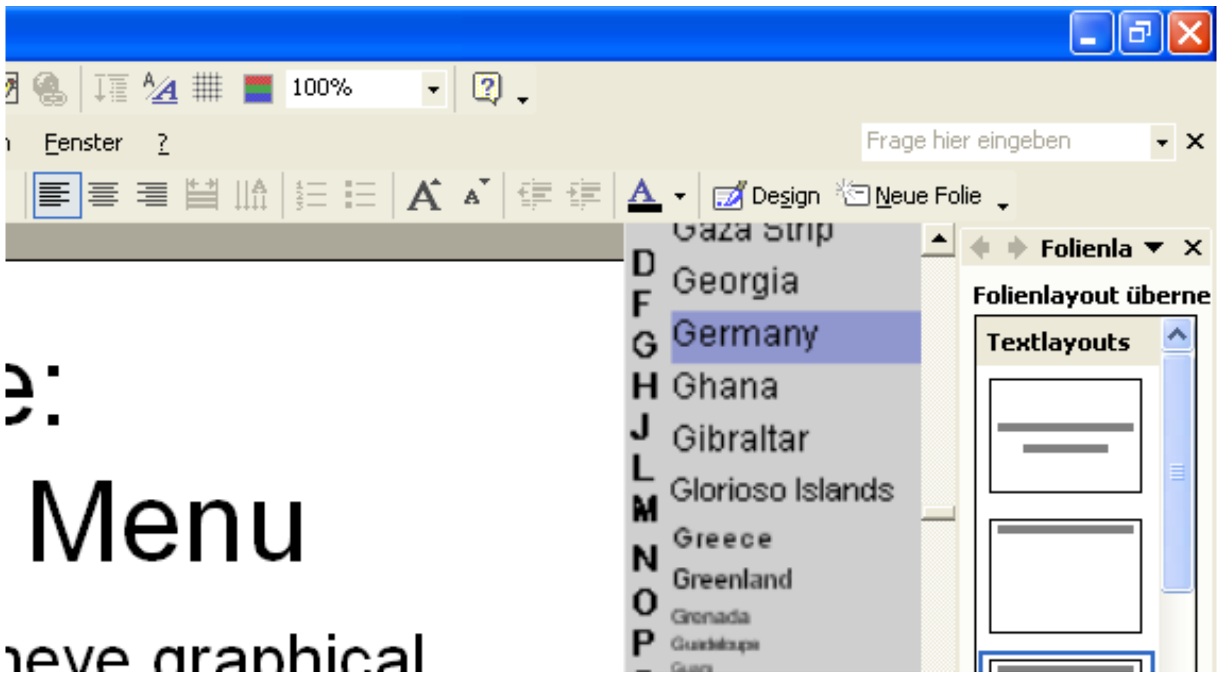
Semantic Depth of Field - Example

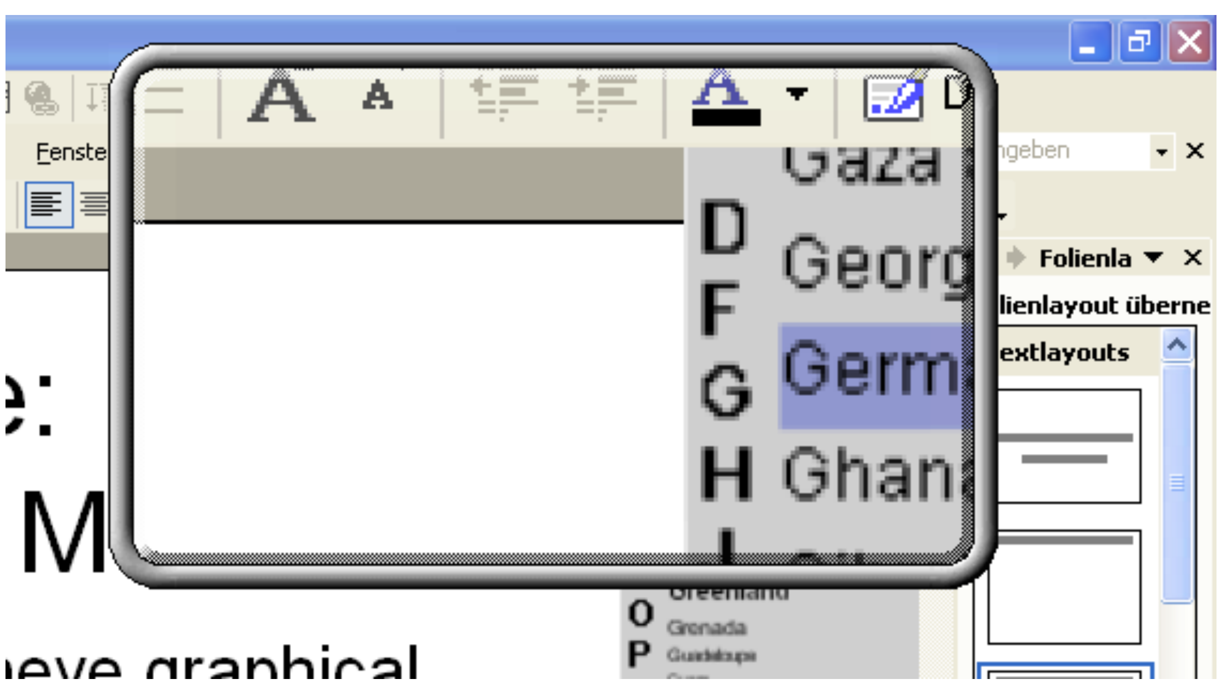


Semantic Depth of Field - Example



Magnifying Glass





- Magnifying glass hides context!
- This is not focus +context

Focus + Context

- Basic Idea:
  - Show selected regions of interest in greater detail (*focus*)
  - Preserve global view at reduced detail (*context*)
  - NO occlusion - All information is visible simultaneously
- Techniques
  - Fisheye views
  - Fisheye lens
  - Continuously variable zoom
  - Nonlinear magnification
  - Hyperbolic views
  - Distortion viewing
  - Rubber sheet views

Alternate Geometry

- Euclidean geometry – we use it since primary school…
  - 3 angles of a triangle add up to?
  - Shortest distance between two points?

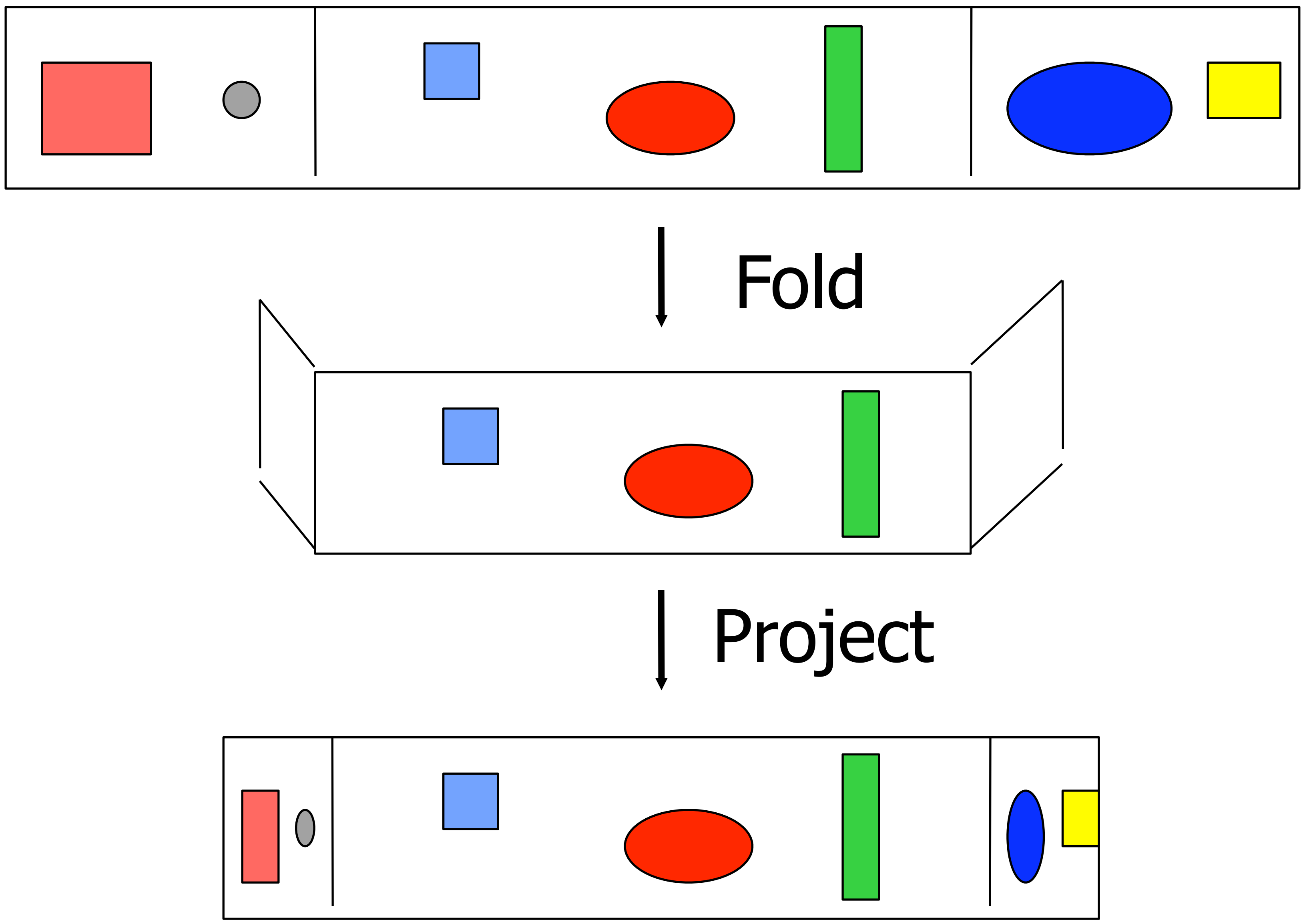
- Spherical geometry
  - Geographical view of the world
    - » What is the shortest way from Moscow to San Francisco?
    - » Sum of angles of a triangle between Paris, NY, and Cape Town?
  - http://math.rice.edu/~pcmi/sphere/

- Hyperbolic Geometry / Space
  - Theory of Relativity
  - The "fifth" dimension
  - Can be projected into 2-D as a *pseudosphere*
  - Key: As a point moves away from the center towards the boundary circle, its distance approaches *infinity*
  - http://cs.unm.edu/~joel/NonEuclid/NonEuclid.html (Applet)

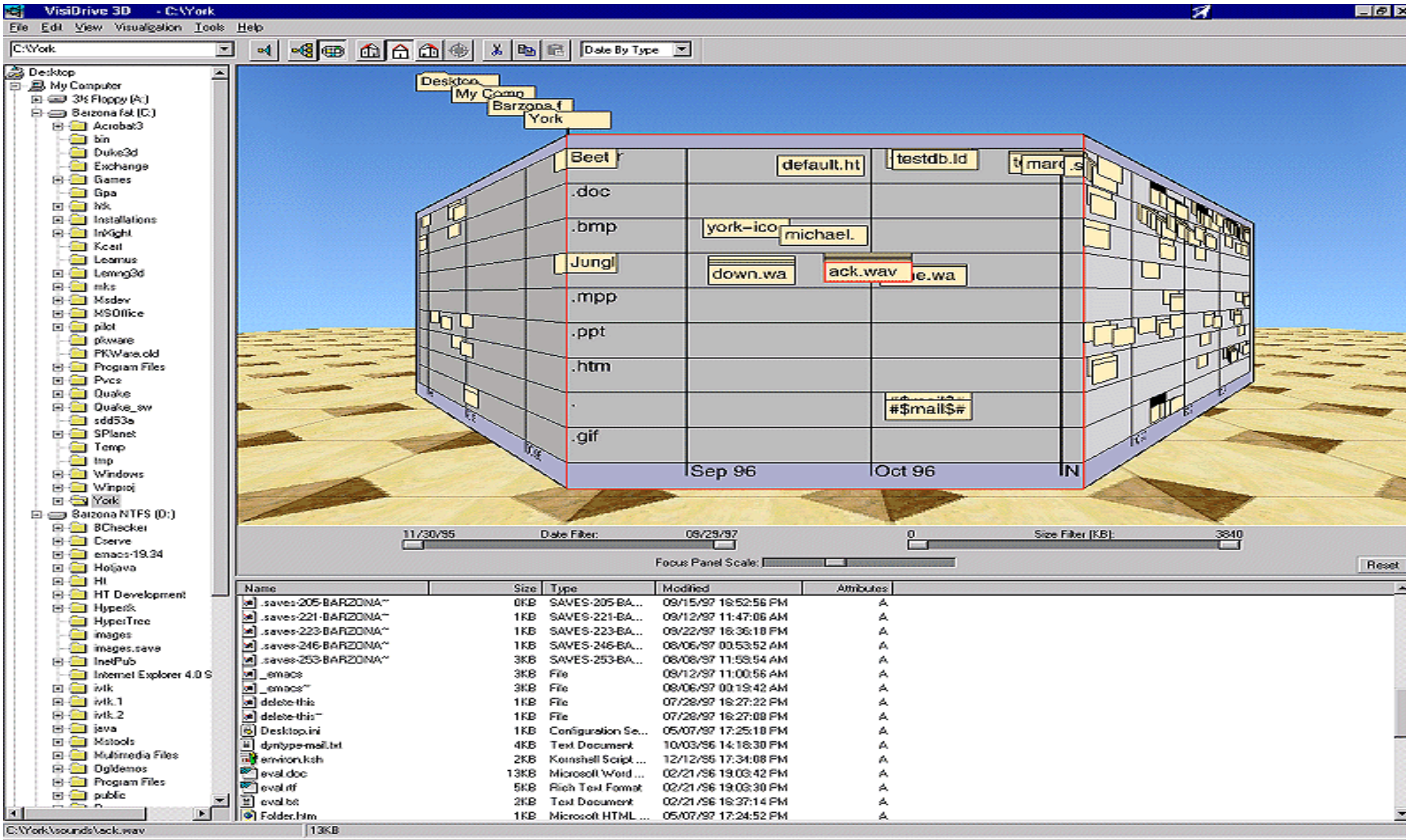
Distorted vs. Non-distorted

- Non-distorted
  - Display only a selection at a time
  - Scrolling
  - Paging access
  - hierarchical structure
  - Structure-specific presentation
- Distorted
  - See the following slides

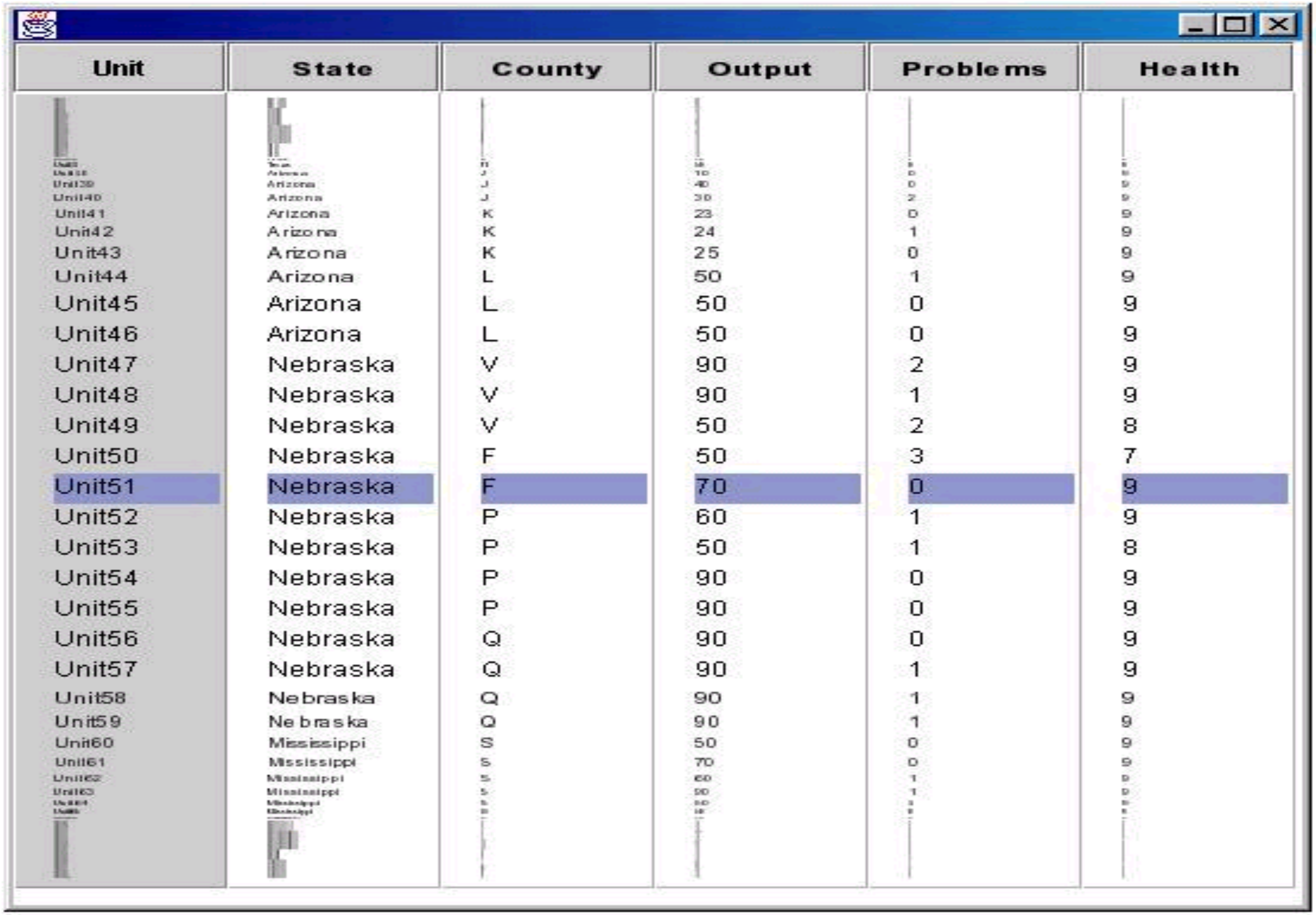
Basic Idea – Perspective Wall



From http://www.cs.ubc.ca/~tmm/courses/cpsc533c-03-spr/0324.fengdongdu.ppt


VisiDrive 3D - C:\York
File Edit View Visualization Tools Help
C:\York
Date By Type
Desktop
My Computer
Barzona fat (C:)
York
.doc
.bmp
.mpp
.ppt
.htm
.gif
default.ht
testdb.ld
york–ico
michael.
down.wa
ack.wav
#$mail$#
Sep 96
Oct 96
11/30/95
Date Filter:
09/29/97
Size Filter [KB]:
3840
Focus Panel Scale:
Reset
Name
Size
Type
Modified
Attributes
C:\York\sounds\ack.wav
13KB

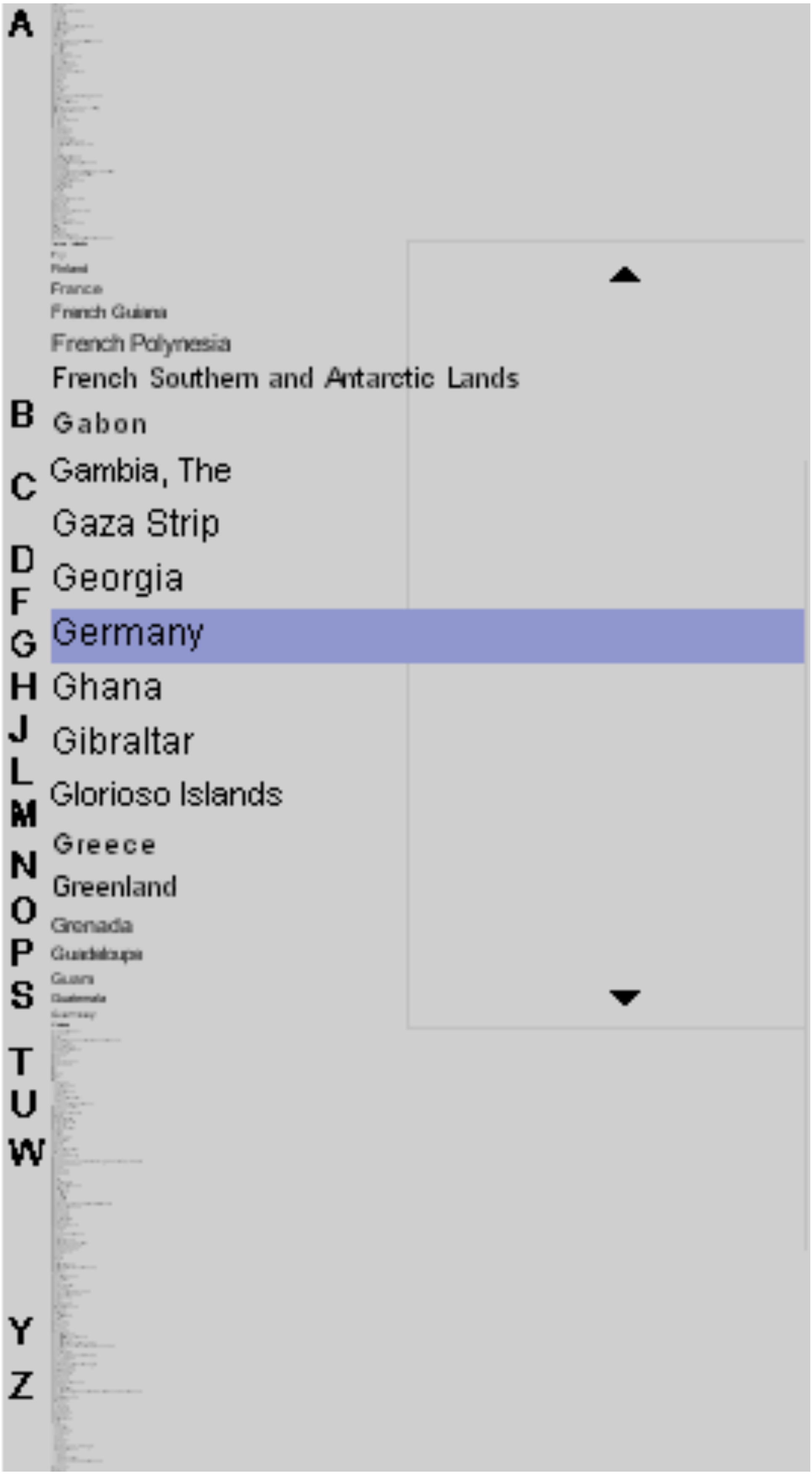
Fisheye View



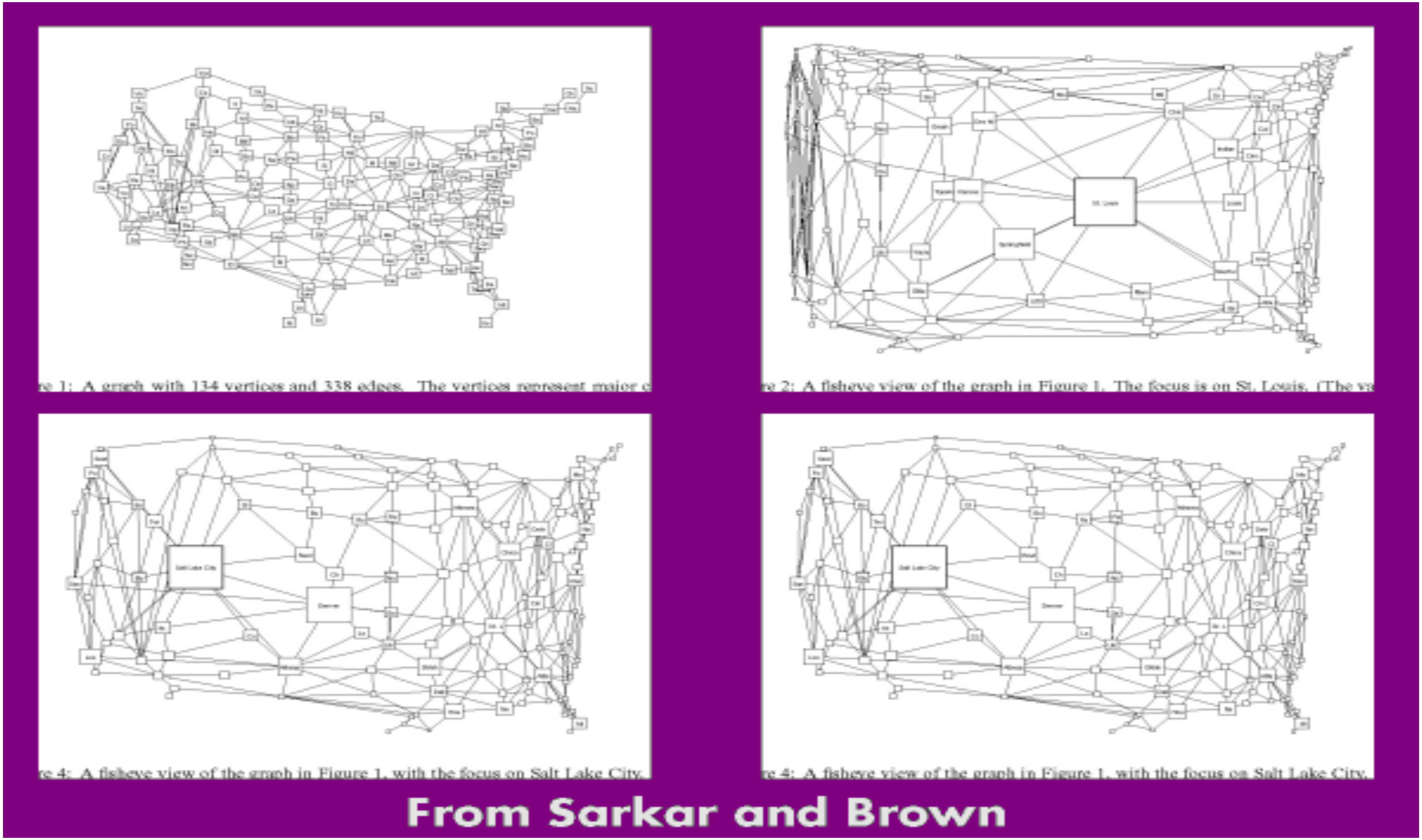
Example: Fisheye Menu

- Applies fisheye graphical visualization techniques to linear menus
- For very long menus as alternative to
  - Hierarchies
  - Scrolling
  - Arrow-bars

- Benjamin B. Bederson. Fisheye Menus. UIST'00
- Demo
  http://www.cs.umd.edu/hcil/fisheyemenu/fisheyemenu-demo.shtml



Fisheye View - Networks



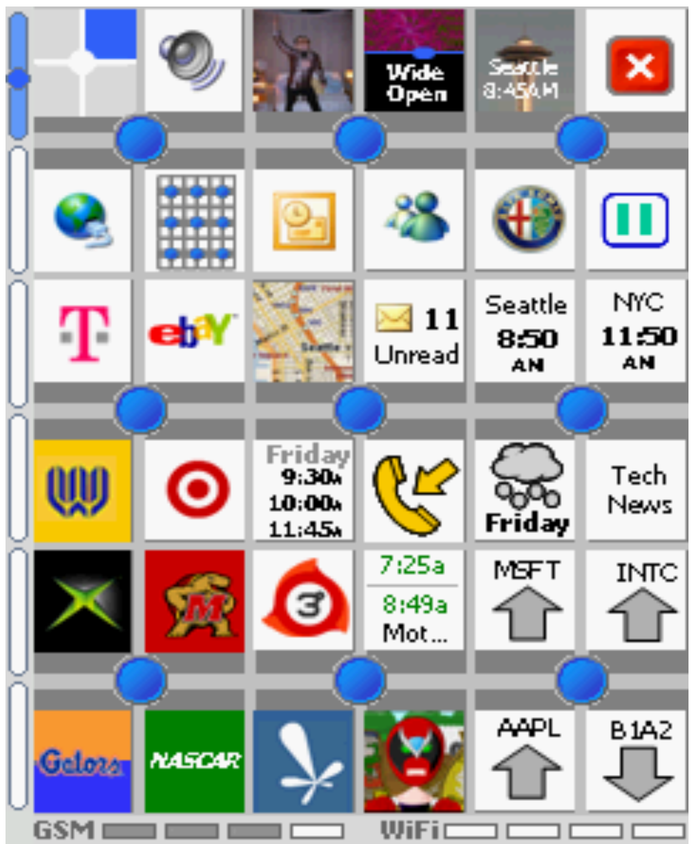
Panning and Zooming

- Panning
  - Smooth movement of camera across scene (or scene moves and camera stays still)
- Zooming
  - Increasing or decreasing the magnification of the objects in a scene

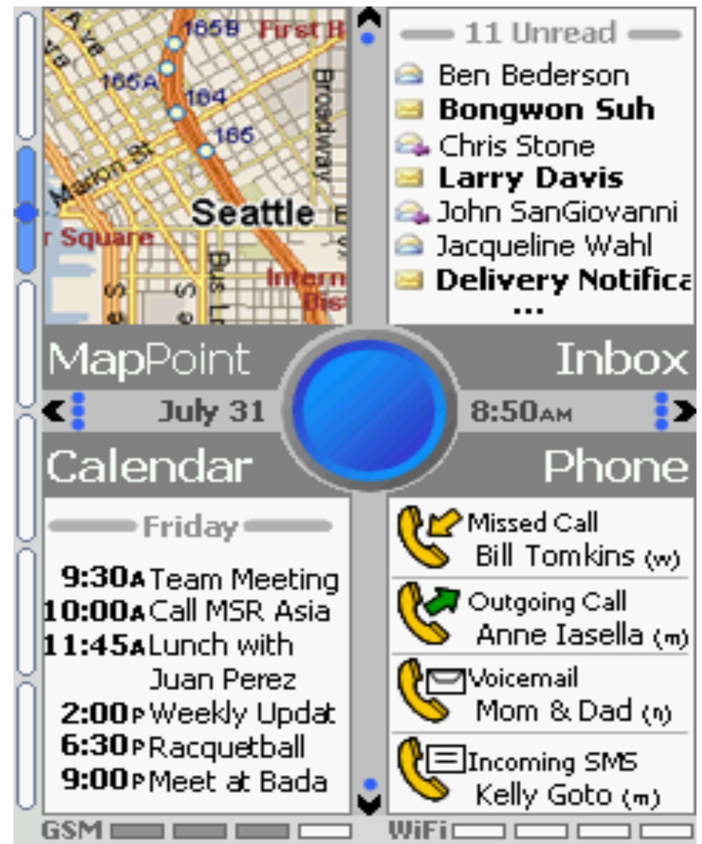
- Useful for changing focal point
- Also used in creating moving pictures from still pictures
  - “Ken Burns effect”, see Mac OS X photo screensaver

Example: LaunchTile Visual Design

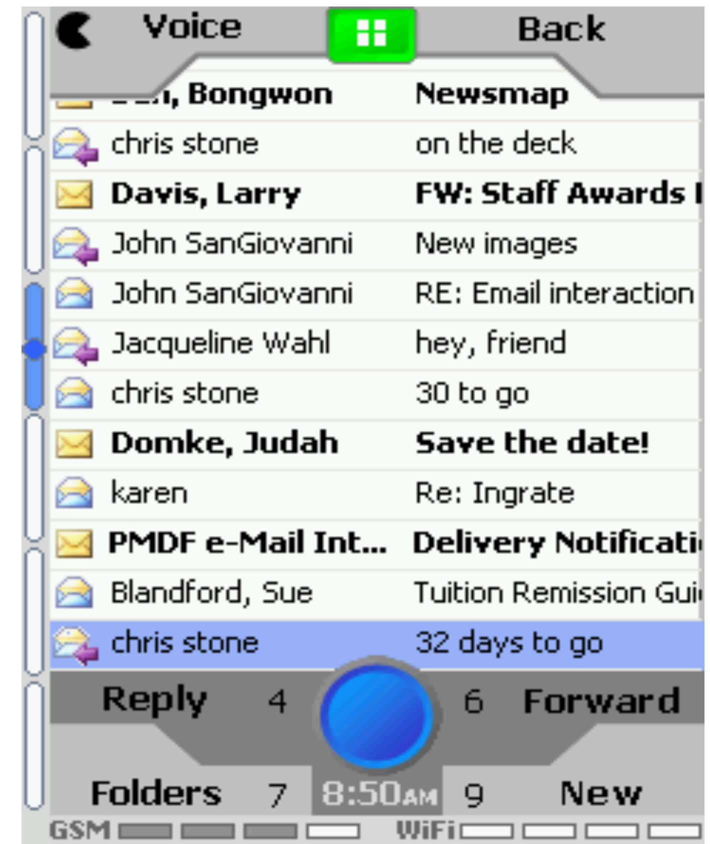
- Three (pure) zoom levels



World



Zone



Application

Karlson, Bederson, SanGiovanni, CHI 2005