Vorlesung
Advanced Topics in HCI
(Mensch-Maschine-Interaktion 2)

Ludwig-Maximilians-Universität München

LFE Medieninformatik

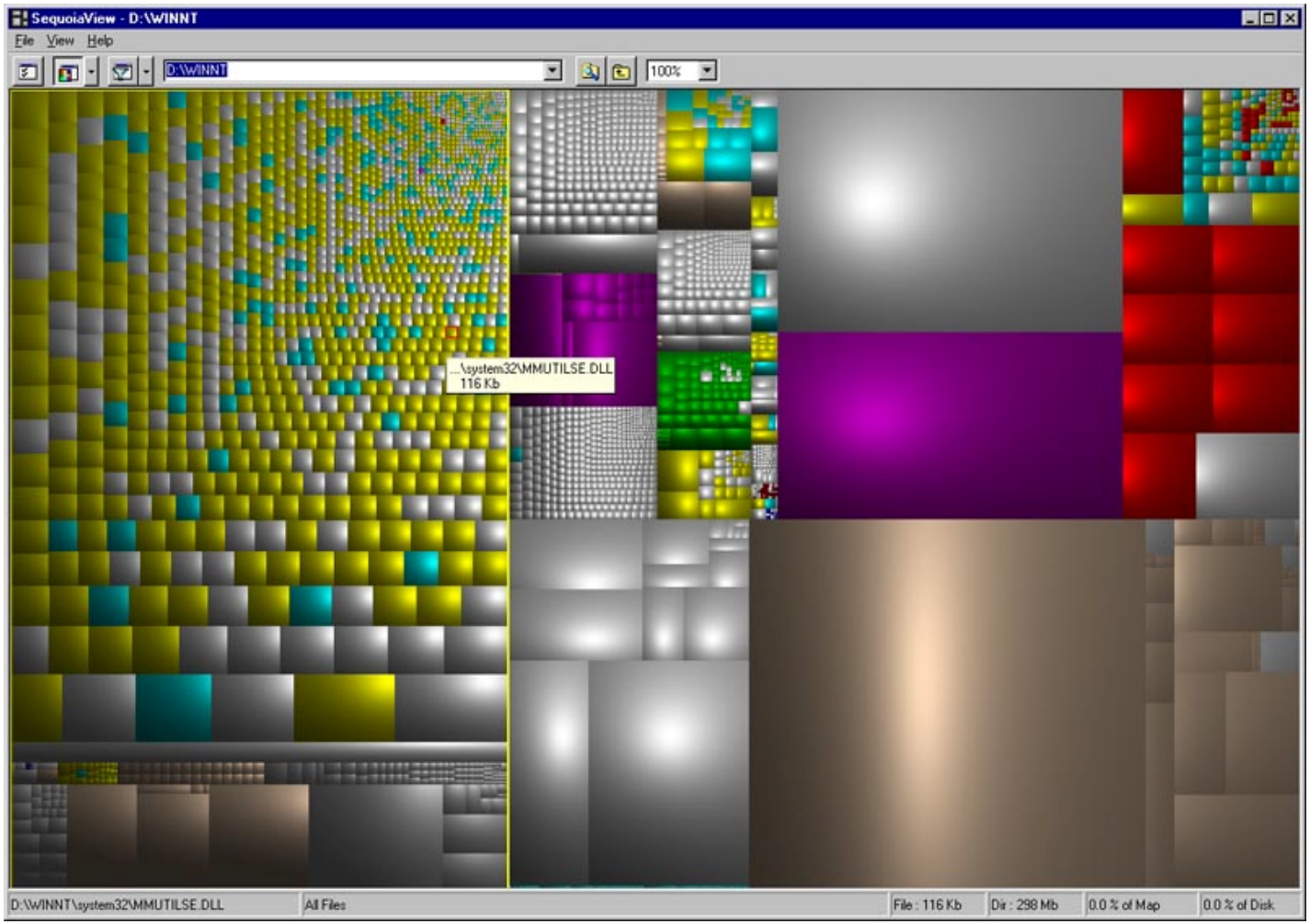
Albrecht Schmidt & Andreas Butz

SS2006

http://www.medien.informatik.uni-muenchen.de/

SequoiaView

http://www.win.tue.nl/sequoiaview/



Human Perception & Visual Properties

- Preattentive Processing
- Accuracy of Interpretation of Visual Properties
- Illusions and the Relation to Graphical Integrity

All Preattentive Processing figures from Healey 97
http://www.csc.ncsu.edu/faculty/healey/PP/PP.html

User's Expectations from the physical world

Marti Hearst, 2003

- Well-Defined Surfaces

  Objects have mostly smooth surfaces

- Temporal Persistence

  Objects don't randomly appear/vanish

- Light travels in Straight Lines

  reflects off surfaces in certain ways

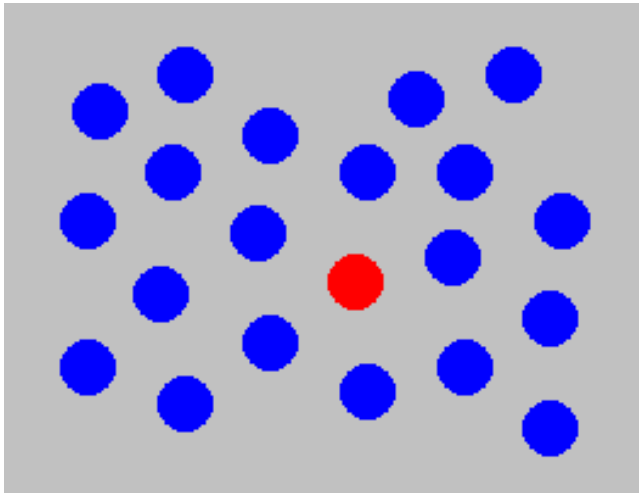
- Law of Gravity

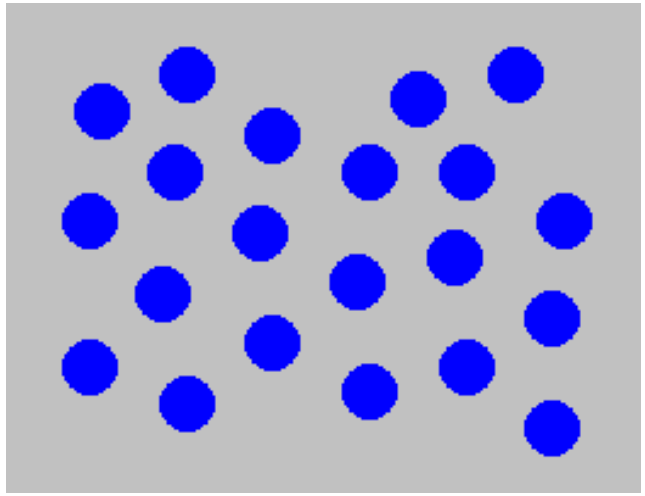
Preattentive Processing

- 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
  - what properties are good discriminators
  - what can mislead viewers

Hearst, 2003

Example: Color Selection

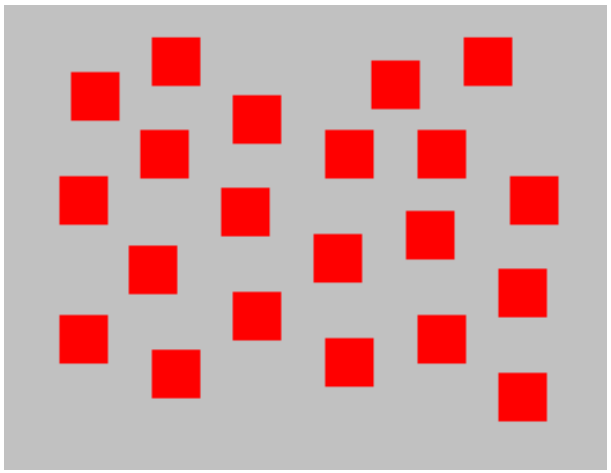


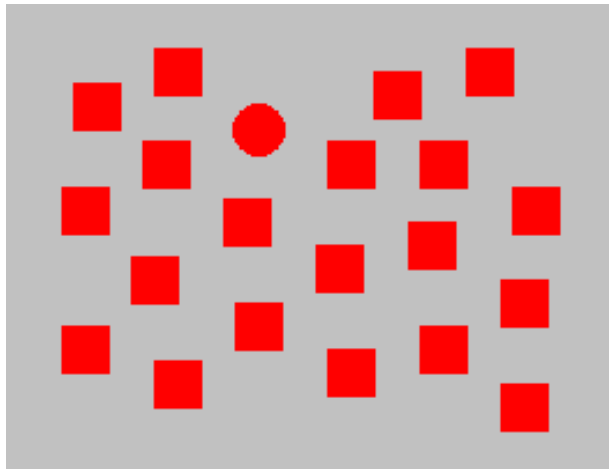


Viewer can rapidly and accurately determine whether the target (red circle) is present or absent. Difference detected in color.

Hearst, 2003

Example: Shape Selection





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

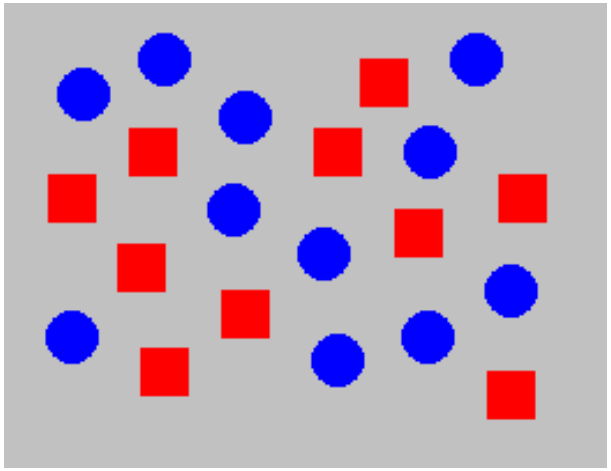
Hearst, 2003

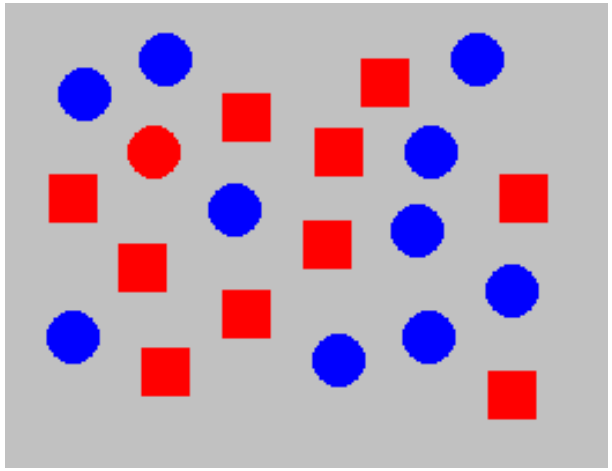
Pre-attentive Processing

- < 200 - 250ms qualifies as pre-attentive
  - eye movements take at least 200ms
  - 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.

Hearst, 2003

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.

All Preattentive Processing figures from Healey 97
http://www.csc.ncsu.edu/faculty/healey/PP/PP.html

Preattentive Visual Properties
(Healey 97)

length	Triesman & Gormican [1988]
width	Julesz [1985]
size	Triesman & Gelade [1980]
curvature	Triesman & Gormican [1988]
number	Julesz [1985]; Trick & Pylyshyn [1994]
terminators	Julesz & Bergen [1983]
intersection	Julesz & Bergen [1983]
closure	Enns [1986]; Triesman & Souther [1985]
colour (hue)	Nagy & Sanchez [1990, 1992]; D'Zmura [1991] Kawai et al. [1995]; Bauer et al. [1996]
intensity	Beck et al. [1983]; Triesman & Gormican [1988]
flicker	Julesz [1971]
direction of motion	Nakayama & Silverman [1986]; Driver & McLeod [1992]
binocular lustre	Wolfe & Franzel [1988]
stereoscopic depth	Nakayama & Silverman [1986]
3-D depth cues	Enns [1990]
lighting direction	Enns [1990]

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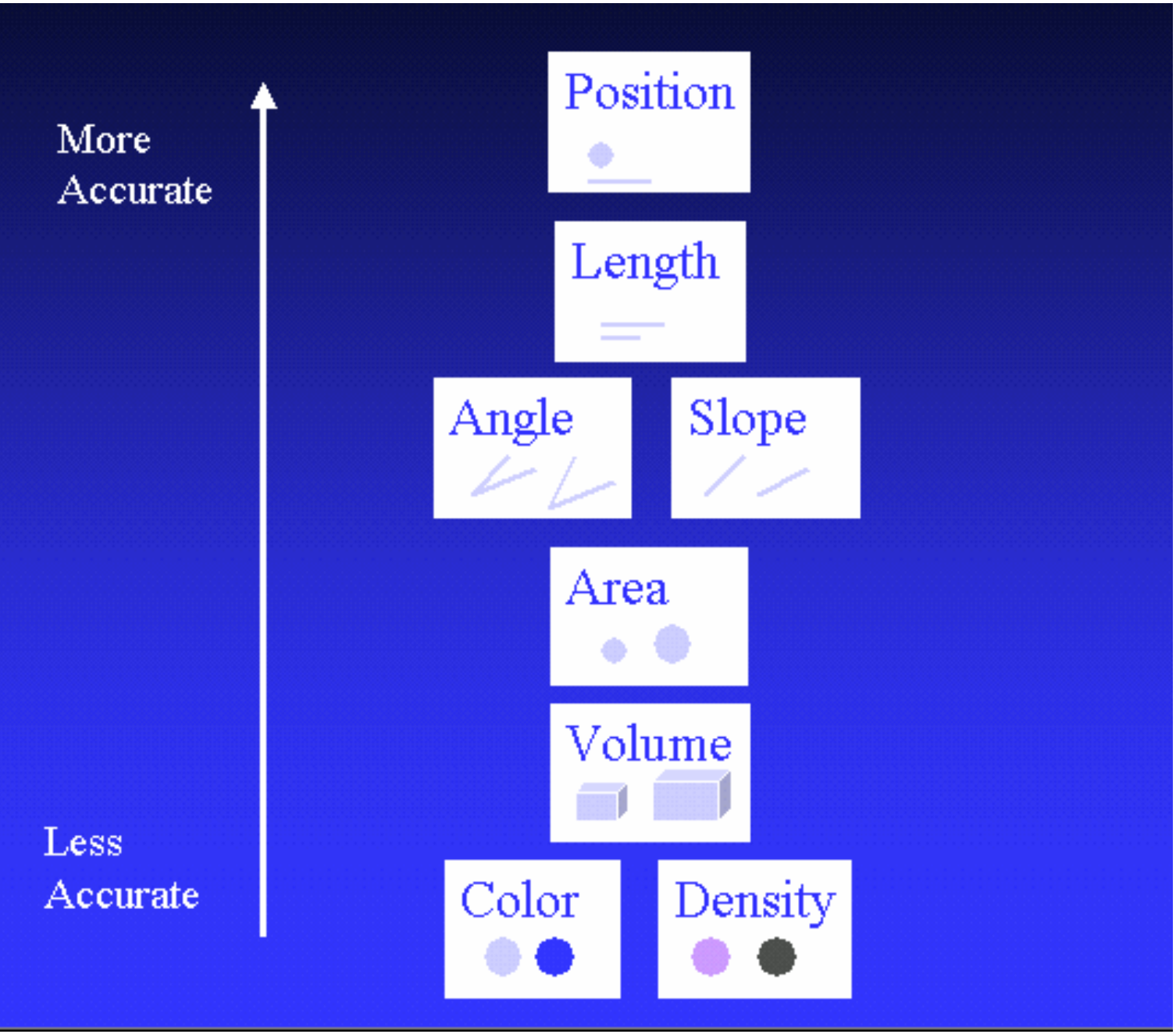


Accuracy Ranking of Quantitative Perceptual Tasks Estimated; only pairwise comparisons have been validated (Mackinlay 88 from Cleveland & McGill)

Hearst, 2003

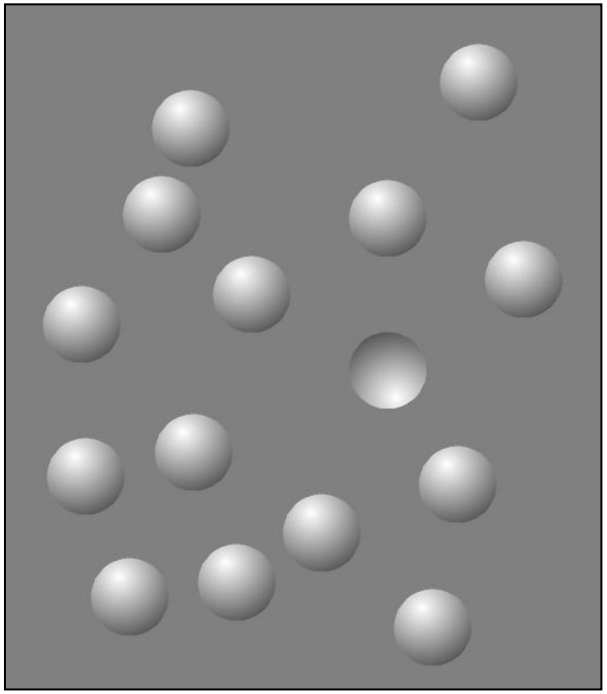
Preattentive Processing (Pop Out)

- Time required to find target independent of overall number

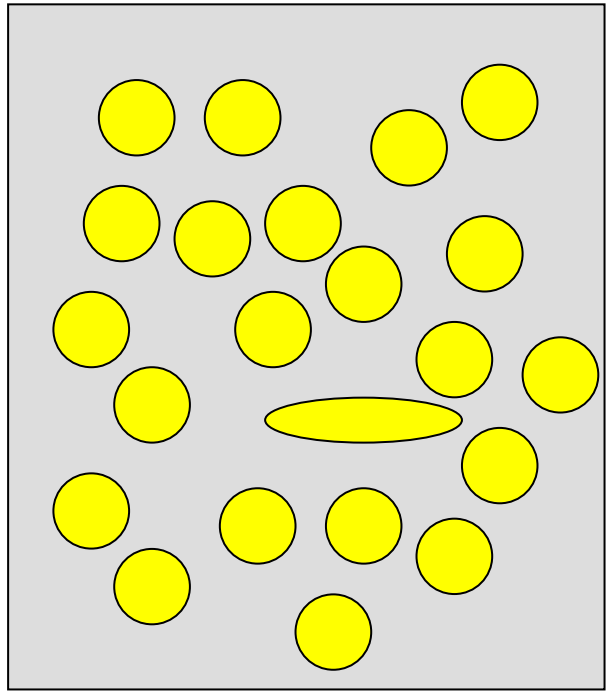
- Form:
  - line orientation, length, width
  - spatial orientation, added marks, numerosity (4)
- Colour:
  - hue, intensity

- Motion:
  - flicker, direction of motion
- Spatial Position:
  - stereoscopic depth, convex/concave shape, shadows

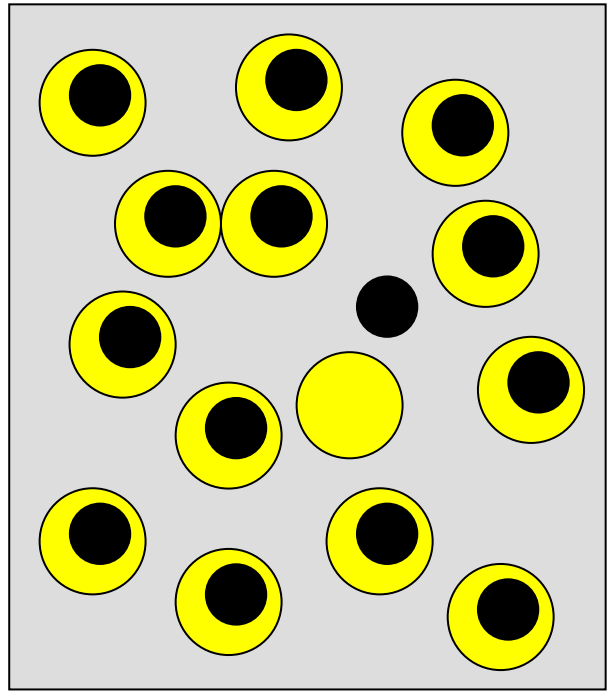
Examples (pop-out)



Shading

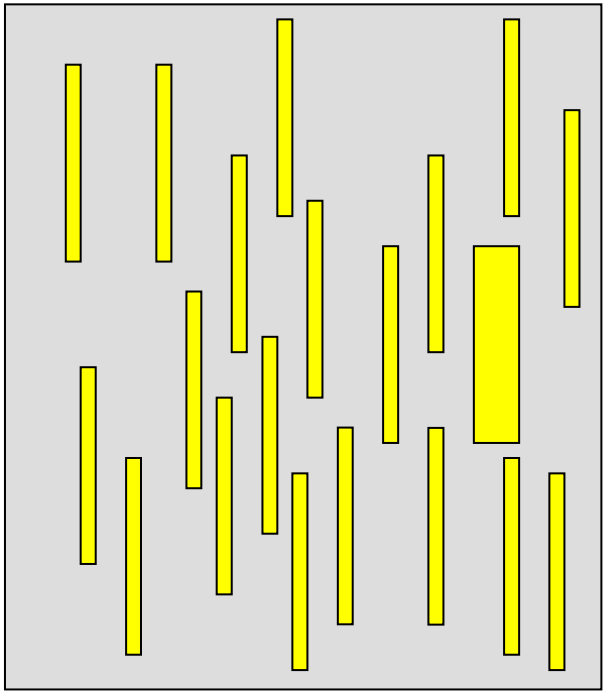


Shape

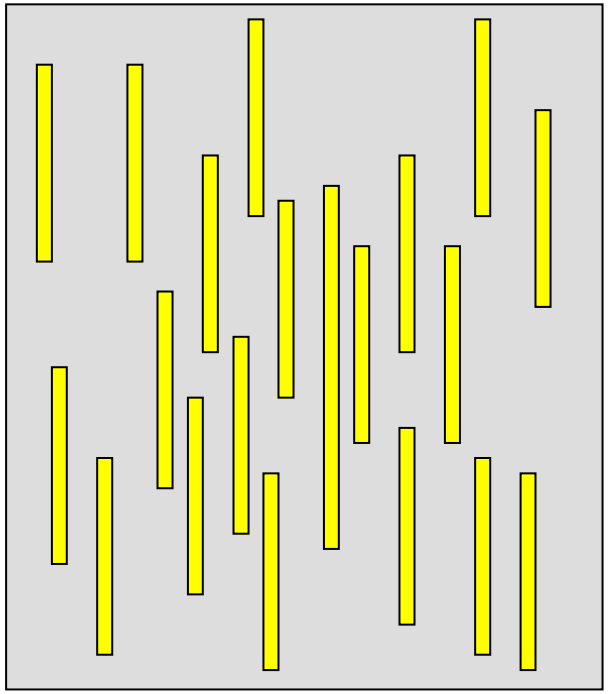


Enclosure

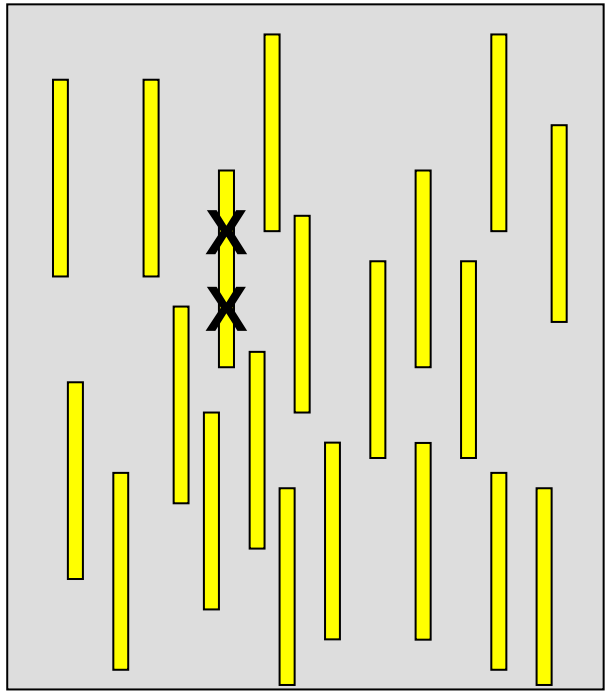
Examples (pop-out)



width



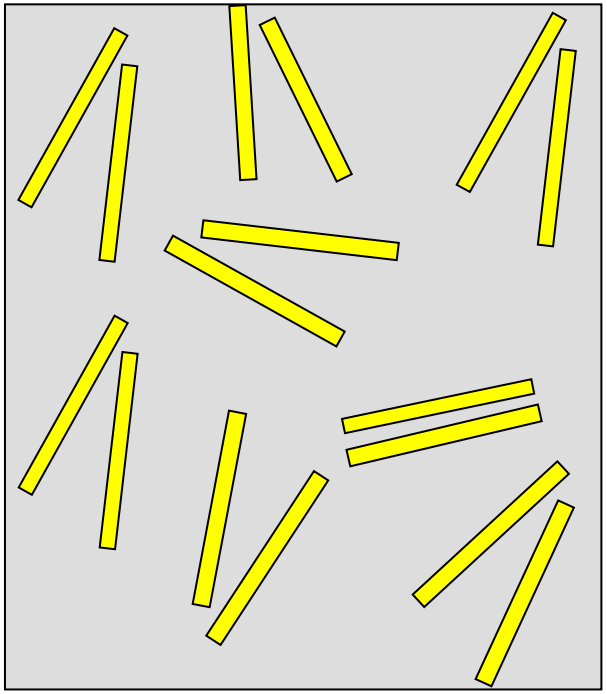
length



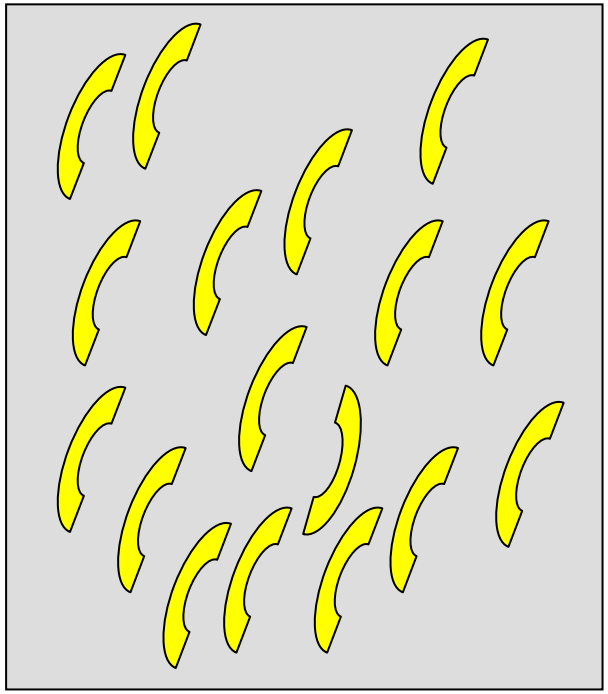
marked

Hiding features
due to placement

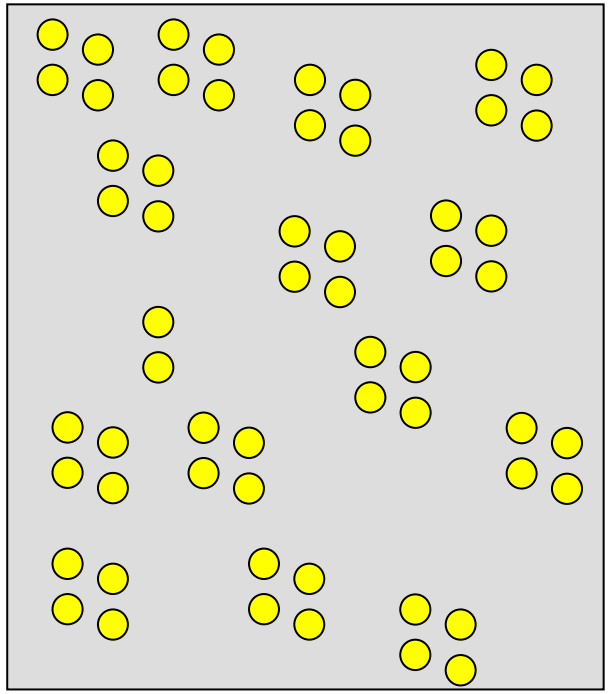
Examples (pop-out)



angle

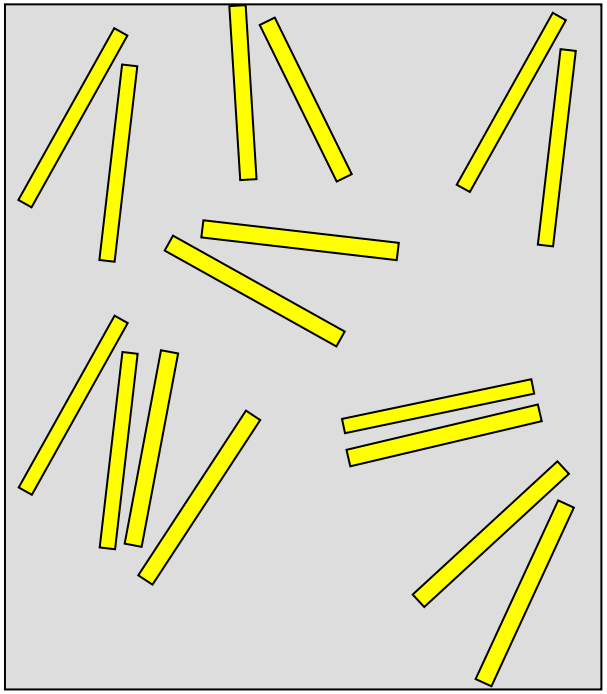


curve



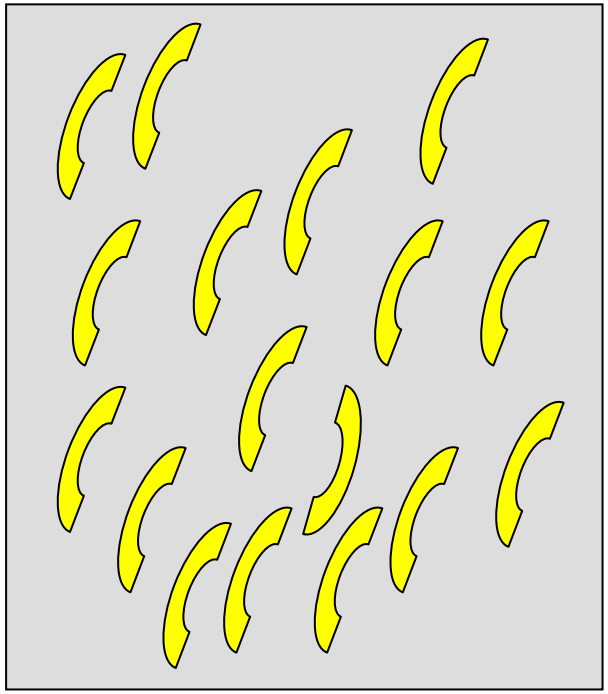
Clusters/count

Examples (pop-out)

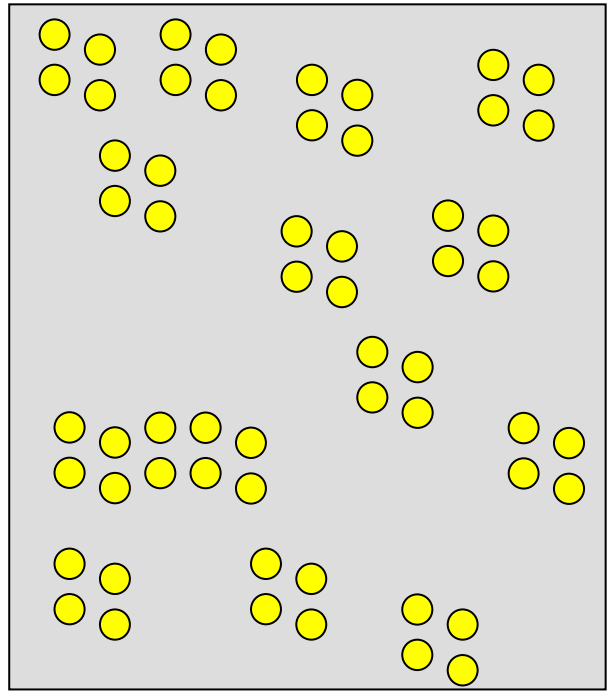


angle

Hiding features
due to placement



curve



Clusters/count

Hiding features
due to placement

Visual Illusions

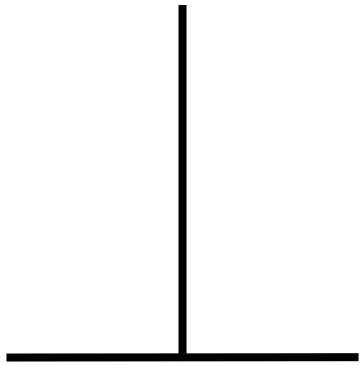
- People don’t perceive length, area, angle, brightness they way they “should”.
- Some illusions have been reclassified as systematic perceptual errors
  - e.g., brightness contrasts (grey square on white background vs. on black background)
  - partly due to increase in our understanding of the relevant parts of the visual system
- Nevertheless, the visual system does some really unexpected things.

Hearst, 2003

Illusions of Linear Extent

- Mueller-Lyon (off by 25-30%)

- Horizontal-Vertical



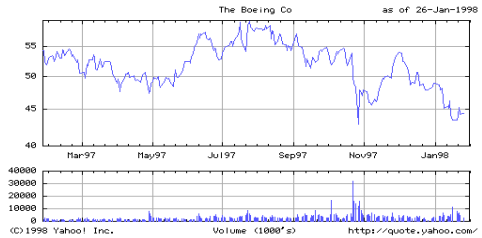
Hearst, 2003

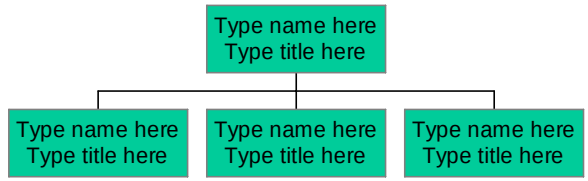
References

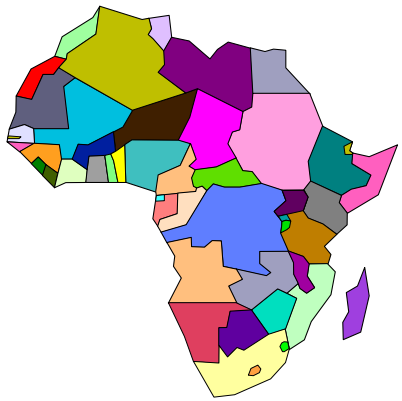
- Marti Hearst
  - http://bailando.sims.berkeley.edu/infovis.html
  - http://bailando.sims.berkeley.edu/talks/chi03-tutorial.ppt
- Margret-Anne Storey
  - http://www.csr.uvic.ca/~mstorey/
  - http://www.cs.uvic.ca/~mstorey/teaching/infovis/course_notes/introduction.pdf
- Ben Shneiderman
  - http://www.cs.ubc.ca/~tmm/courses/cpsc533c-03-spr/readings/shneiderman96eyes.pdf

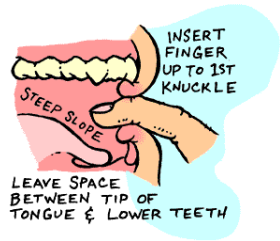
Basic Types of Symbolic Displays
(Kosslyn 89)

- Graphs
- Charts
- Maps
- Diagrams









From Hearst, 2003

Basic Types of Data

- Nominal (qualitative)
  - (no inherent order)
  - city names, types of diseases, ...
- Ordinal (qualitative)
  - (ordered, but not at measurable intervals)
  - first, second, third, …
  - cold, warm, hot
- Nominal/Interval (quantitative)
  - list of integers or reals

Hearst, 2003

Interpretations of Visual Properties

Some properties can be discriminated more 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

Hearst, 2003

Accuracy Ranking of Quantitative Perceptual Tasks static features

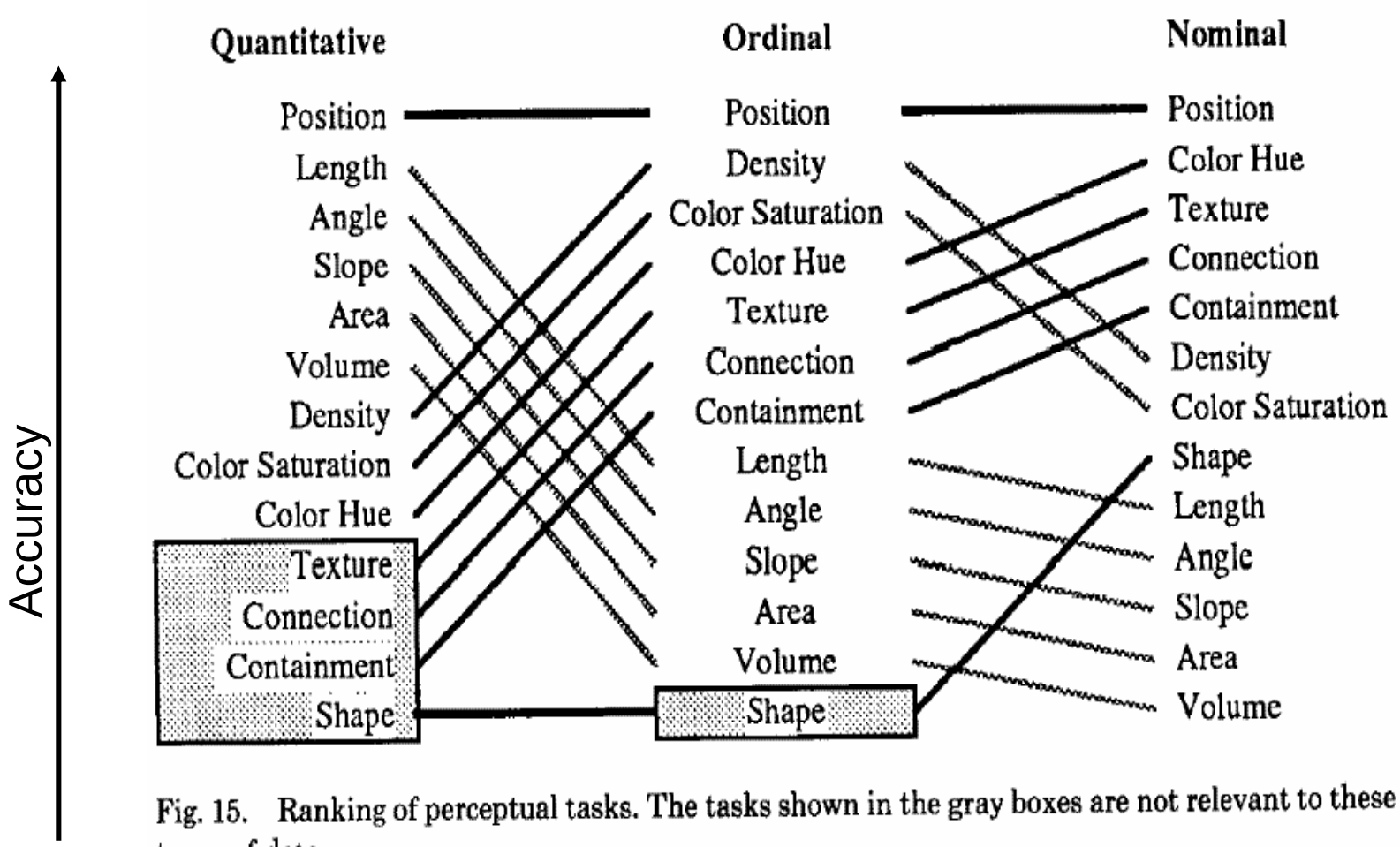


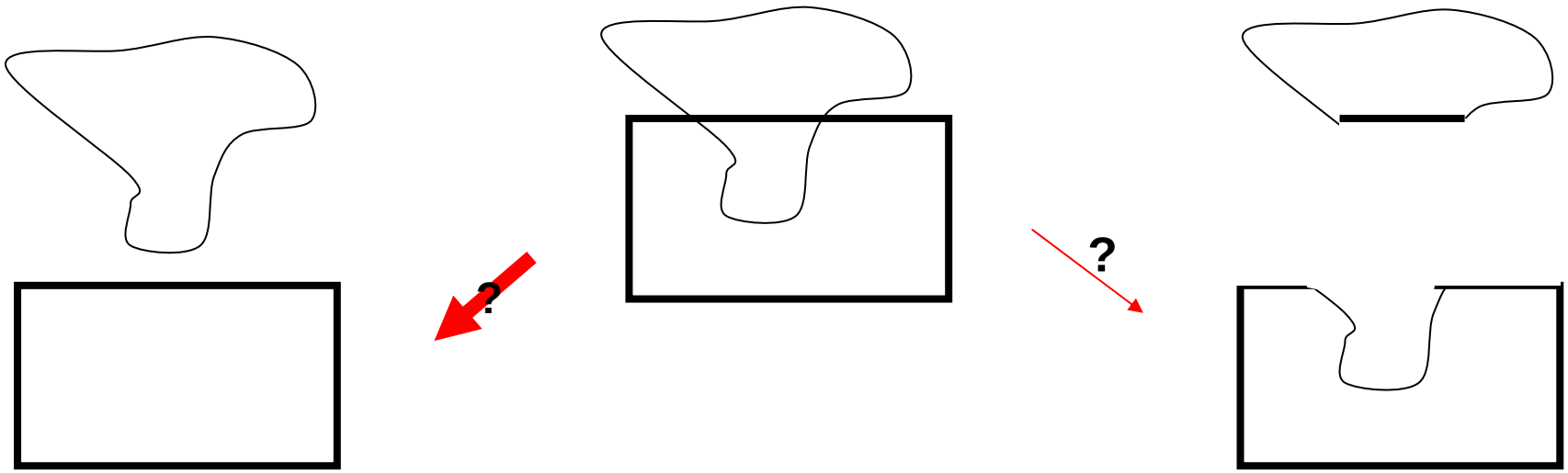
Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data.

Mackinlay 88

Concepts & Principles

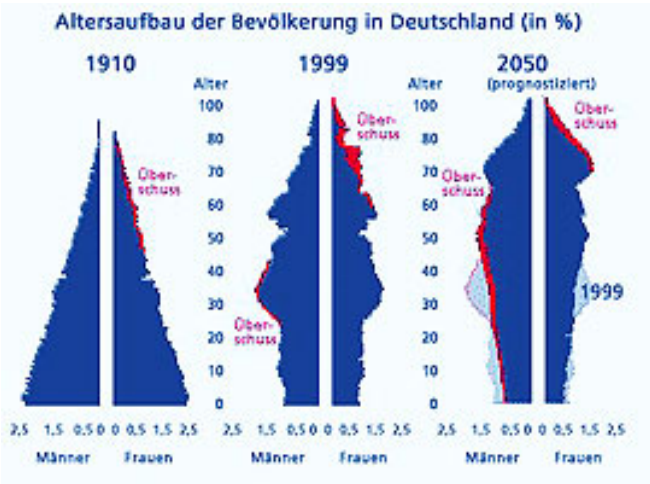
Continuity

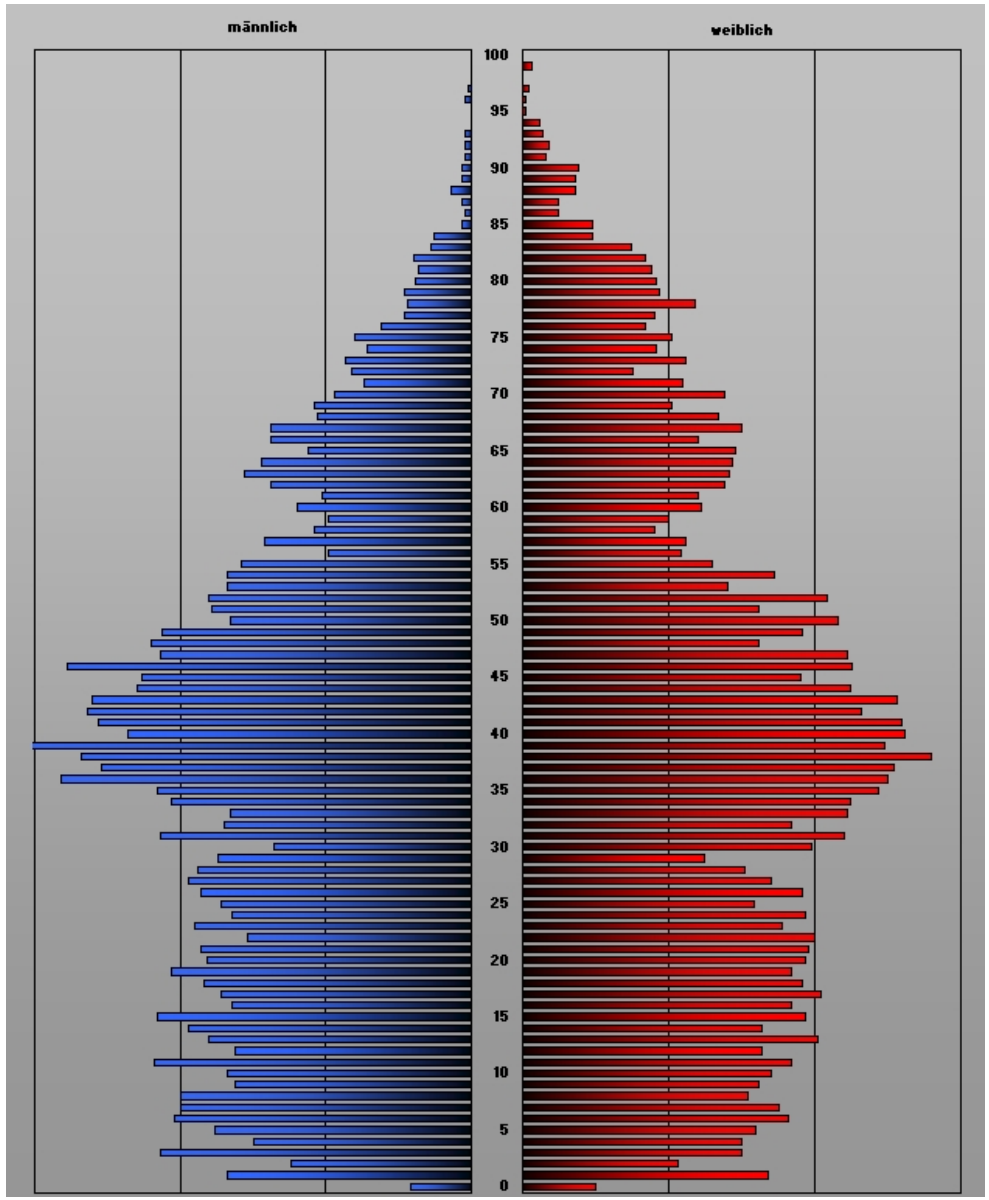
- Experience tells that visual elements are more likely to be continuous
- Implied connection
- connections are used to show relations



Symmetry

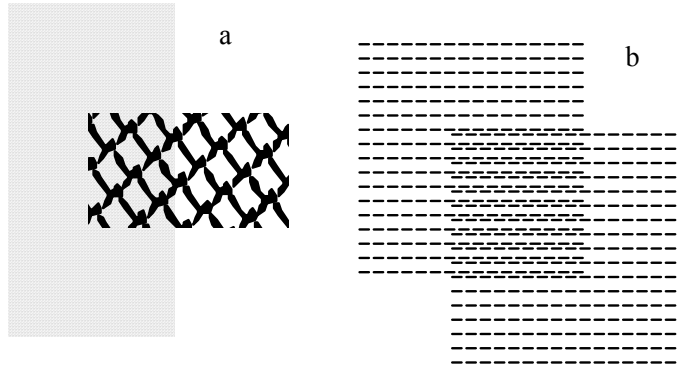
- Symmetrical to emphasize relationship

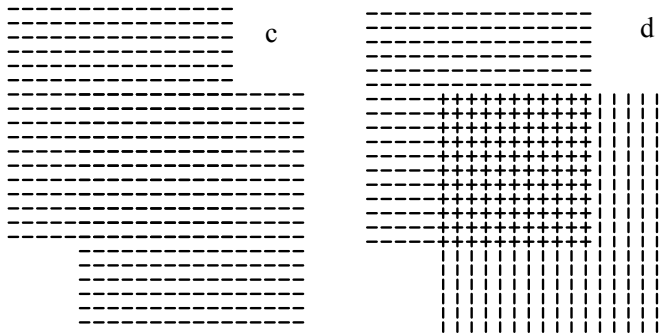




Figure, Background Transparency, Overlap

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





Tufte – Principles of Graphical Excellence

- 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

Maximize the data-ink ratio
(Avoid “chart junk”)

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

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

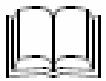
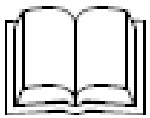
$$\textbf{lie factor} = \frac{\text{size of effect shown in graph}}{\text{size of effect in data}}$$

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.

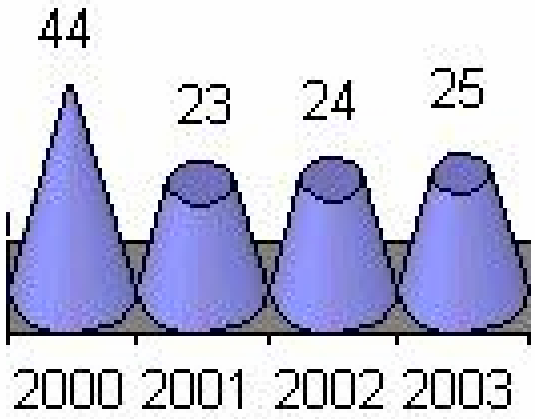
A common example of a **high** lie factor occurs when both dimensions of a two-dimensional figure are made proportional to the same data, so that the size of the figure is proportional to the square of the data; for instance,

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.



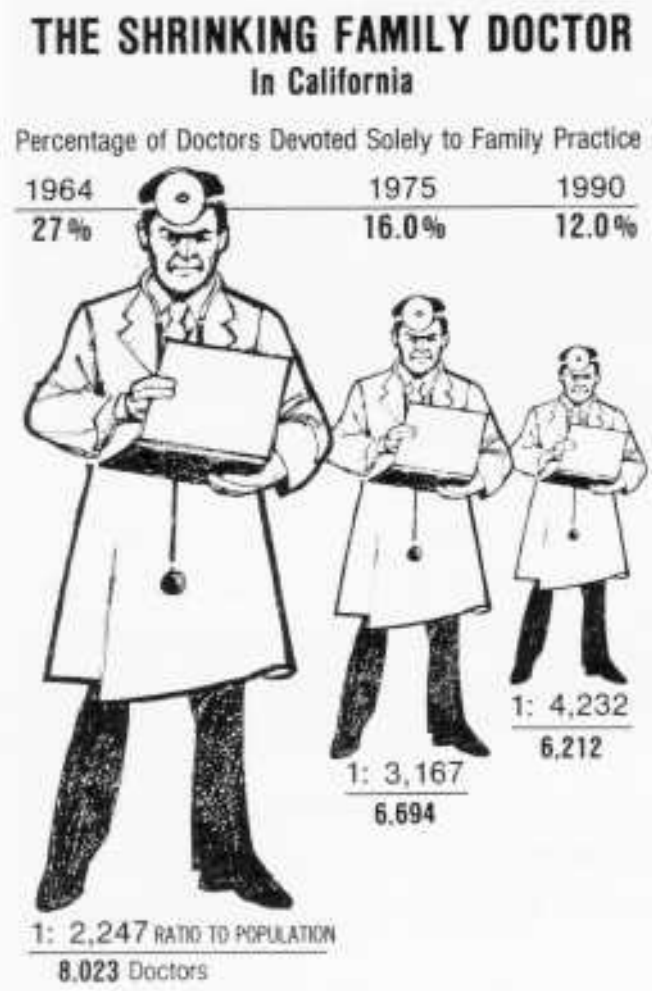
The heights of the (truncated) cones are proportional to the data, but their areas on the screen and their apparent volumes make the larger data values seem relatively small.

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



“Lie factor” = 2.8

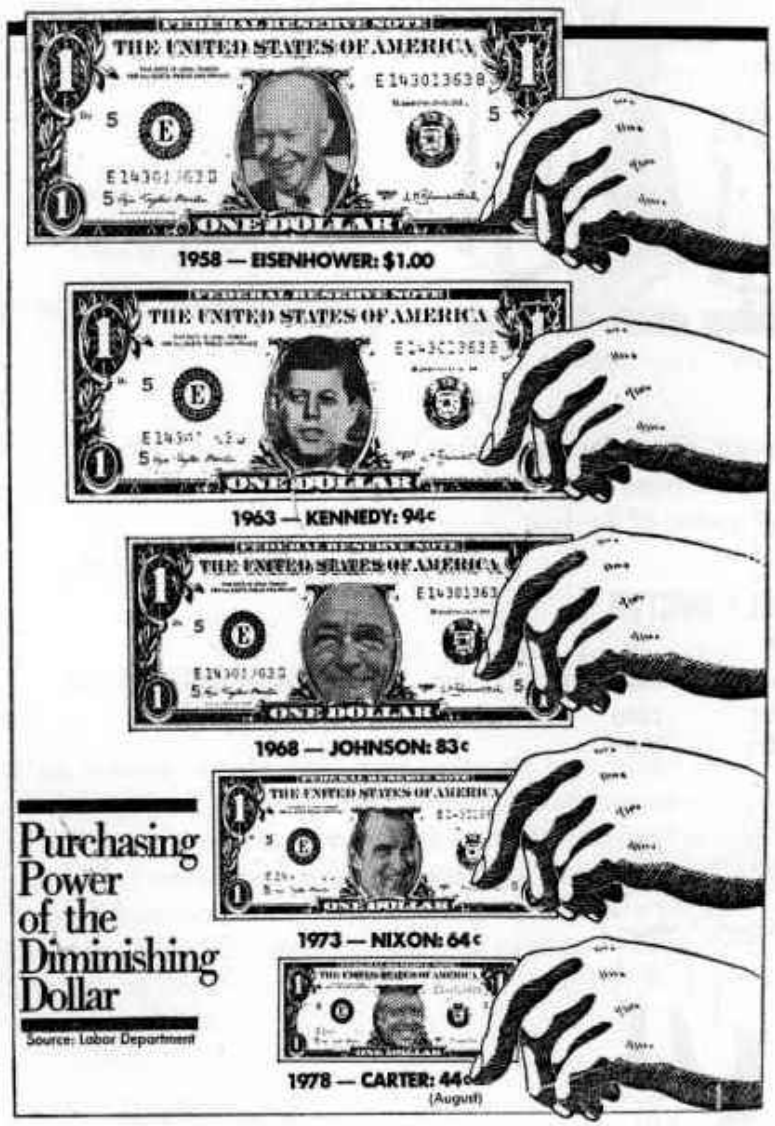
Los Angeles Times, August 5, 1979, p. 3.

Marti Hearst

How to Exaggerate with Graphs

from Tufte ’83

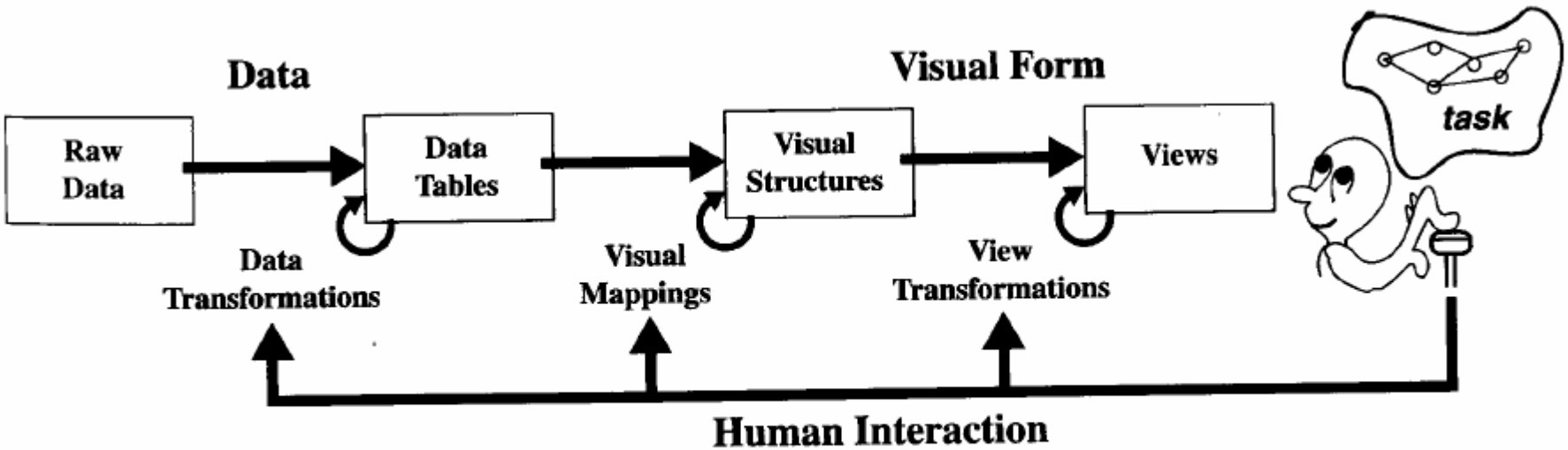
Error: Shrinking along both dimensions



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

Marti Hearst

Visualization Reference Model Human Interaction

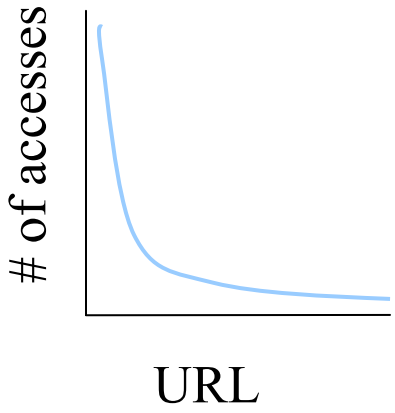


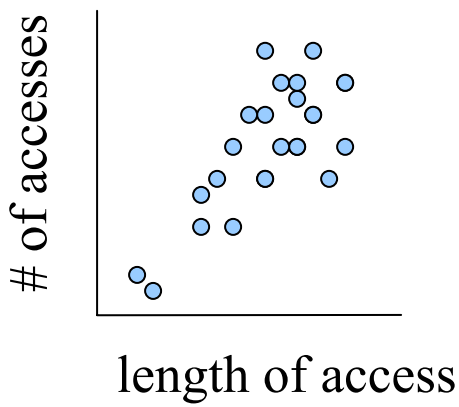
- Raw Data → Data Table
  filtering
- Data Table → Visual Structure
  pick mappings
- Visual Structure → Views
  probes, viewpoints, distortions

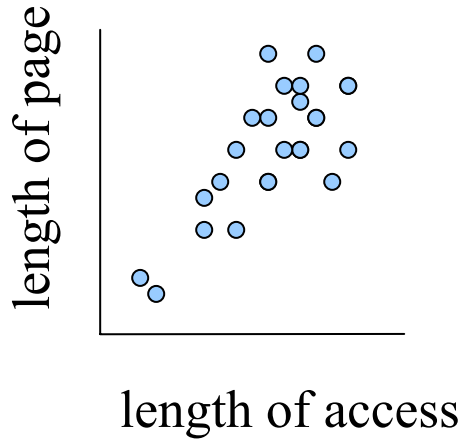
(Storey, 2004)

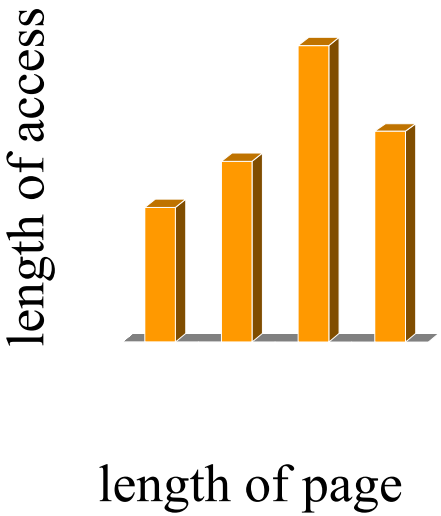
Standard Visualization

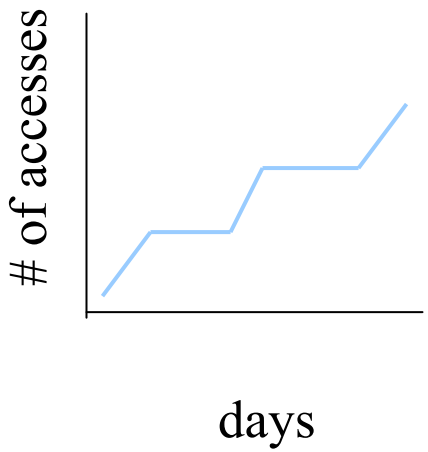
Common Graph Types

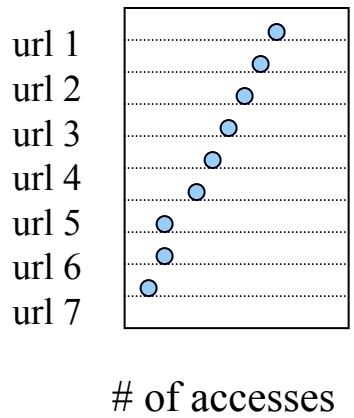












Hearst, 2003

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

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

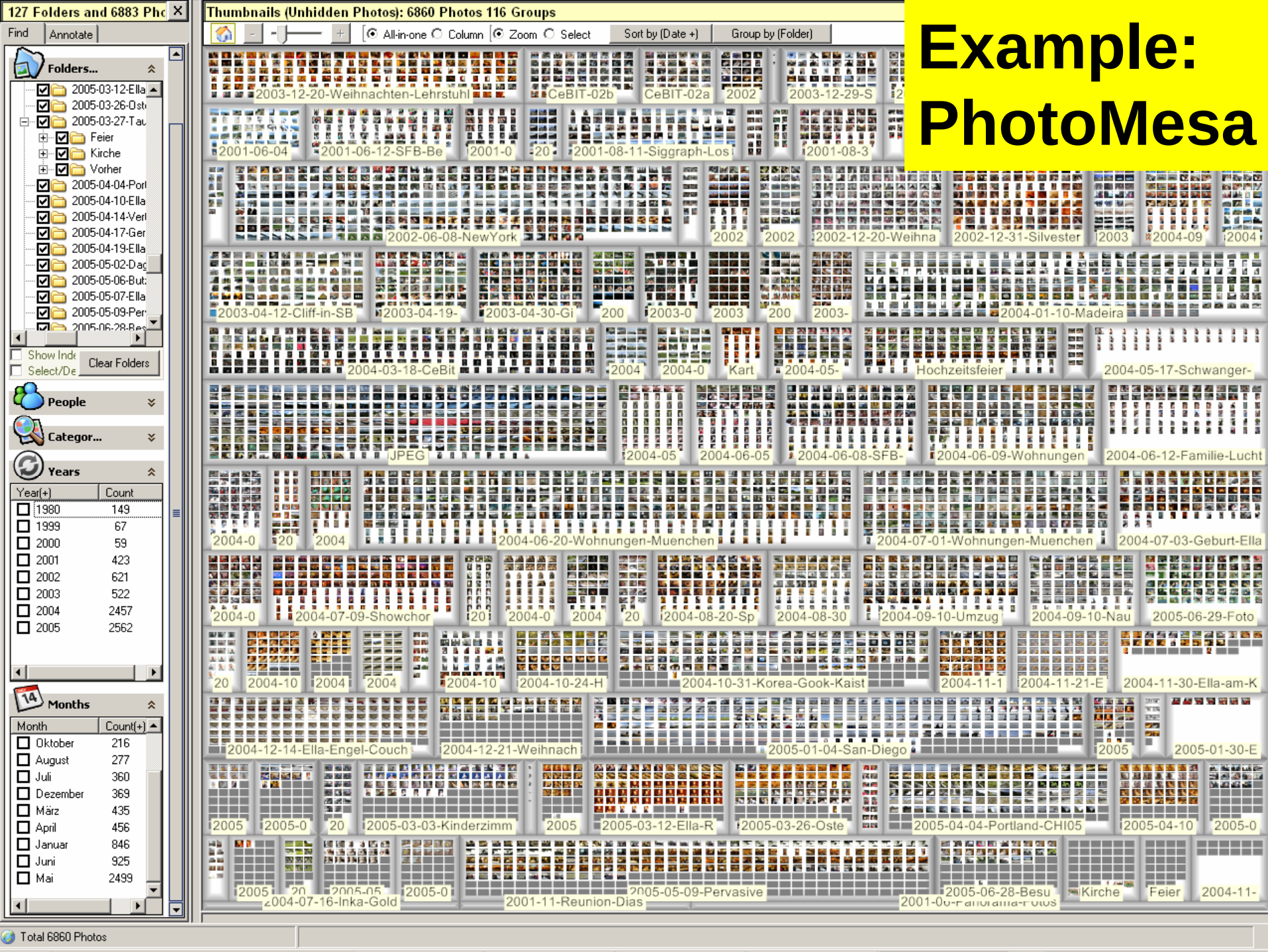
…

Shneiderman, 2003

Information Visualization Tasks

- **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


Example:
PhotoMesa
127 Folders and 6883 Pho
Find
Annotate
Folders...
People
Categor...
Years
Year(+) Count
1980 149
1999 67
2000 59
2001 423
2002 621
2003 522
2004 2457
2005 2562
Months
Month Count(+)
Oktober 216
August 277
Juli 360
Dezember 369
März 435
April 456
Januar 846
Juni 925
Mai 2499
Clear Folders
Thumbnails (Unhidden Photos): 6860 Photos 116 Groups
All-in-one Column Zoom Select
Sort by (Date +)
Group by (Folder)
Total 6860 Photos

Information Visualization: Design Guidelines

Direct manipulation strategies

- Visual presentation of query components
- Visual presentation of results

- Rapid, incremental and reversible actions
- Selection by pointing (not typing)
- Immediate and continuous feedback

- Reduces errors
- Encourages exploration

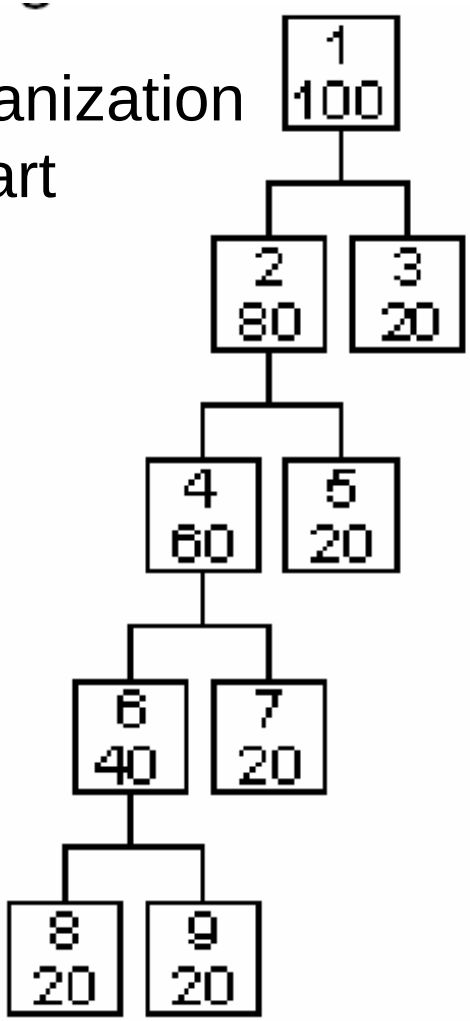
Shneiderman, 2003

Basic Visualization Techniques

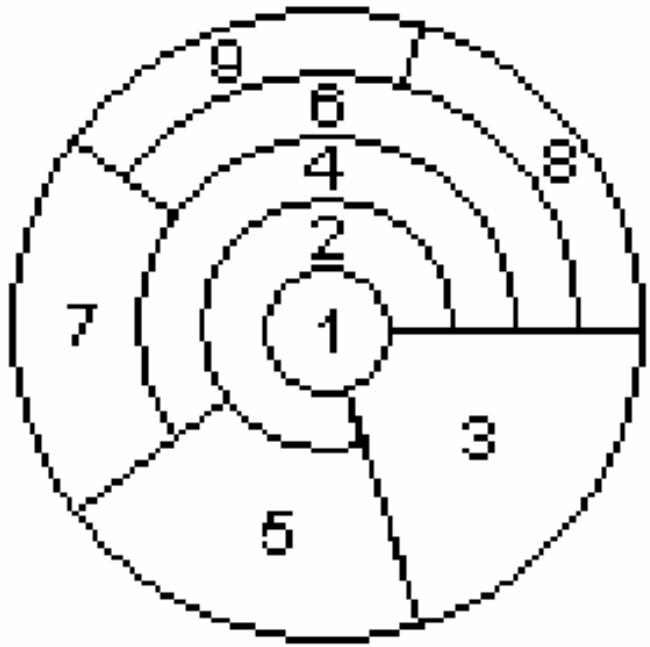
- Finding appropriate visualization for data structures
- Example: trees / graphs

Alternative Tree Visualization

Organization Chart

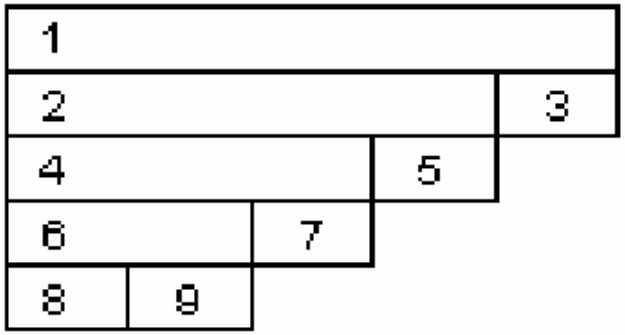


Tree Ring

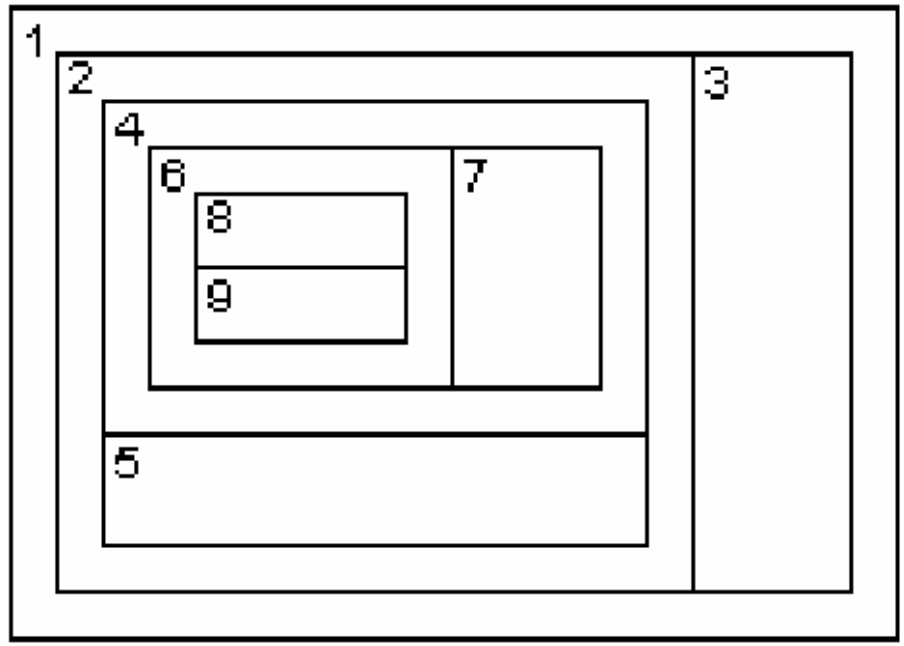


Alternative Tree Visualization

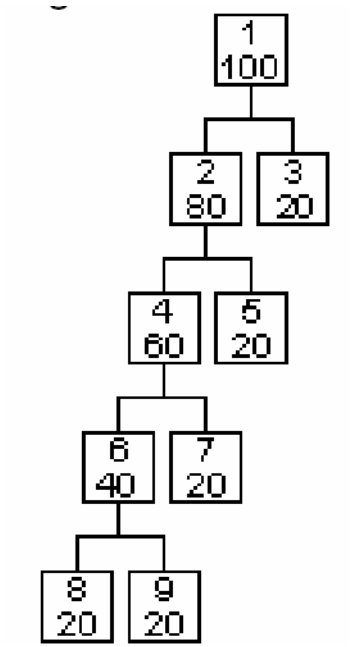
Icicle Plot

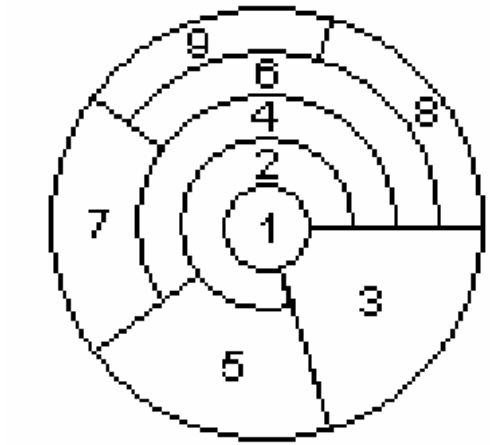


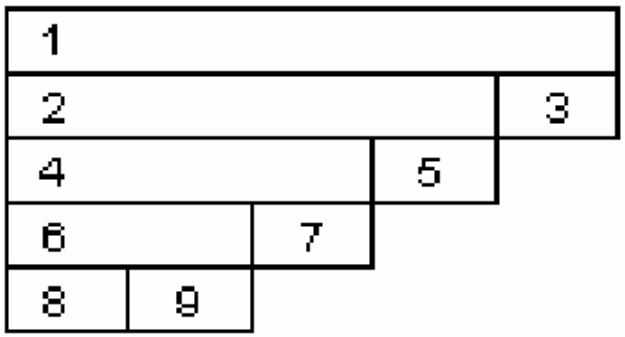
Tree Map

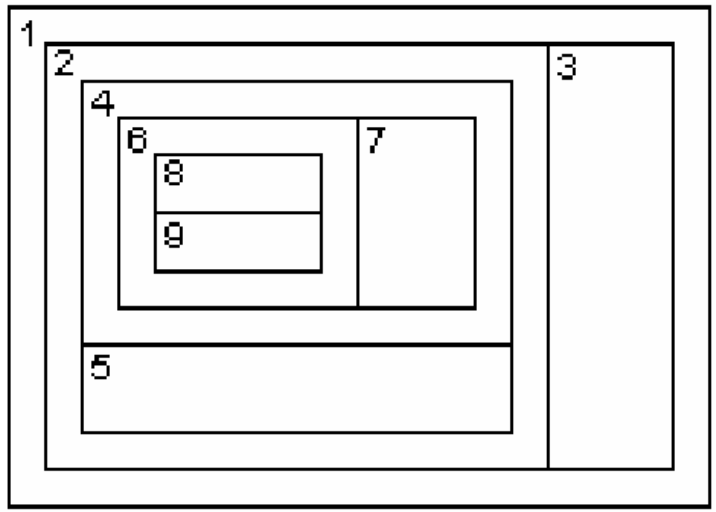


Comparing Visualizations









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

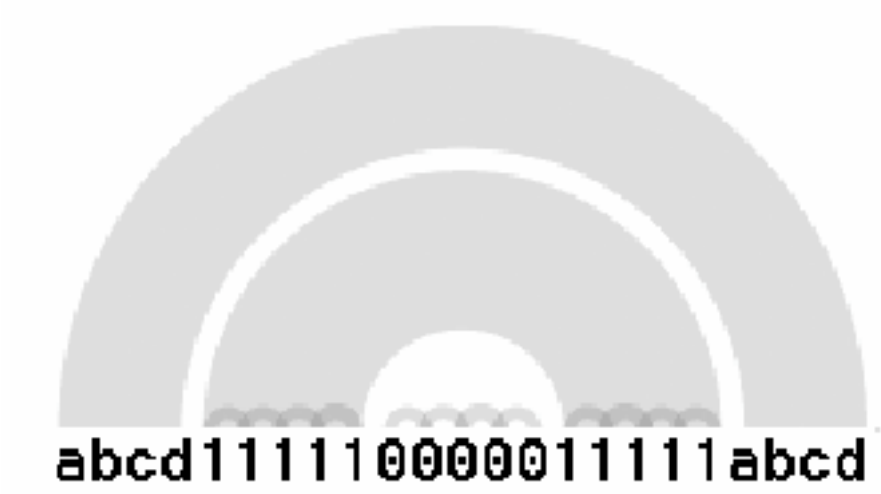
More details see:

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

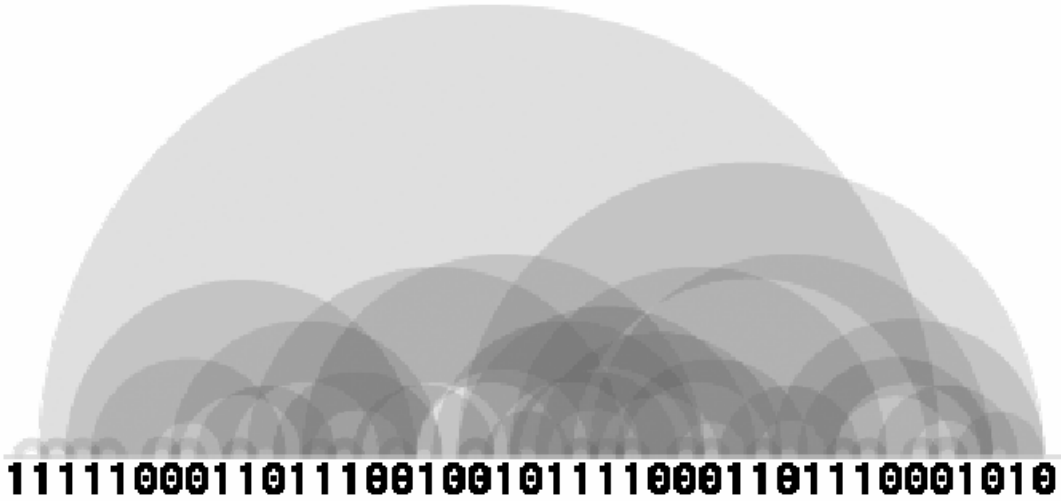
Arc Diagrams

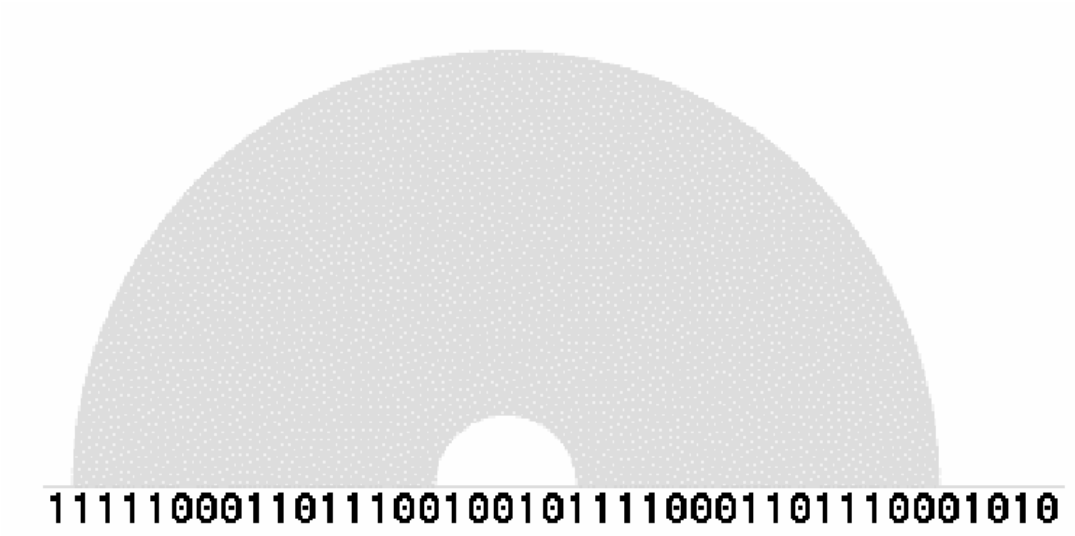
- Visualization method
  - For representing complex patterns of repetition in string data.
  - Arc diagrams scale efficiently for strings that contain many instances of the same subsequence.
  - idea of visualizing only a subset of all possible pairs of matching substrings.
  - highlight just the subsequences essential to understanding the string's structure

Arc Diagrams - Basics



Arc Diagram – Level of Detail



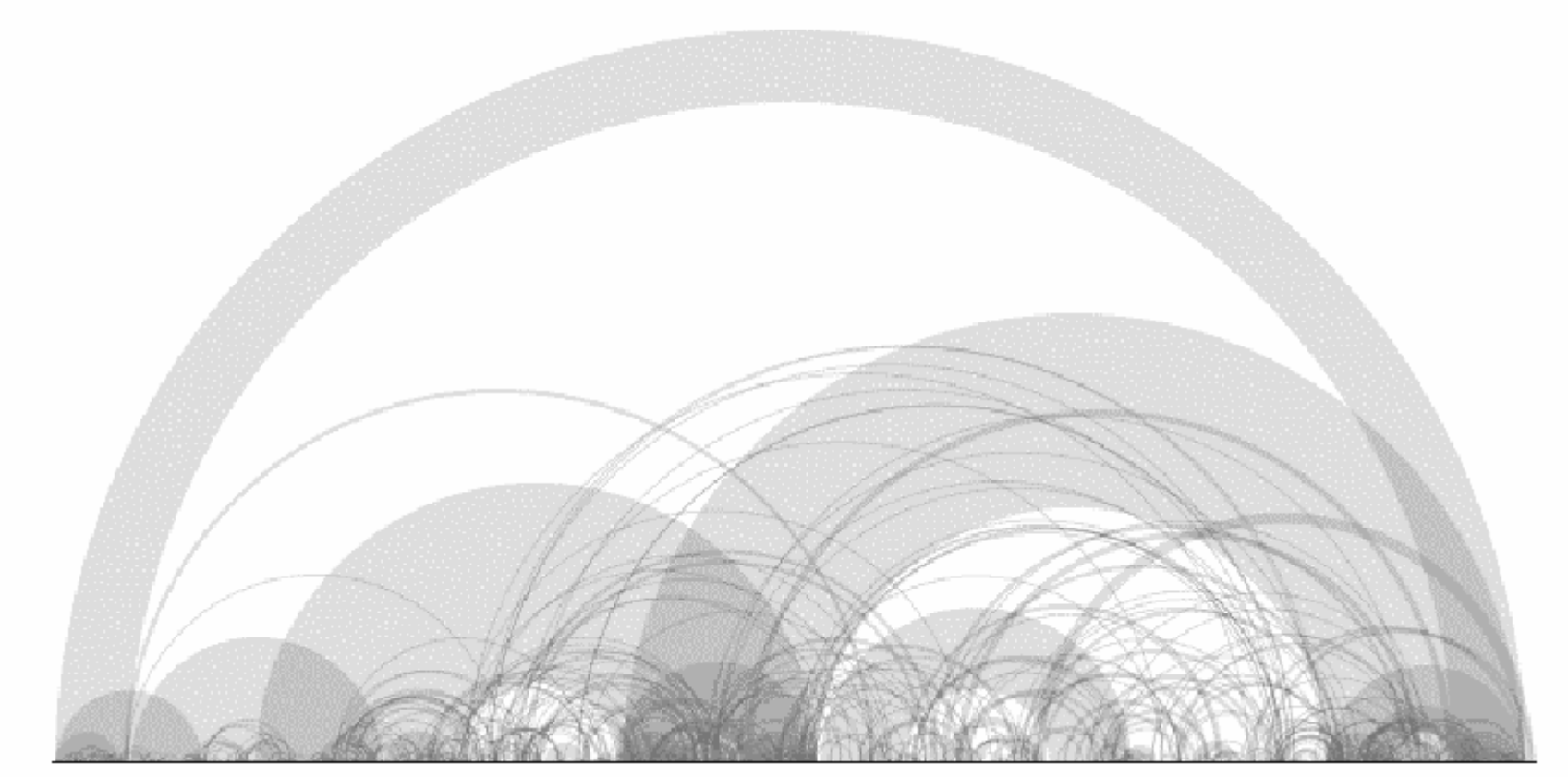


Applied to

- Music
- DNA
- Web pages
- Byte code

Arc Diagram applied to Music

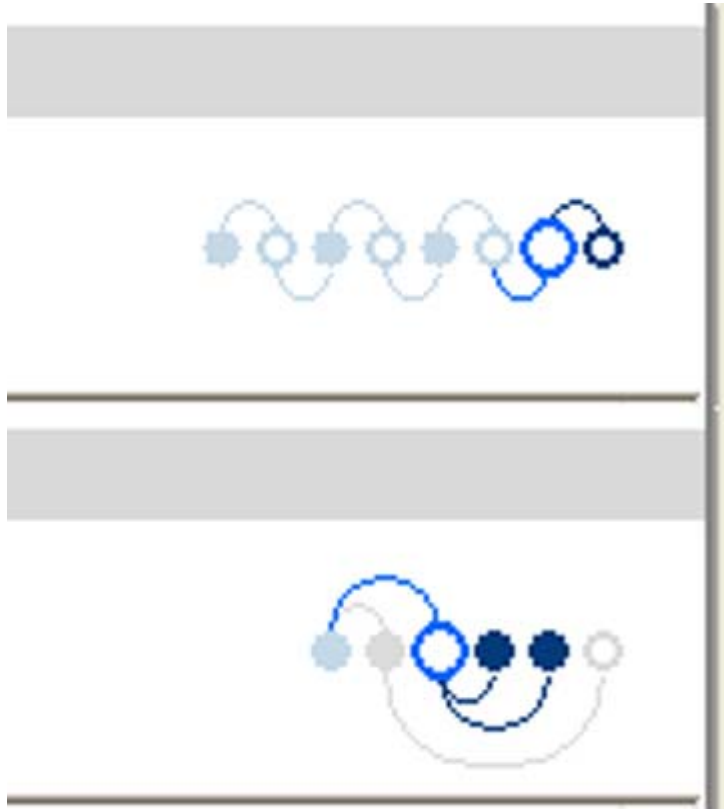
Arc Diagram applied to Music “für Elise”



- More details
  Martin Wattenberg. Arc Diagrams: Visualizing Structure in Strings
  IBM Watson Research Center, Technical report 2002-11
  http://domino.research.ibm.com/cambridge/research.nsf/0/e2a83c4986332d4785256ca7006cb621?OpenDocument

Thread Arcs

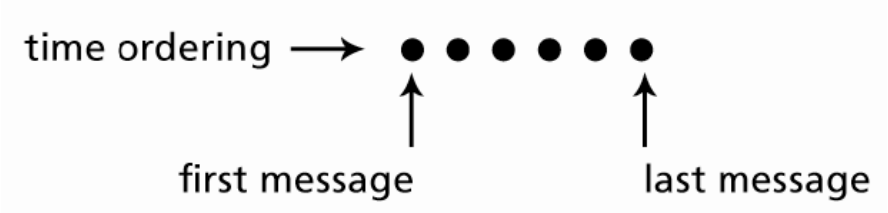
- Thread Arcs combine the chronology of messages with the branching tree structure of a conversational thread
- Benefits
  - Chronology.
  - Relationships
  - Stability:
  - Compactness:
  - Attribute Highlighting:
  - Scale:
  - Interpretation/Sense

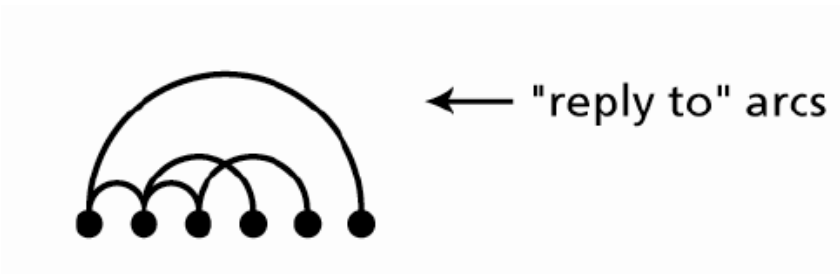


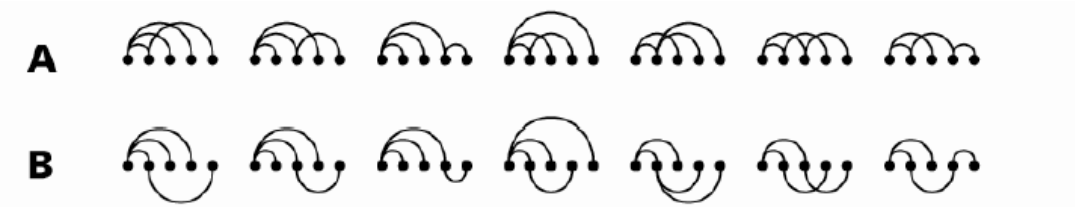
- http://www.research.ibm.com/remail/threadarcs.html

Thread Arcs for Emails

- **Visualization**
  - linear layout of message nodes connected by relationship arcs.
  - each circular node represents a message in the thread.
  - *chronology* of the thread is encoded by the position
  - The width of a Thread Arc is a linear function of the size of the thread
  - *compact visualization* if height is constrain







The relationship between messages are clearer when arcs are draw above and below nodes (B).

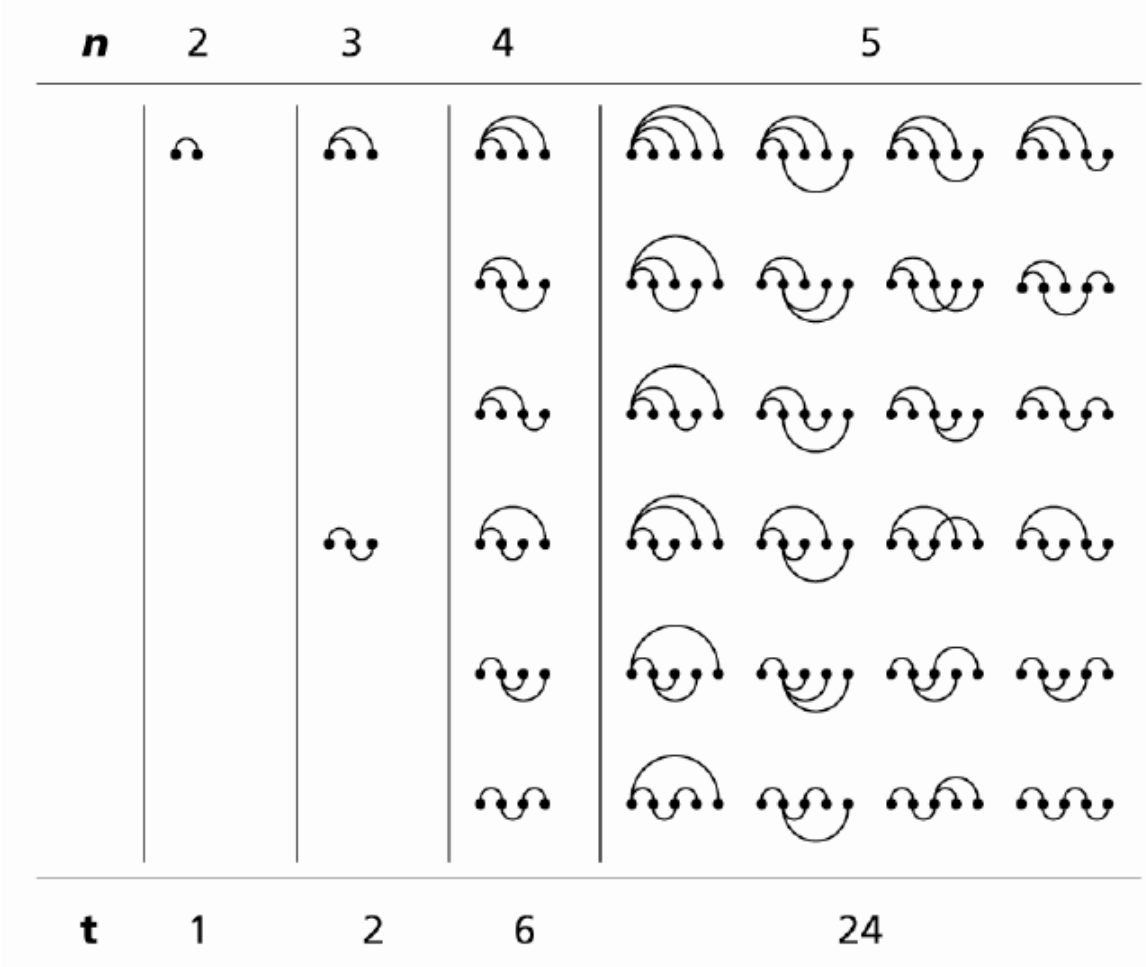
Pseudo code for drawing a thread arc

To make a Thread Arc

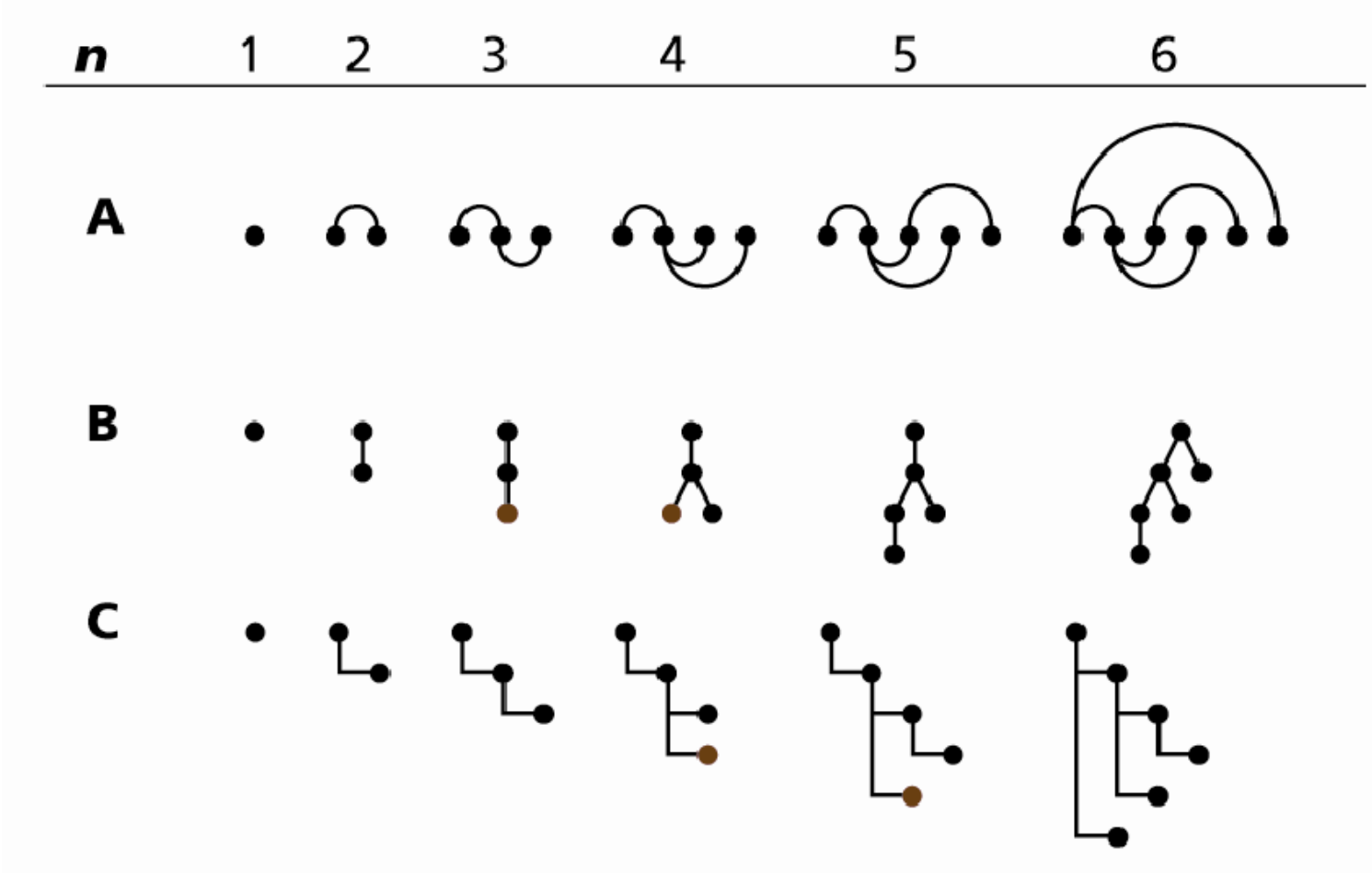
```
sort all messages chronologically
find the generation depth of each message

for each message
      if the message is the root message then
            place the node at the starting position
            don't draw an arc
      else
            place the message to the right of the last message
            if the message generation depth is odd then
                  draw an arc above the line to the message's parent
            else
                  draw an arc below the line to the message's parent
next message
```

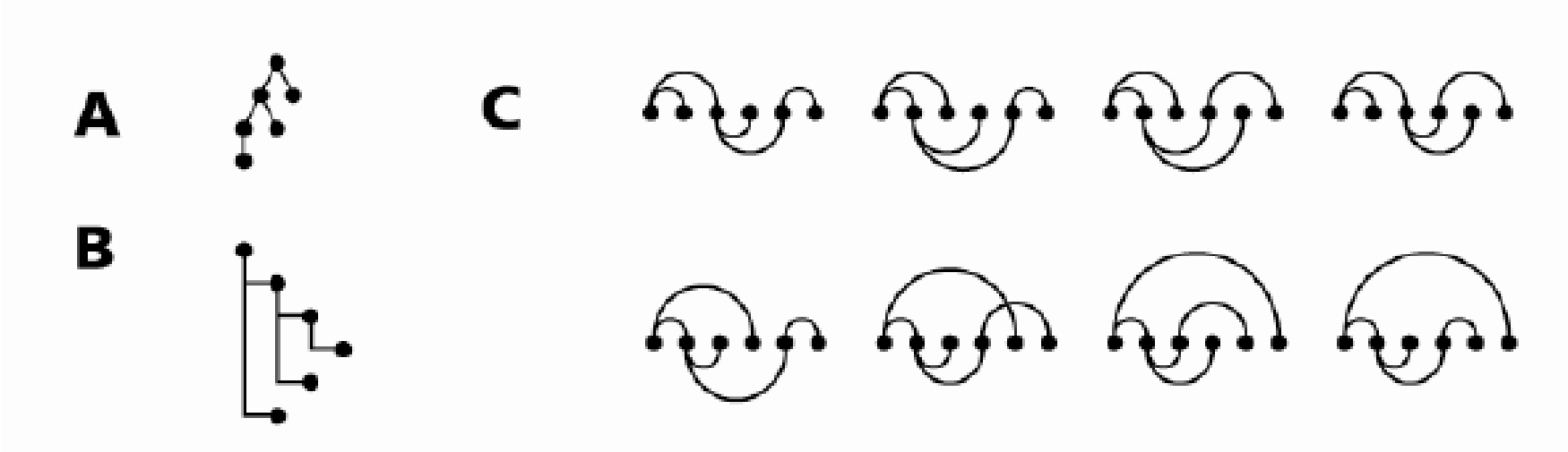
Possible Thread Arcs that can be built with 2 to 5 messages.



Stability of Thread Arcs

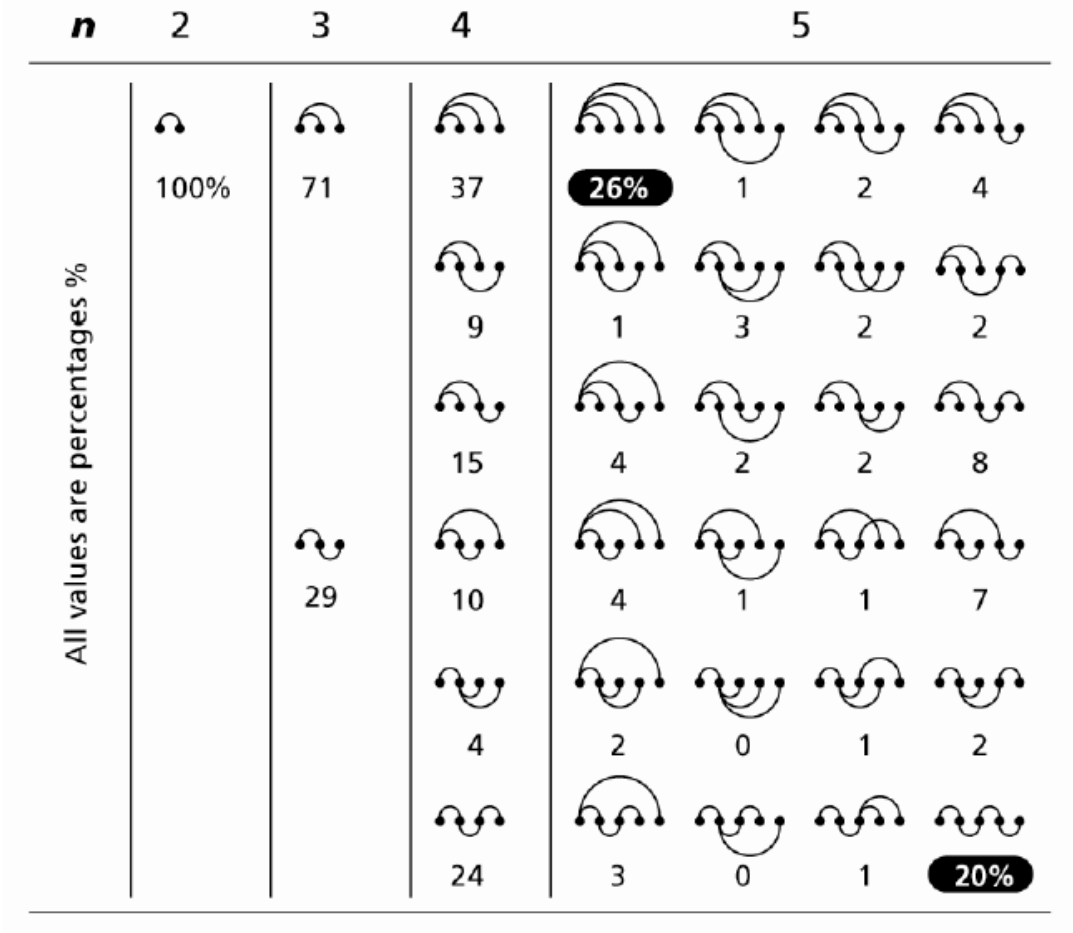


Chronological Information in the Thread Arcs



Example Email Client using Thread Arcs

Distribution of distinctive Thread Arcs of 2 to 5 messages



More details: http://www.research.ibm.com/remail/publications.html

Techniques

- Focus & Context
- Zoom & Pan

Background

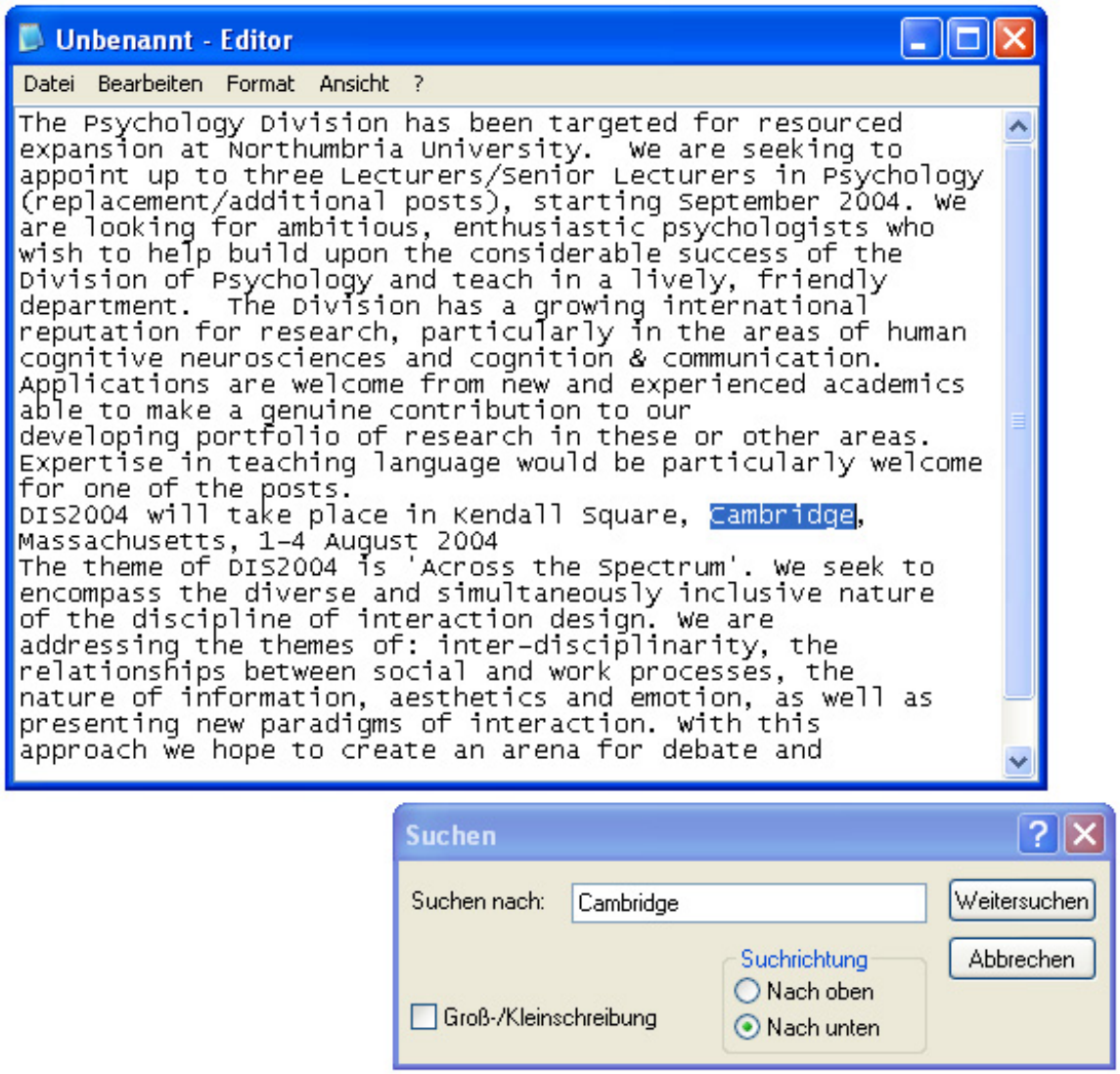
- Useful Field of View (UFOV)
  - expands searchlight metaphor
  - size of region from which we can rapidly take information
  - maintains constant number of targets
- Tunnel Vision and Stress
  - UFOV narrows as cognitive load/stress goes up
- Role of Motion in Attracting Attention
  - UFOV larger for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

Depth of Field

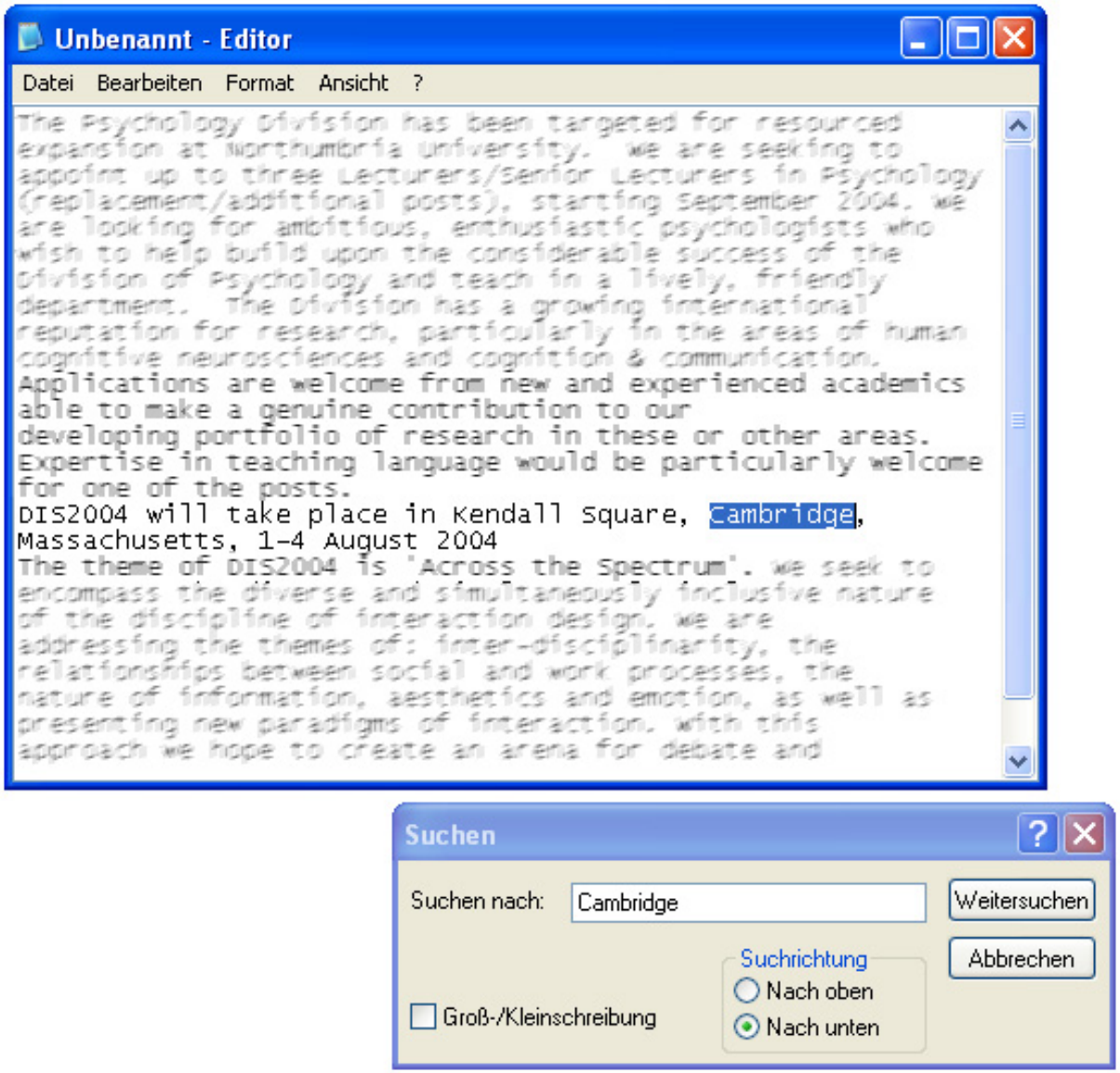
- Guiding user attention by blurring less relevant parts of an image
- Keeping the context

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

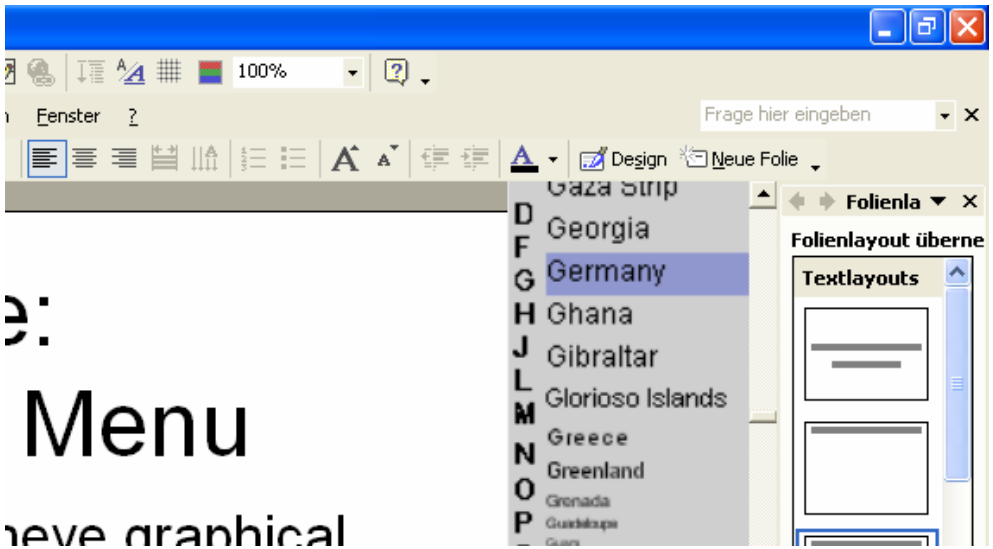
Semantic Depth of Field - Example

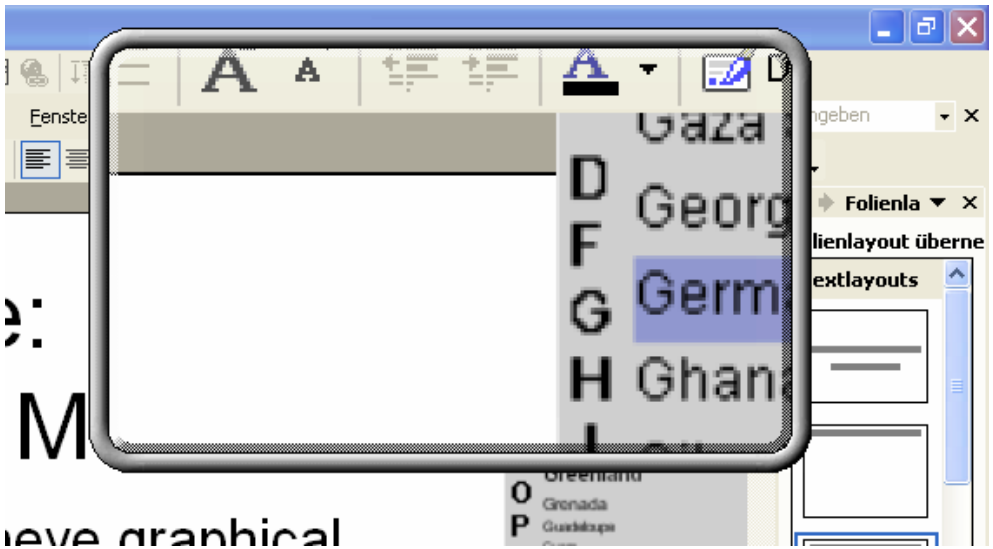


Semantic Depth of Field - Example



Magnifying Glass





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

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/ (Applet)

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

Focus + Context

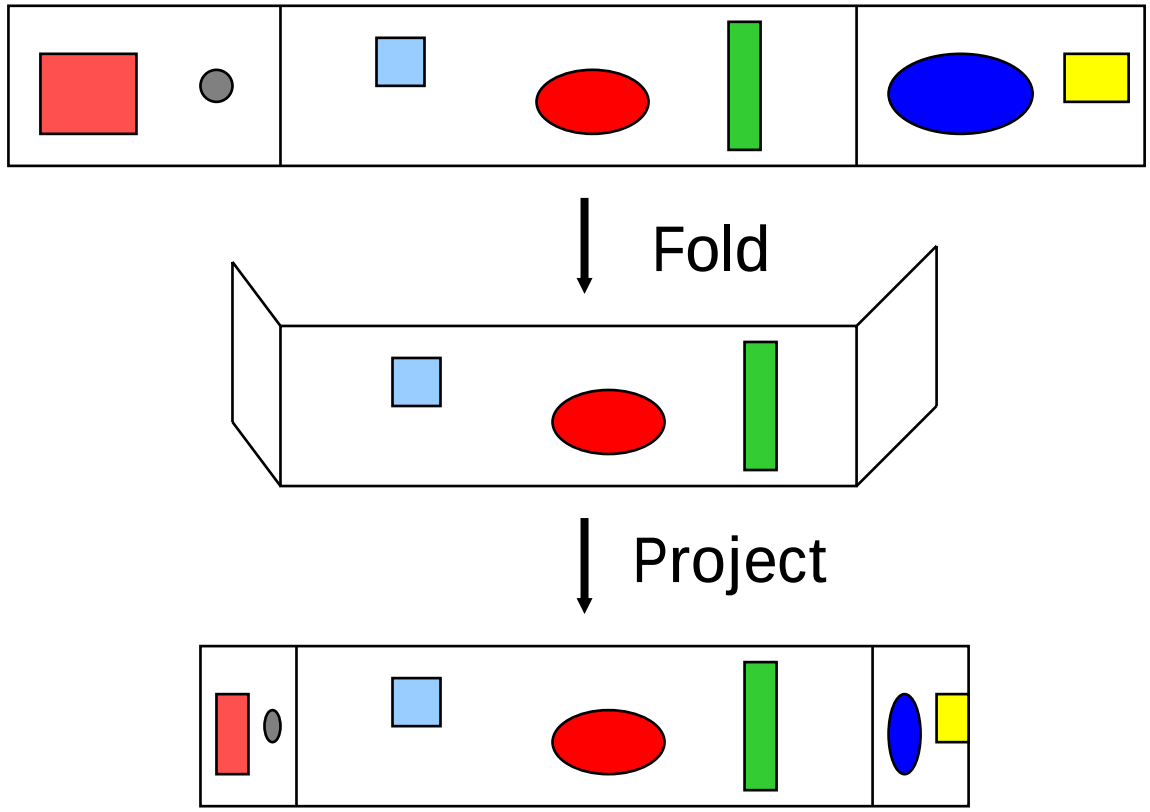
- Often combined with distortion
  - E.g. fisheye
  - Data not in focus is suppressed and distorted
  - Data of interest is larger and clearer

- “Allows dynamic interactive positioning of the local detail without severely compromising spatial relationships.”
  - *Leung & Apperley*
- “One challenge in navigating through any large dataspace is maintaining a sense of relationship between what you are looking at and where it is with respect to the rest of the data.”
  - *Bederson & Hollan*

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

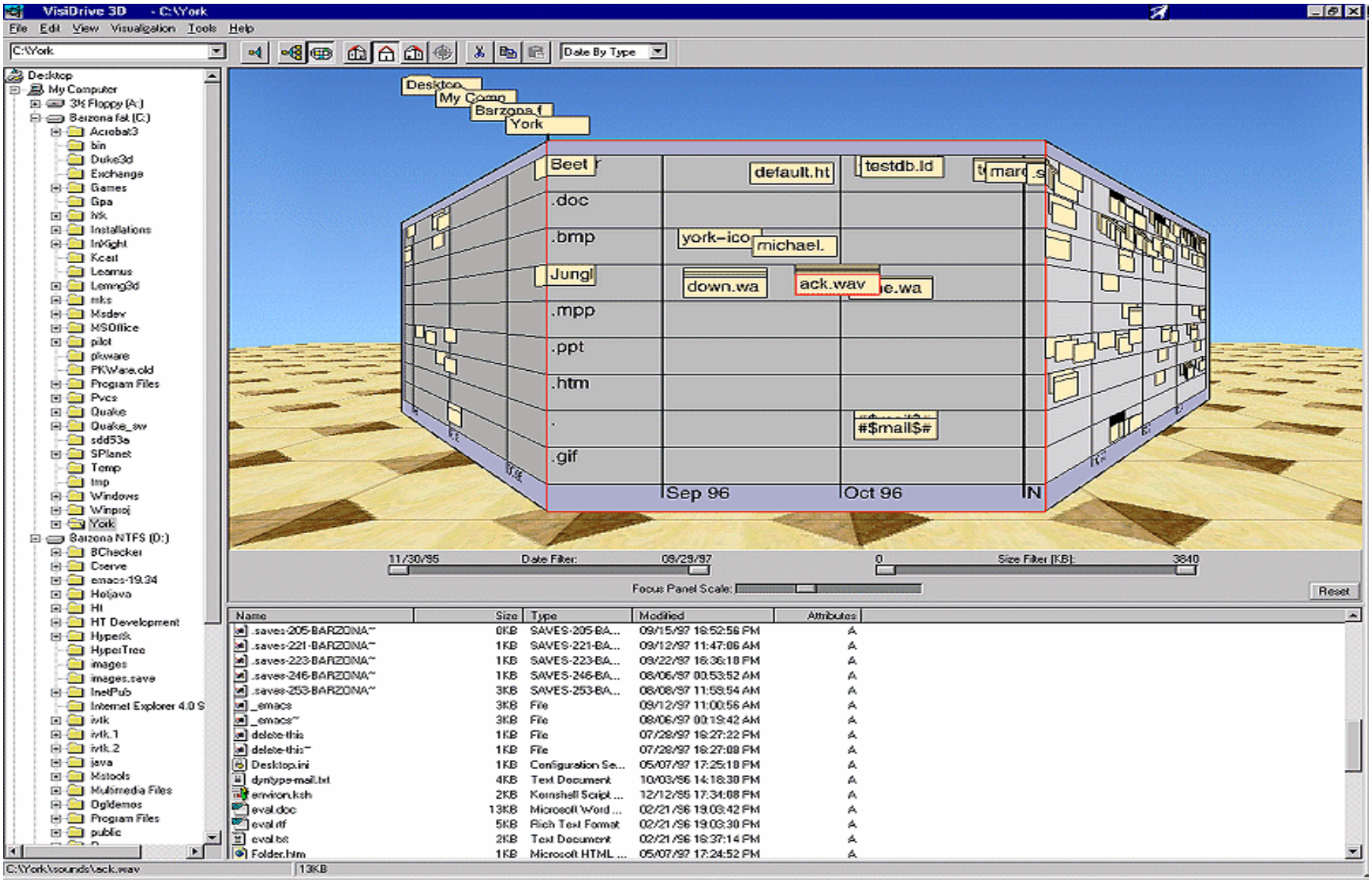


From http://www.cs.ubc.ca/~tmm/courses/cpsc533c-03-spr/0324.fengdongdu.ppt

Perspective Wall

- A conceptual descendent of the Bifocal display.
- Smoothly integrated detailed and contextual views.
- Side panels are demagnified directly proportional to their distance from the viewer.

From http://www.sims.berkeley.edu/courses/is247/s02/lectures/ZoomingFocusContextDistortion.ppt


VisiDrive 3D - C:\York
File Edit View Visualization Tools Help
C:\York
Date By Type
Desktop
My Computer
3½ Floppy (A:)
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Acrobat3
bin
Duke3d
Exchange
Games
Gpa
htk
Installations
InKight
Kcell
Learnus
Lemng3d
mks
Msdev
MSOffice
pilot
pkware
PKWare.old
Program Files
Pvcs
Quake
Quake_sw
sdd53e
SPlanet
Temp
tmp
Windows
Winproj
York
Barzona NTFS (D:)
BChecker
Dserve
emacs-19.34
Hotjava
HI
HT Development
Hypertk
HyperTree
images
images.save
InetPub
Internet Explorer 4.0 S
ivtk
ivtk.1
ivtk.2
java
Mstools
Multimedia Files
Ogldemos
Program Files
public
Desktop
My Comp
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.doc
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.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
0
Size Filter [KB]:
3840
Focus Panel Scale:
Reset
Name
Size
Type
Modified
Attributes
.saves-205-BARZONA~
0KB
SAVES-205-BA...
09/15/97 16:52:56 PM
A
.saves-221-BARZONA~
1KB
SAVES-221-BA...
09/12/97 11:47:06 AM
A
.saves-223-BARZONA~
1KB
SAVES-223-BA...
09/22/97 16:36:18 PM
A
.saves-246-BARZONA~
1KB
SAVES-246-BA...
08/06/97 00:53:52 AM
A
.saves-253-BARZONA~
3KB
SAVES-253-BA...
08/08/97 11:59:54 AM
A
_emacs
3KB
File
09/12/97 11:00:56 AM
A
_emacs~
3KB
File
08/06/97 00:19:42 AM
A
delete-this
1KB
File
07/28/97 16:27:22 PM
A
delete-this~
1KB
File
07/28/97 16:27:08 PM
A
Desktop.ini
1KB
Configuration Se...
05/07/97 17:25:18 PM
A
dpmtype-mail.txt
4KB
Text Document
10/03/96 14:18:30 PM
A
environ.ksh
2KB
Kornshell Script ...
12/12/95 17:34:08 PM
A
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13KB
Microsoft Word ...
02/21/96 19:03:42 PM
A
eval.rtf
5KB
Rich Text Format
02/21/96 19:03:30 PM
A
eval.txt
2KB
Text Document
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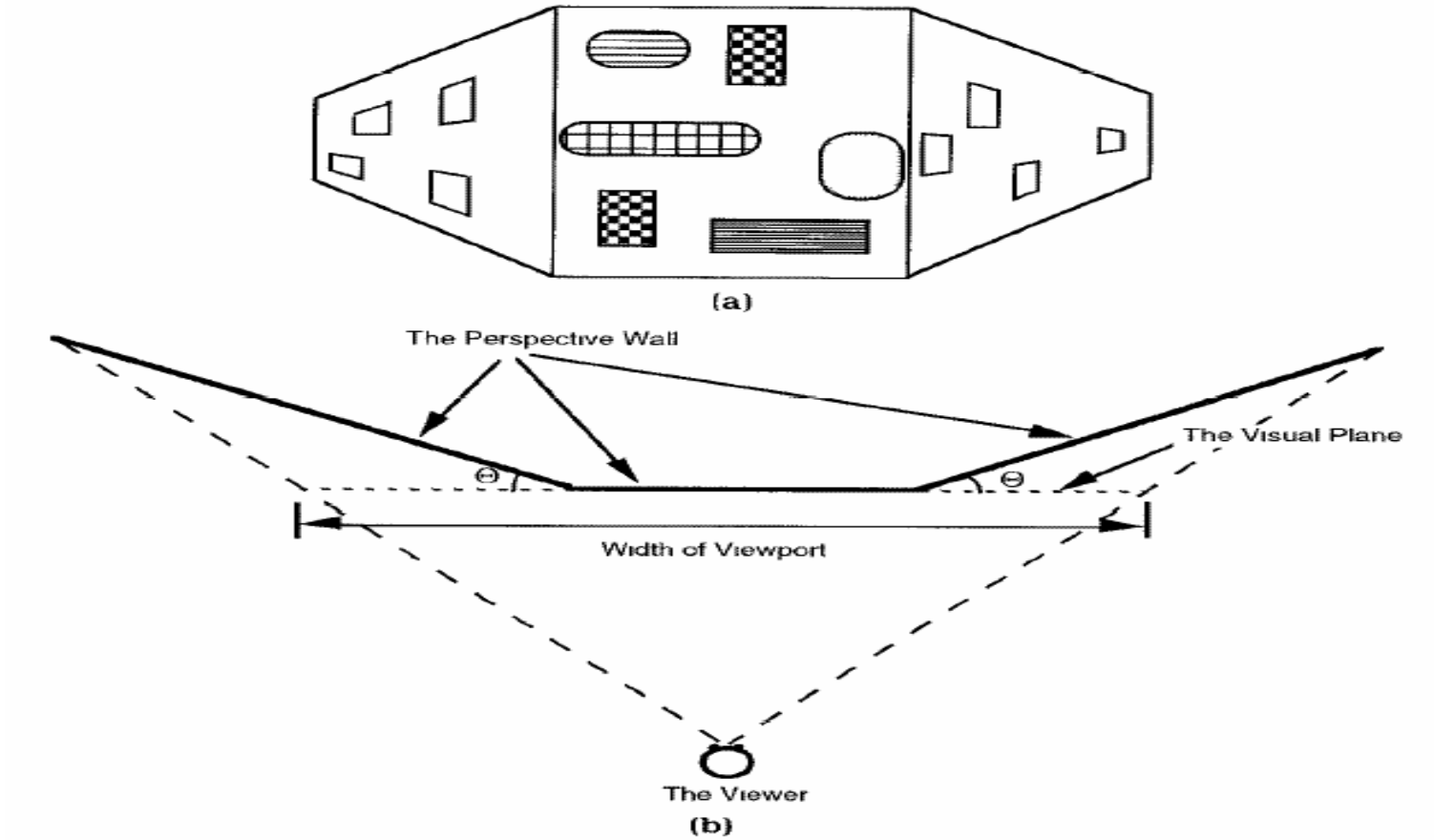
05/07/97 17:24:52 PM
A
C:\York\sounds\ack.wav
13KB



The view is dependent on the length of the wall, the width of the view port, the angle Θ, the size of the central region.

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

Perspective Wall

- Similar to Bifocal, except demagnifies at increasing rate, while Bifocal is constant
- Visualizes linear information such as timeline
- Adds 3D but wastes real estate on screen (which is contrary to prime objectives of distortion techniques)

From http://www.sims.berkeley.edu/courses/is247/s02/lectures/ZoomingFocusContextDistortion.ppt