University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2010

Tamara Munzner

Spatial/Scientific Visualization II, Nonspatial/Information Visualization

Week 13, Mon Apr 12

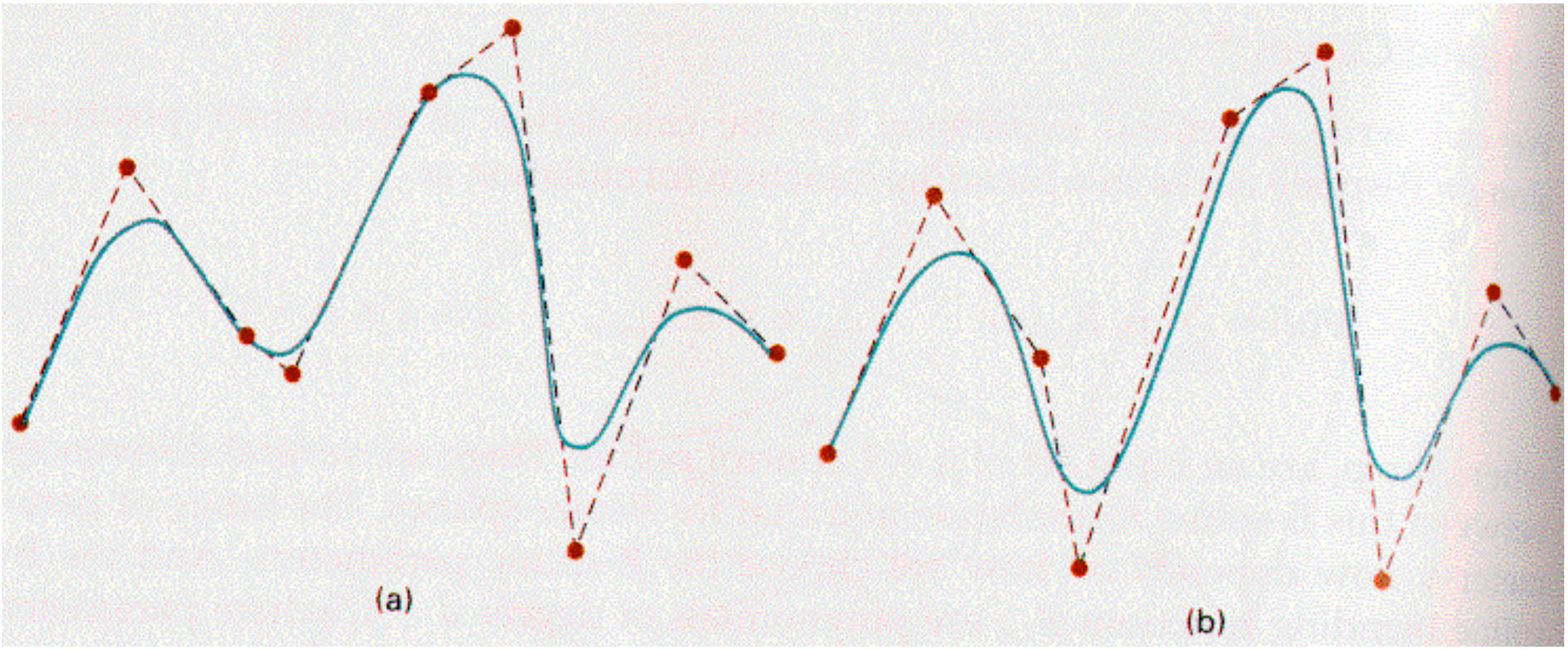
http://www.ugrad.cs.ubc.ca/~cs314/Vjan2010

News

- Reminders
  - H4 due Mon 4/12 5pm
  - P4 due Wed 4/14 5pm
- Extra TA office hours in lab 005 for P4/H4
  - Mon 4/12 11-1, 3-5 (Garrett)
  - Tue 4/13 3:30-5 (Kai)
  - Wed 4/14 2-4, 5-7 (Shailen)
  - Thu 4/15 3-5 (Kai)
  - Fri 4/16 11-4 (Garrett)
- Project 4 demo signup sheet

Review: B-Spline

- C_0, C_1, and C_2 continuous
- piecewise: locality of control point influence

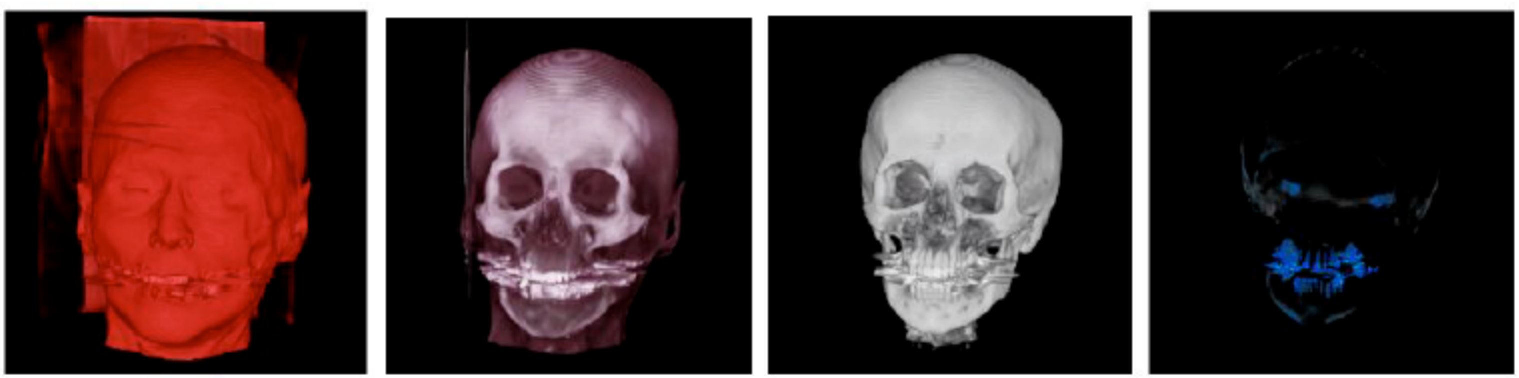


Review: Volume Graphics

- for some data, difficult to create polygonal mesh
- voxels: discrete representation of 3D object
  - volume rendering: create 2D image from 3D object
- translate raw densities into colors and transparencies
  - different aspects of the dataset can be emphasized via changes in transfer functions

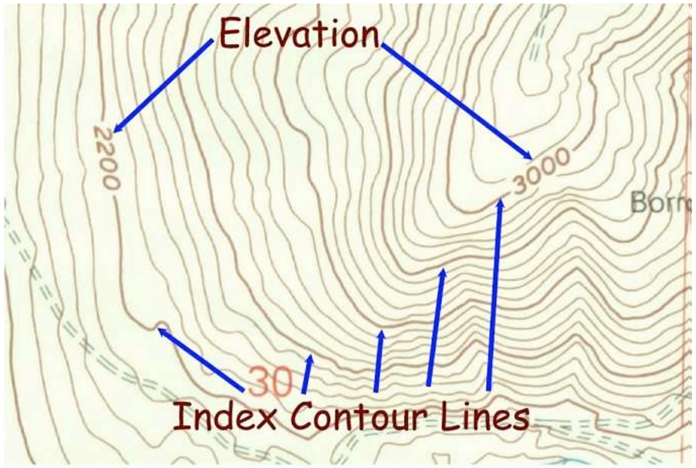
Review: Volume Graphics

- pros
  - formidable technique for data exploration
- cons
  - rendering algorithm has high complexity!
  - special purpose hardware costly (~$3K-$10K)

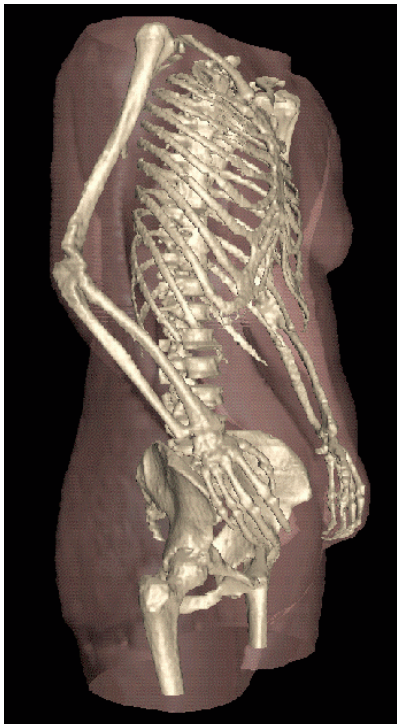


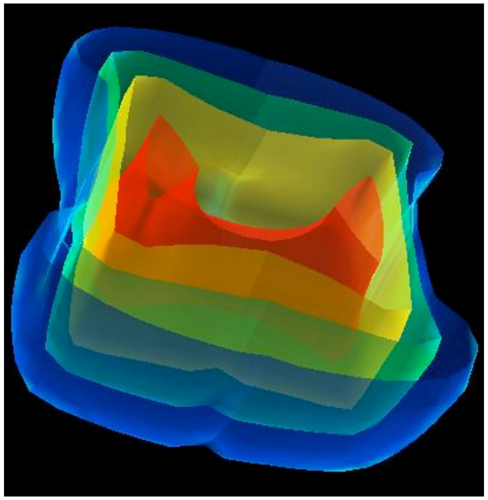
volumetric human head (CT scan)

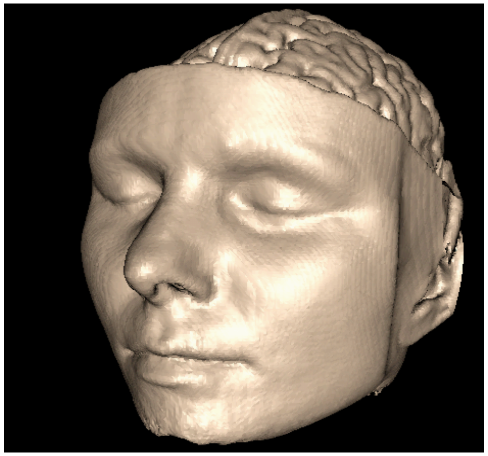
Review: Isosurfaces



- 2D scalar fields: isolines
  - contour plots, level sets
  - topographic maps
- 3D scalar fields: isosurfaces

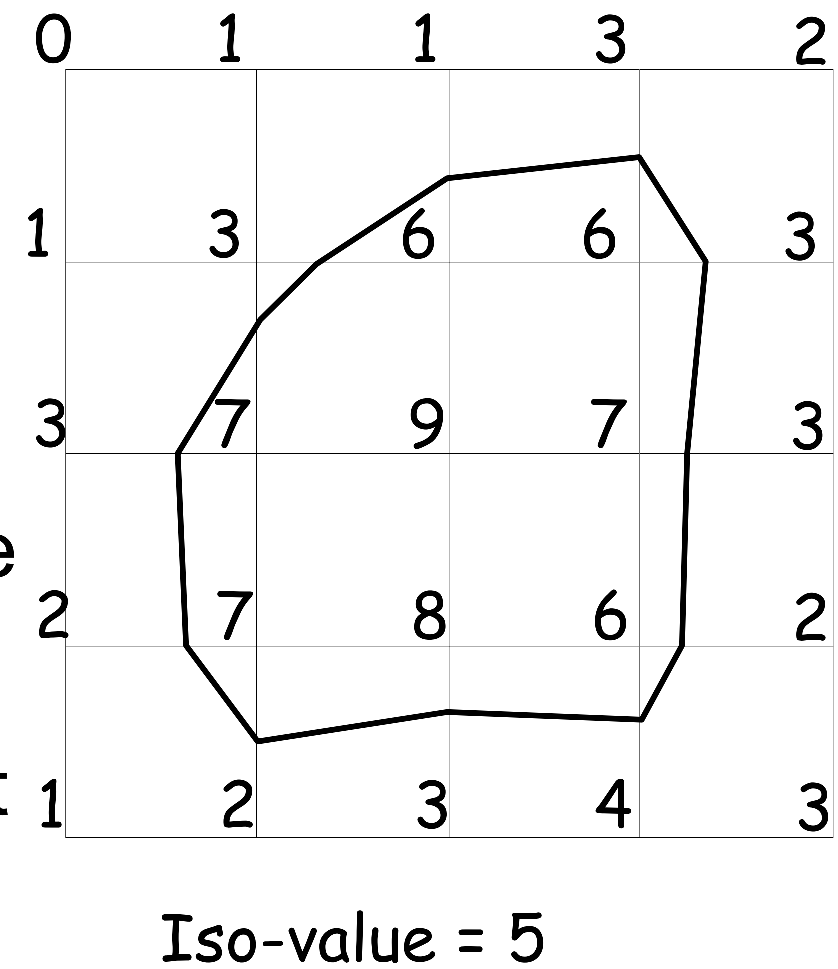






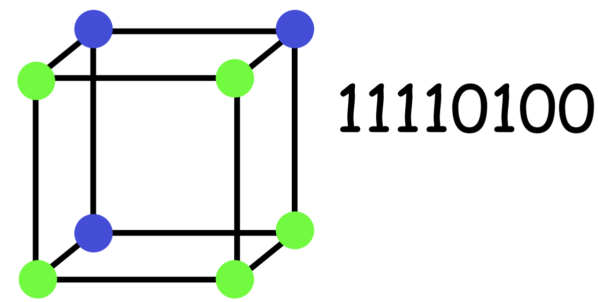
Review: Isosurface Extraction

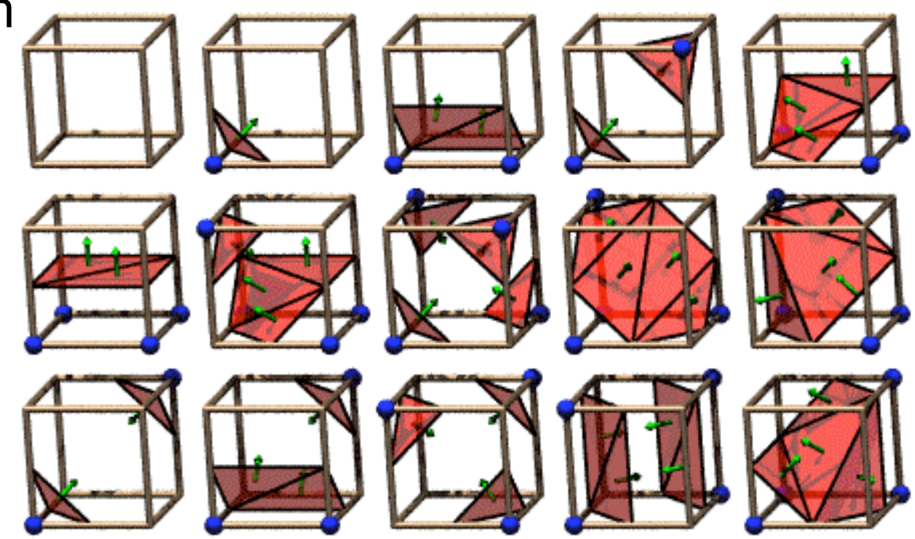
- array of discrete point samples at grid points
  - 3D array: voxels
- find contours
  - closed, continuous
  - determined by iso-value
- several methods
  - marching cubes is most common



Review: Marching Cubes

- create cube
- classify each voxel
- binary labeling of each voxel to create index
- use in array storing edge list
  - all 256 cases can be derived from 15 base cases
- interpolate triangle vertex
- calculate the normal at each cube vertex
- render by standard methods

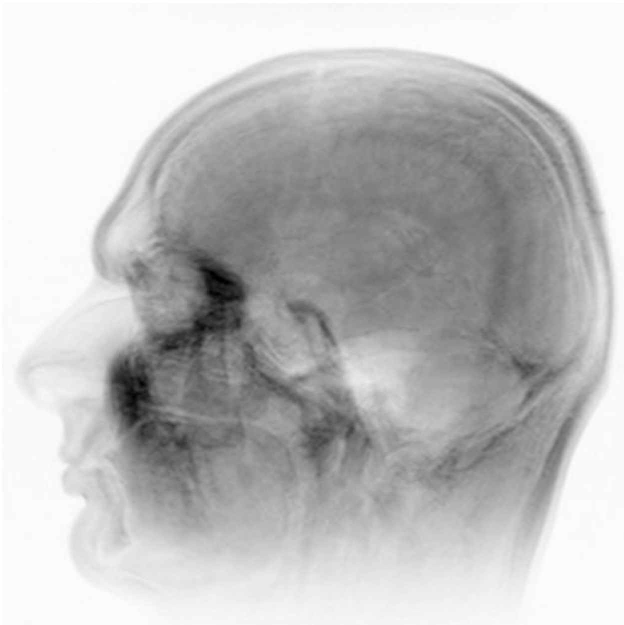


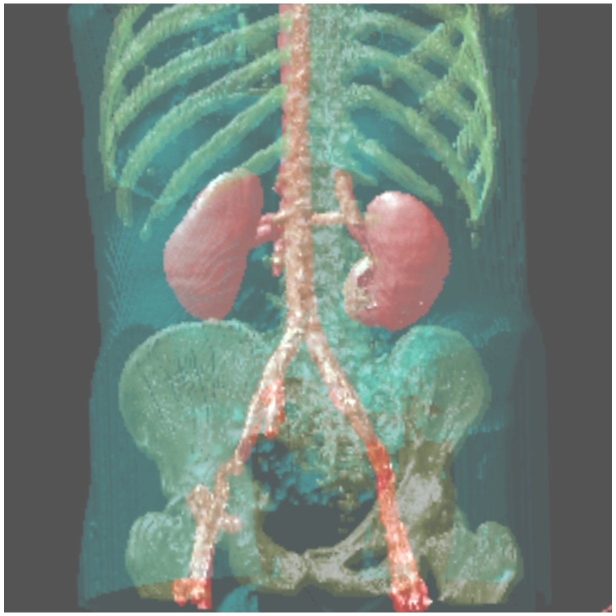


The 15 Cube Combinations

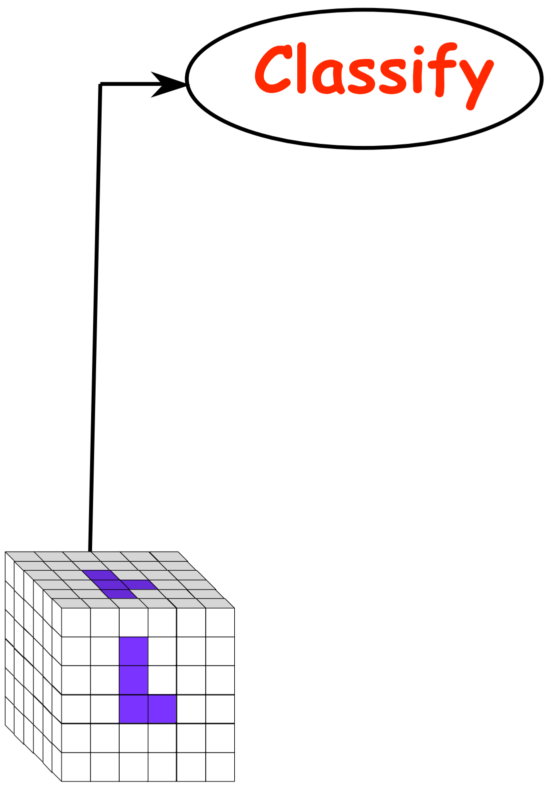
Review: Direct Volume Rendering

- do not compute surface



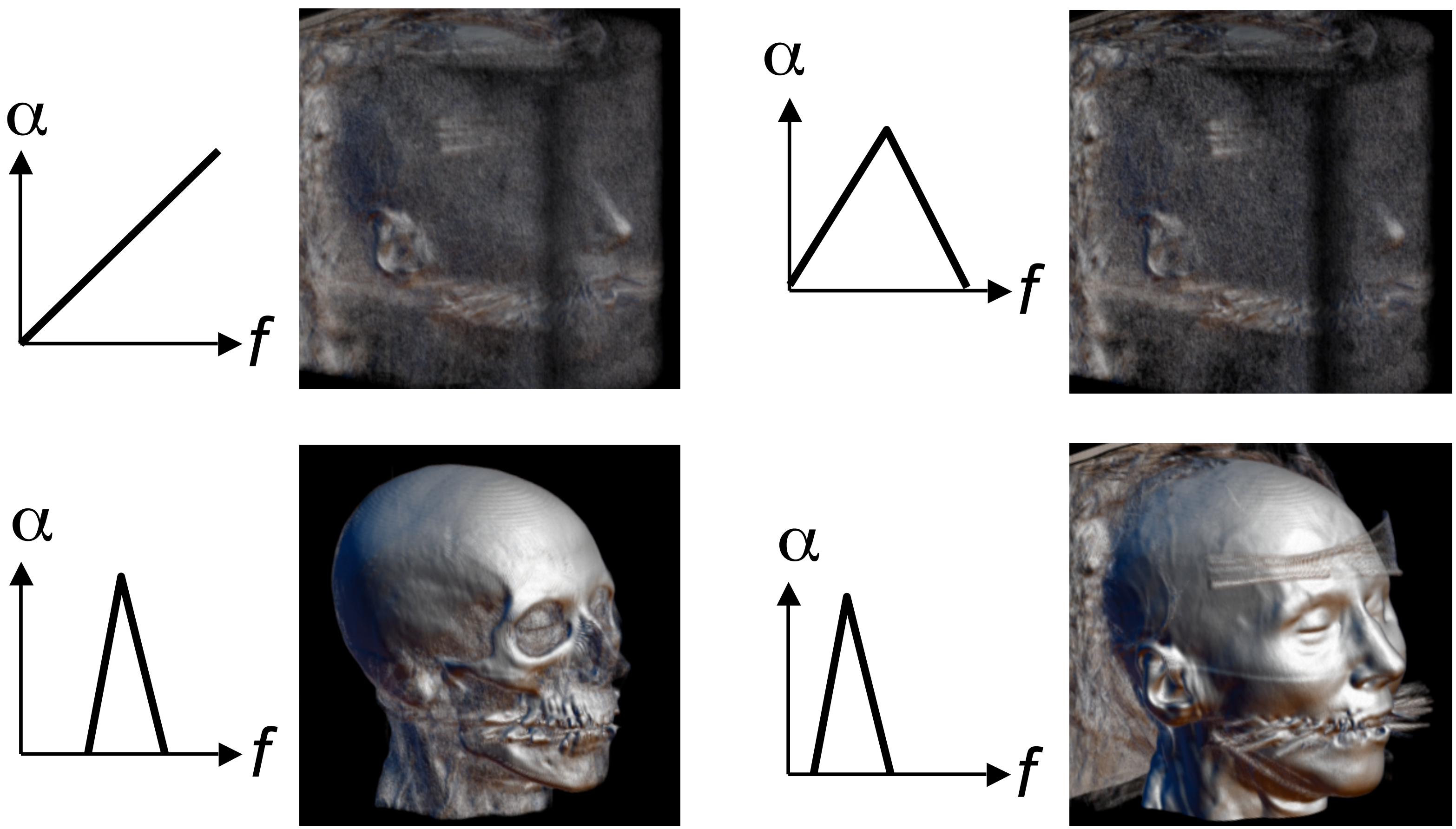


Review: Rendering Pipeline

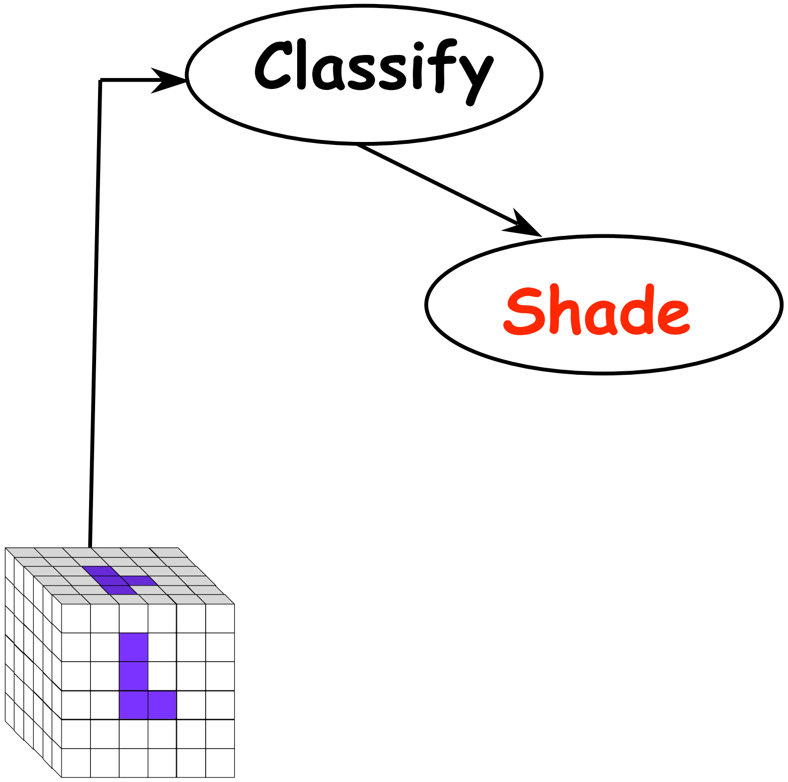


Review: Setting Transfer Functions

- can be difficult, unintuitive, and slow



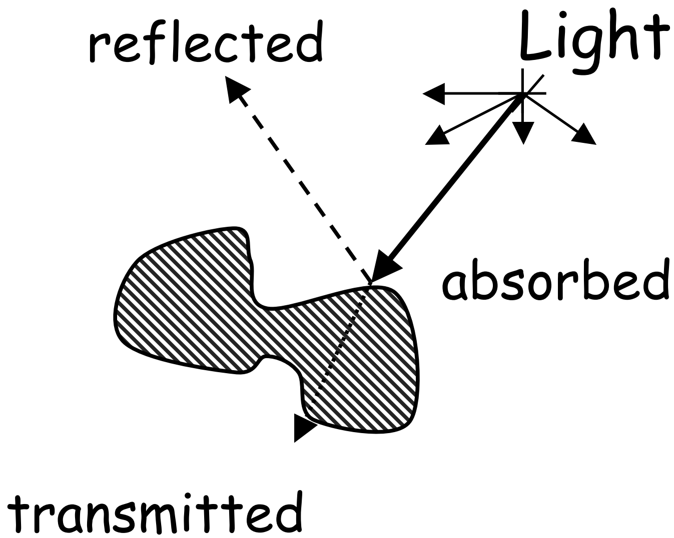
Rendering Pipeline

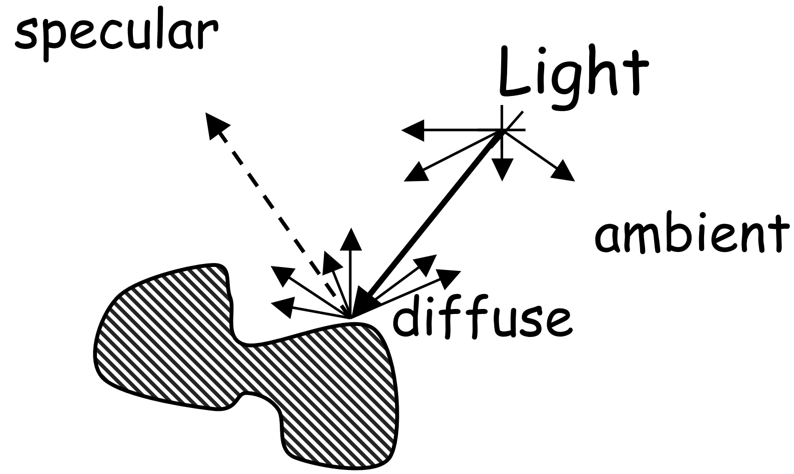


Spatial/Scientific Visualization II

Light Effects

- usually only consider reflected part



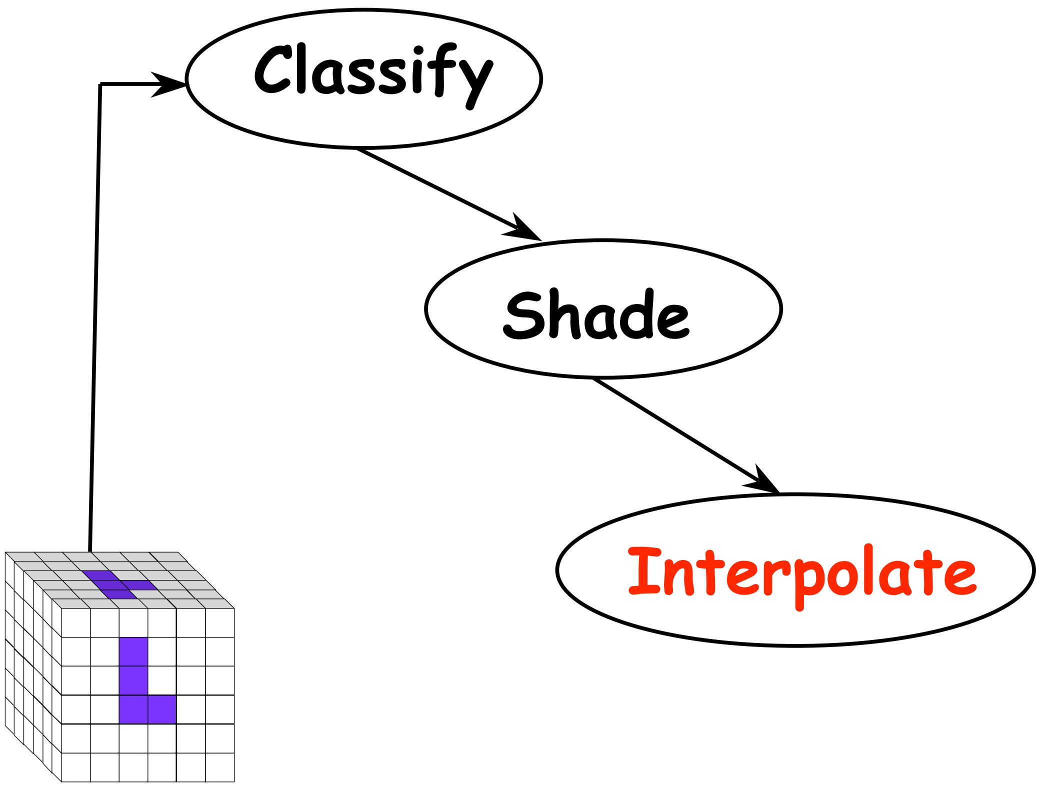


Light=refl.+absorbed+trans.

Light=ambient+diffuse+specular

$$I = k_a I_a + k_d I_d + k_s I_s$$

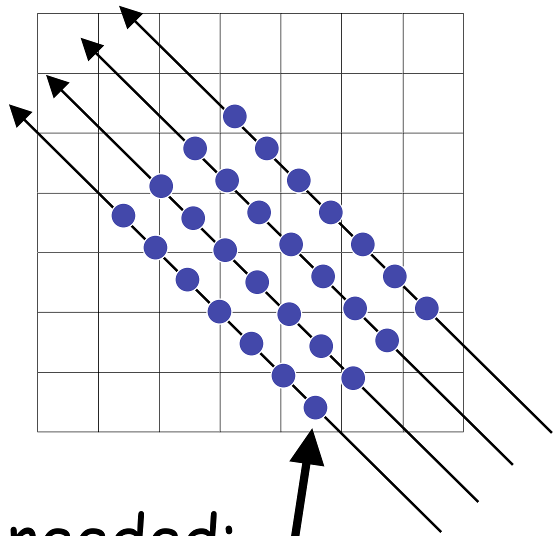
Rendering Pipeline



Interpolation

2D

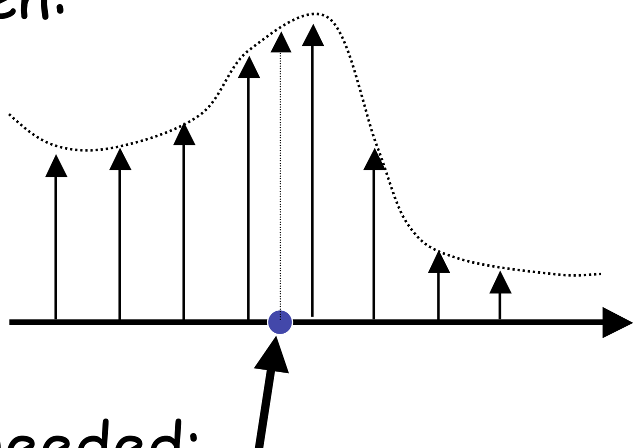
- given:



- needed:

1D

- given:

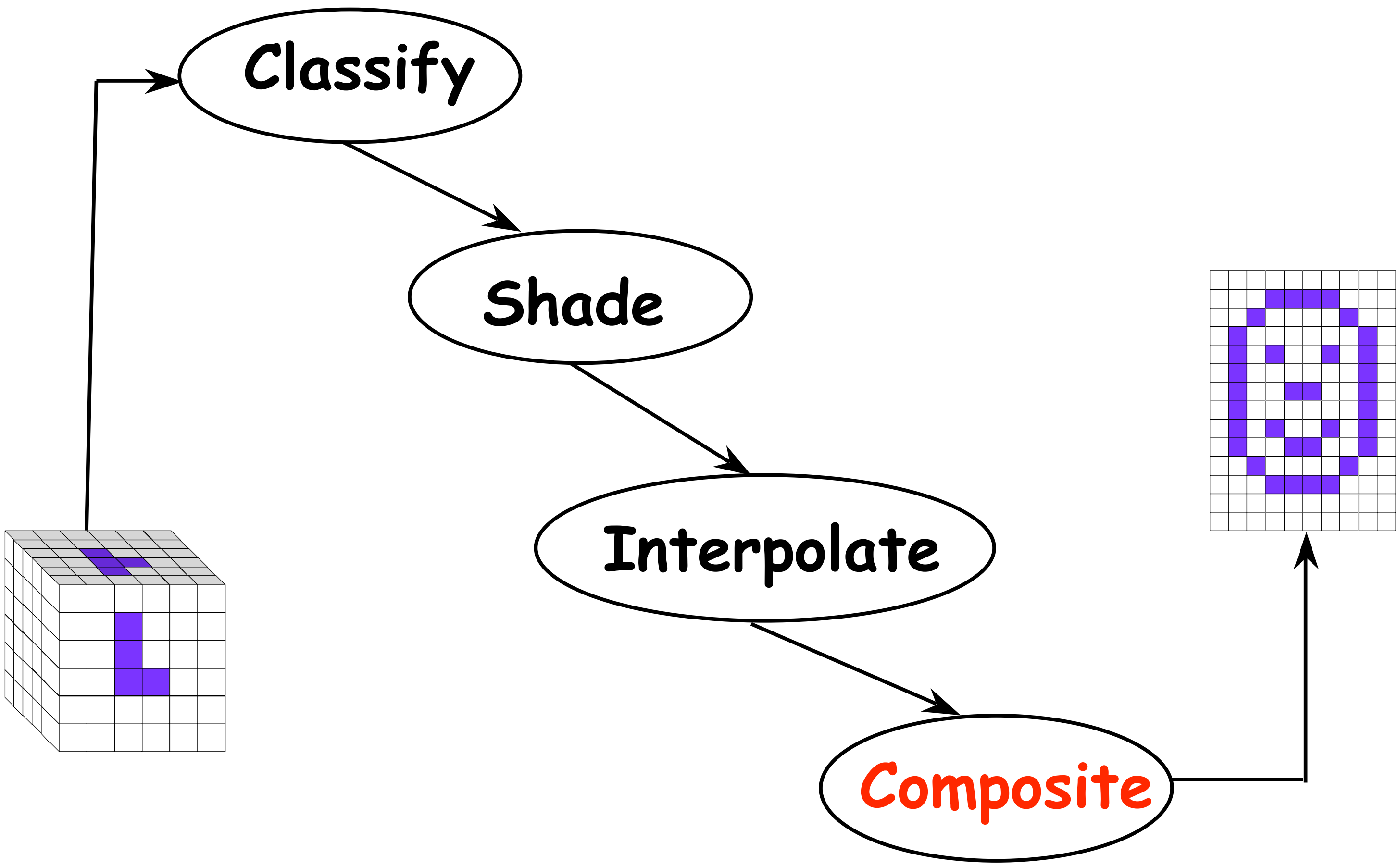


- needed:

nearest neighbor

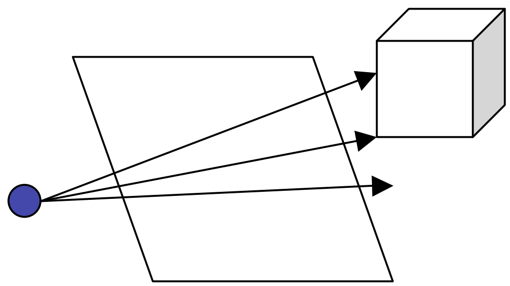
linear

Rendering Pipeline

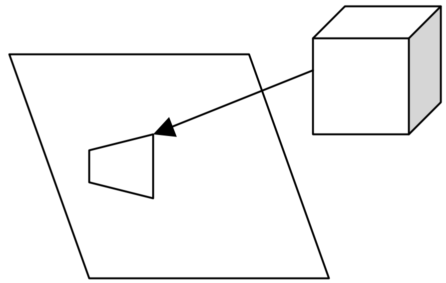


Volume Rendering Algorithms

- ray casting
  - image order, forward viewing

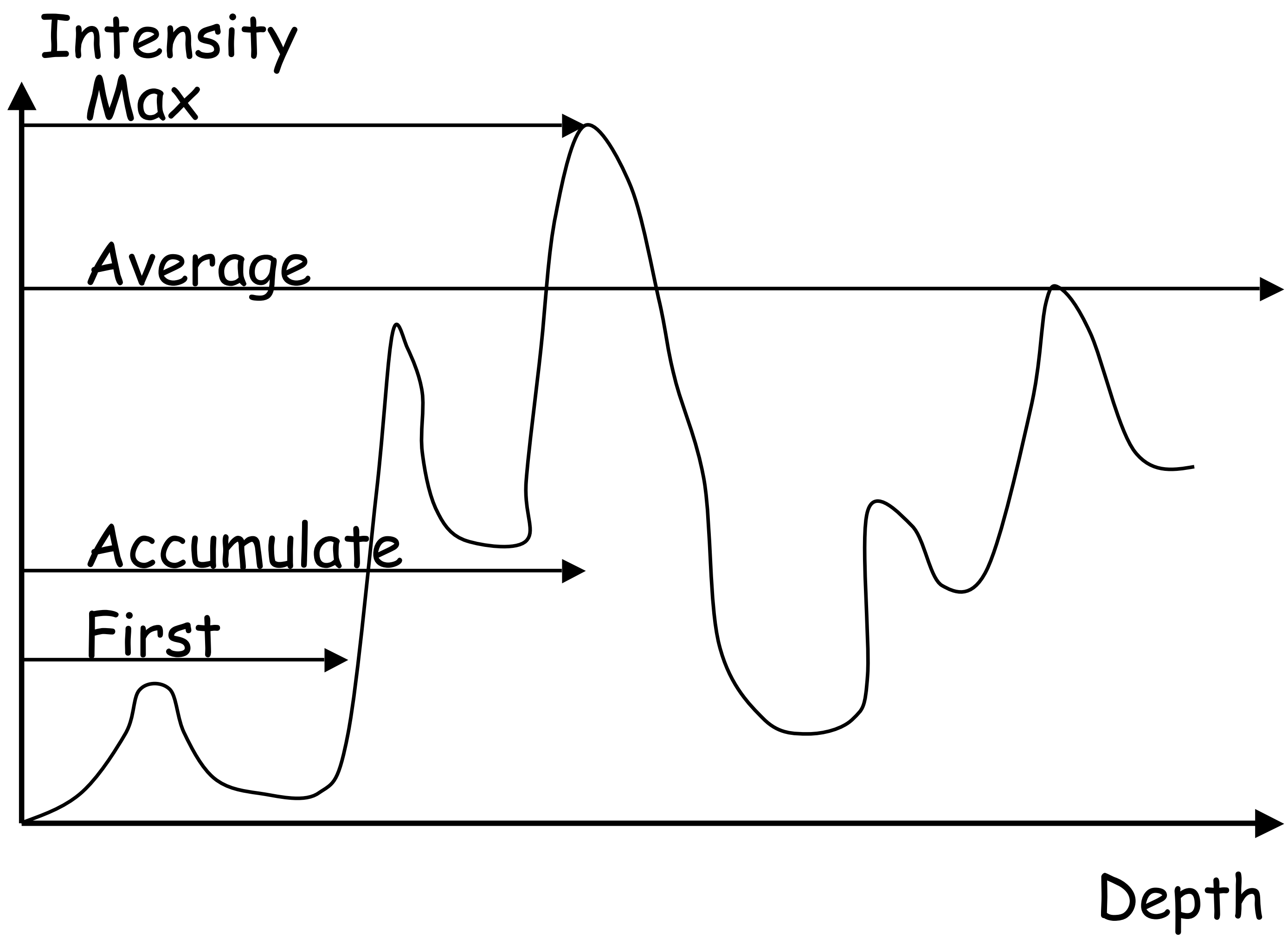


- splatting
  - object order, backward viewing



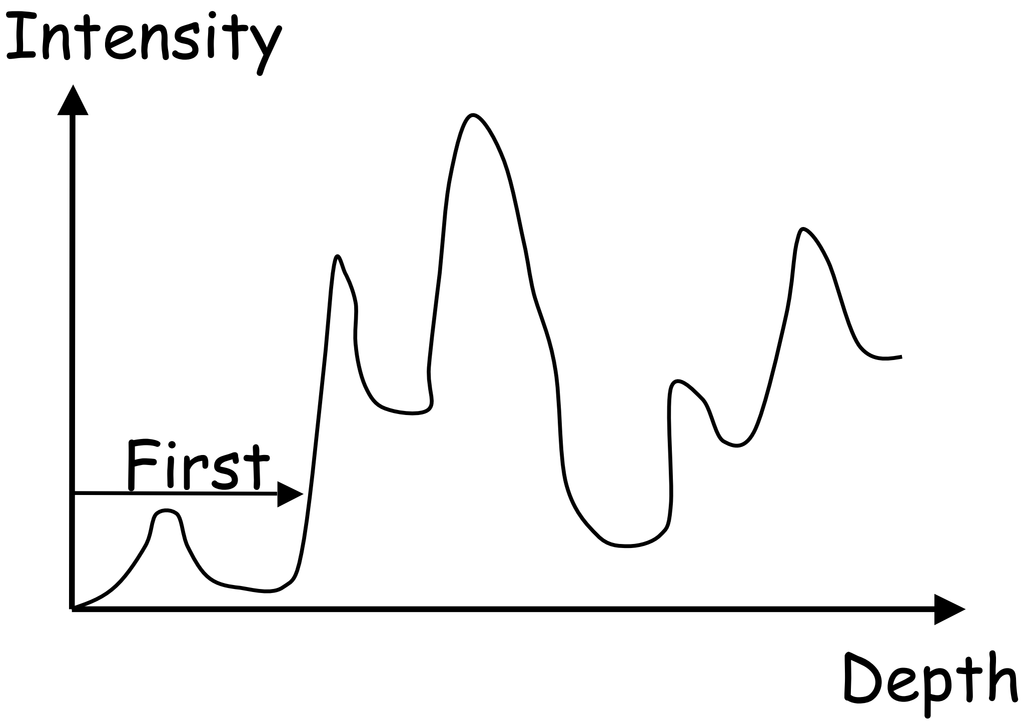
- texture mapping
  - object order
  - back-to-front compositing

Ray Traversal Schemes



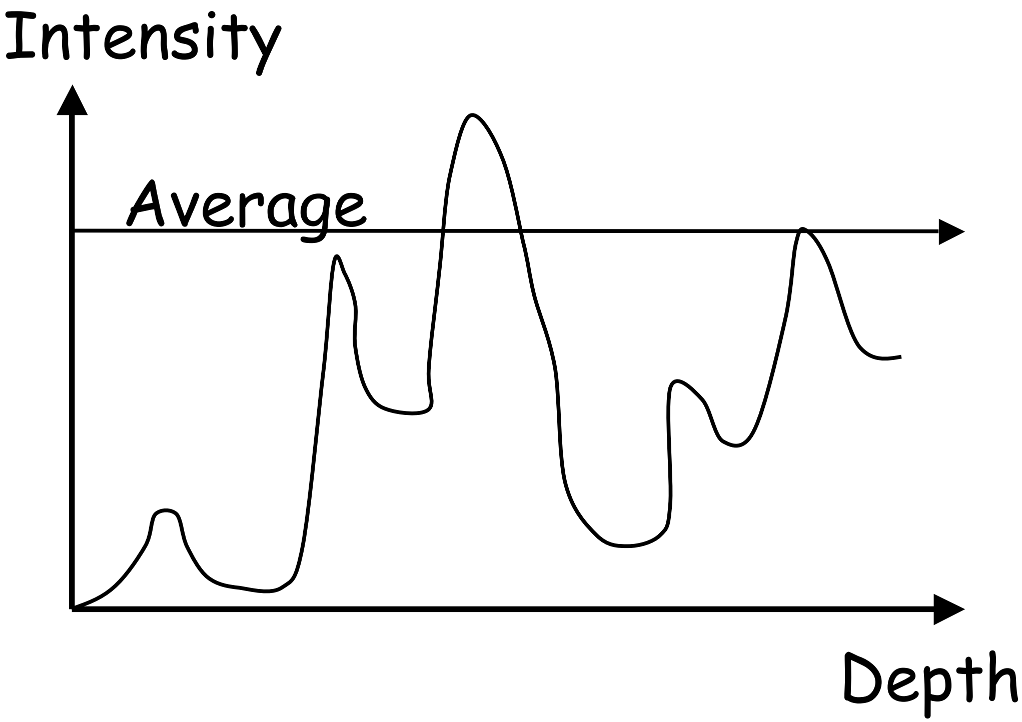
Ray Traversal - First

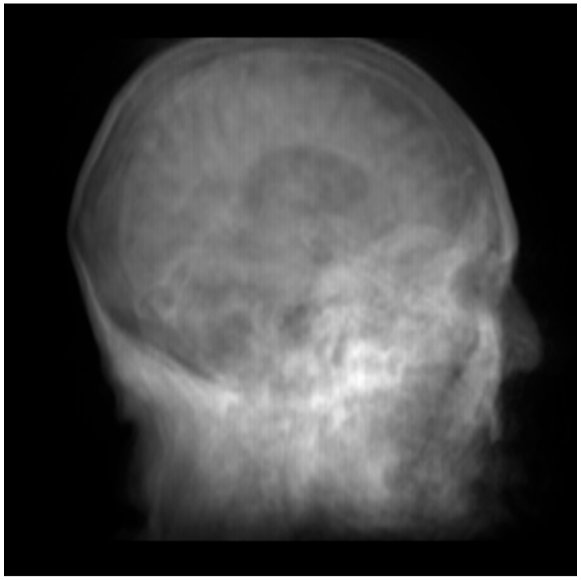
- first: extracts iso-surfaces (again!)



Ray Traversal - Average

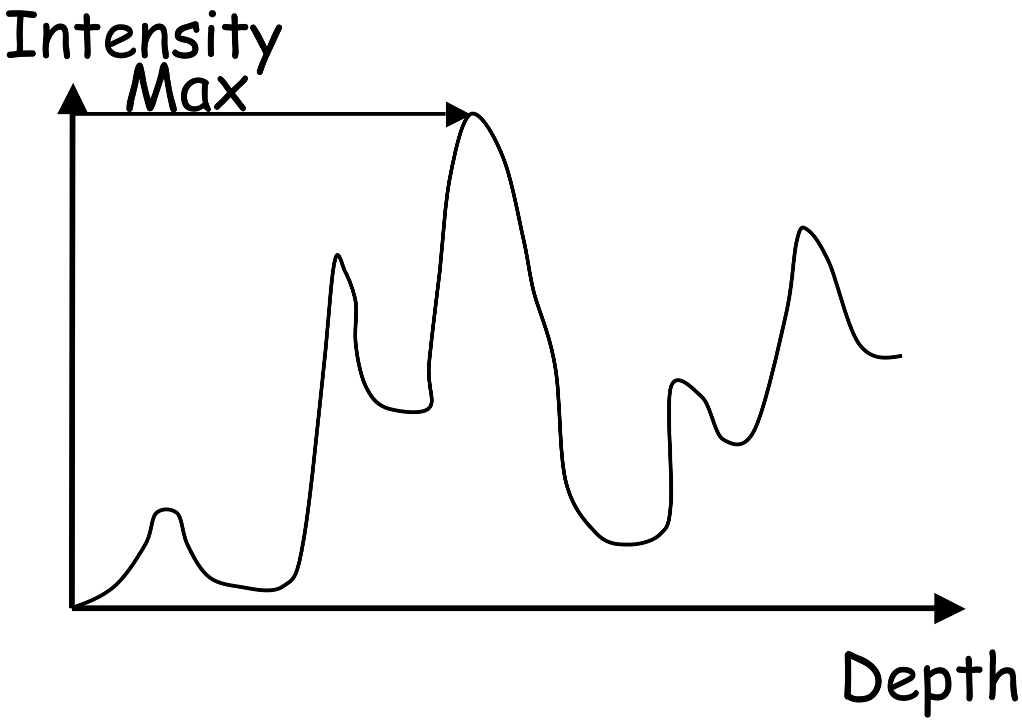
- average: looks like X-ray

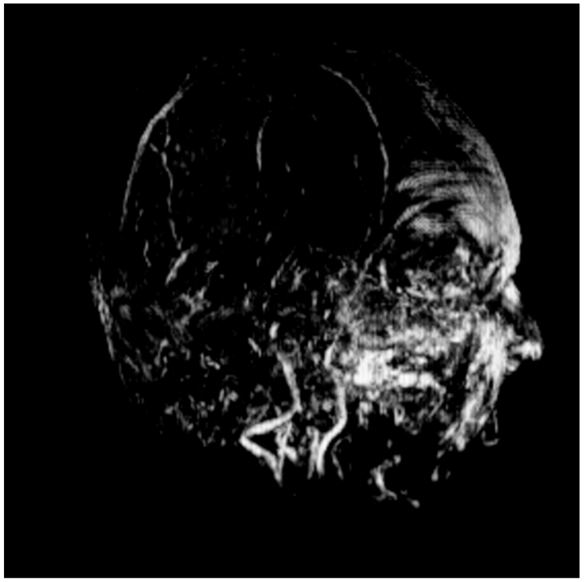




Ray Traversal - MIP

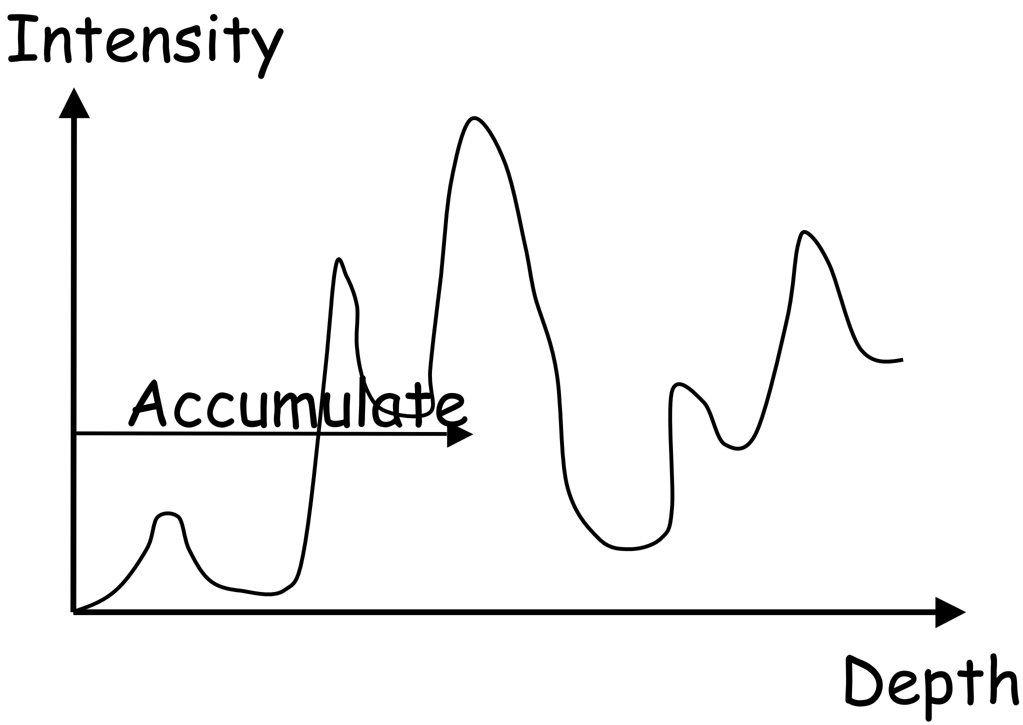
- max: Maximum Intensity Projection
  - used for Magnetic Resonance Angiogram

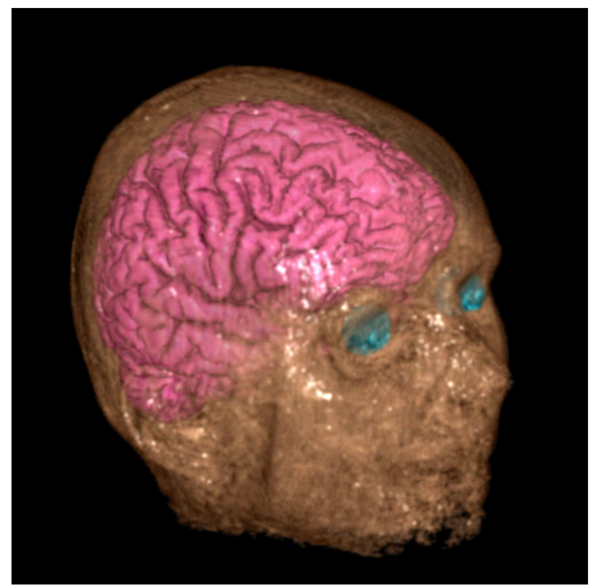




Ray Traversal - Accumulate

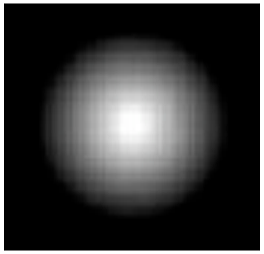
- accumulate: make transparent layers visible



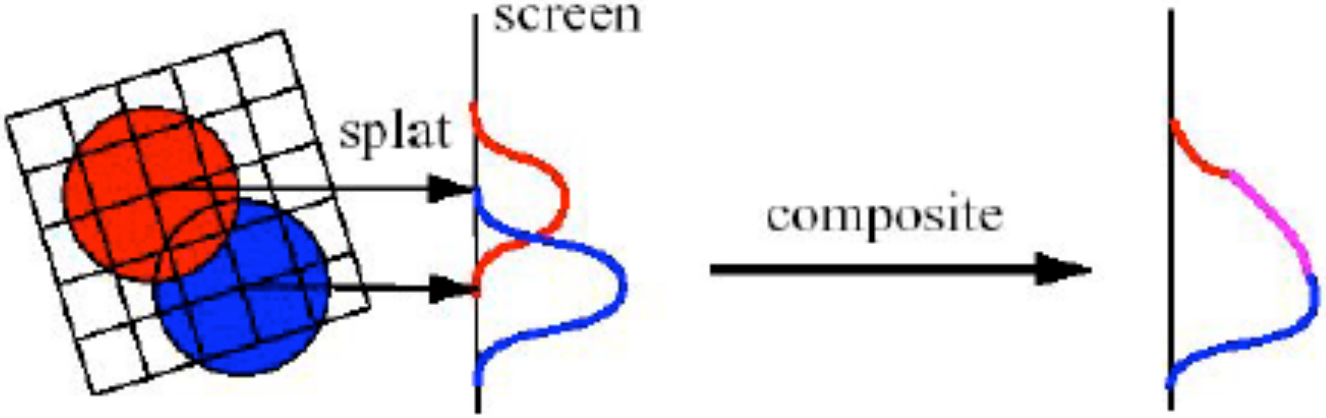


Splatting

- each voxel represented as fuzzy ball
  - 3D gaussian function
  - RGBa value depends on transfer function

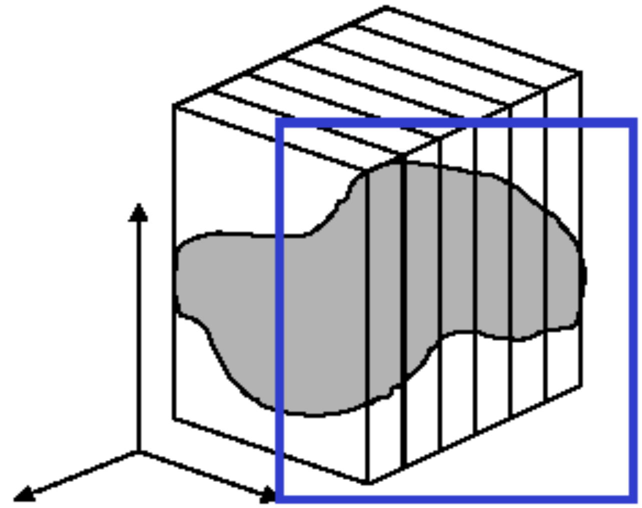


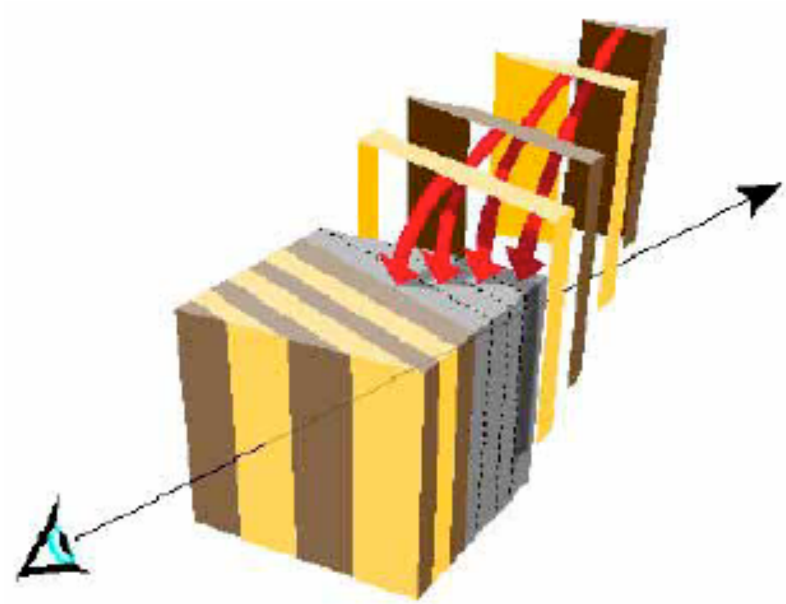
- fuzzy balls projected on screen, leaving footprint called splat
  - composite front to back, in object order



Texture Mapping

- 2D: axis aligned 2D textures
  - back to front compositing
  - commodity hardware support
  - must calculate texture coordinates, warp to image plane
- 3D: image aligned 3D texture
  - simple to generate texture coordinates





Nonspatial/Information Visualization

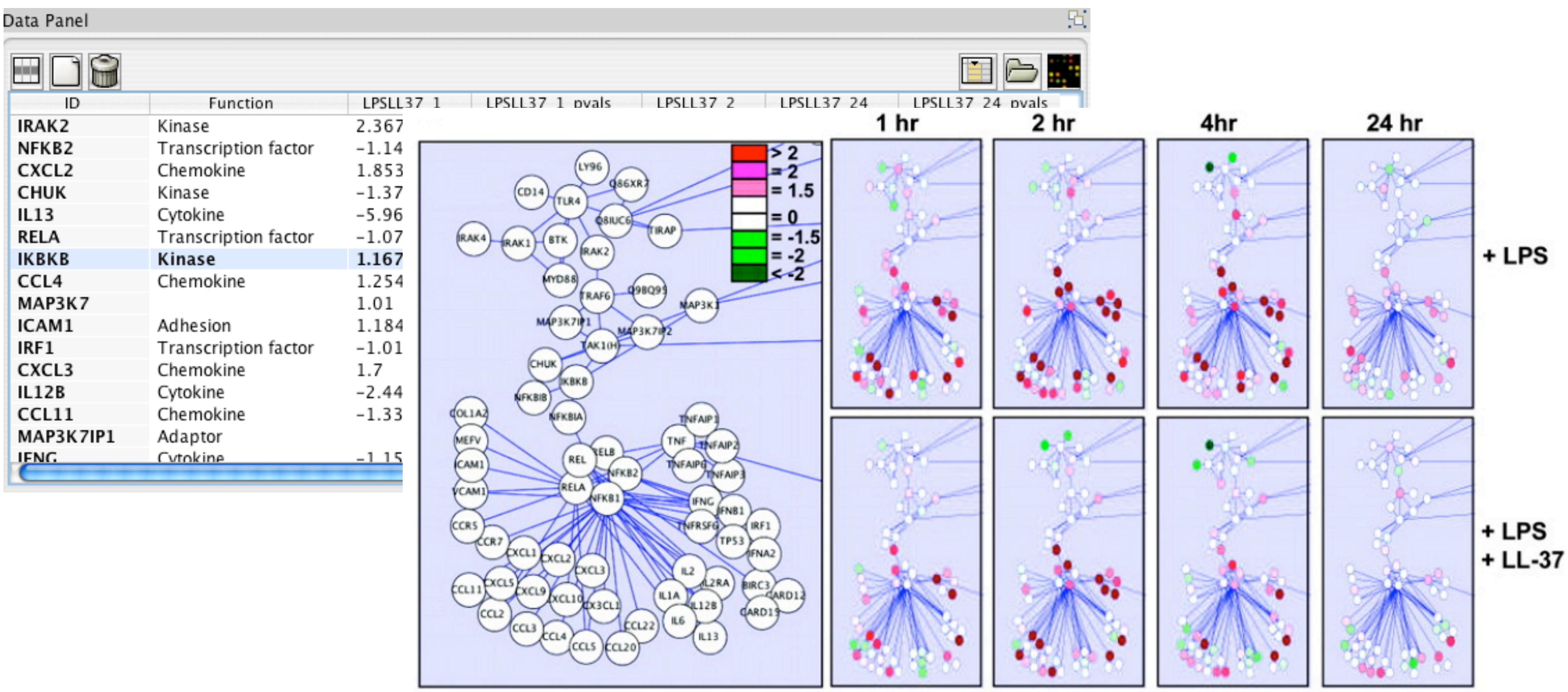
Reading

- FCG Chap 27
  - N/A 2nd edition, available online at

    http://www.cs.ubc.ca/labs/imager/tr/2009/VisChapter

Why Do Visualization?

- pictures help us think
  - substitute perception for cognition
  - external memory: free up limited cognitive/memory resources for higher-level problems



Information Visualization

- interactive visual representation of abstract data
  - help human perform some task more effectively
- bridging many fields
  - computer graphics: interact in realtime
  - cognitive psychology: find appropriate representation
  - HCI: use task to guide design and evaluation
- external representation
  - reduces load on working memory
  - offload cognition
  - familiar example: multiplication/division
  - infovis example: topic graphs

External Representation: Topic Graphs

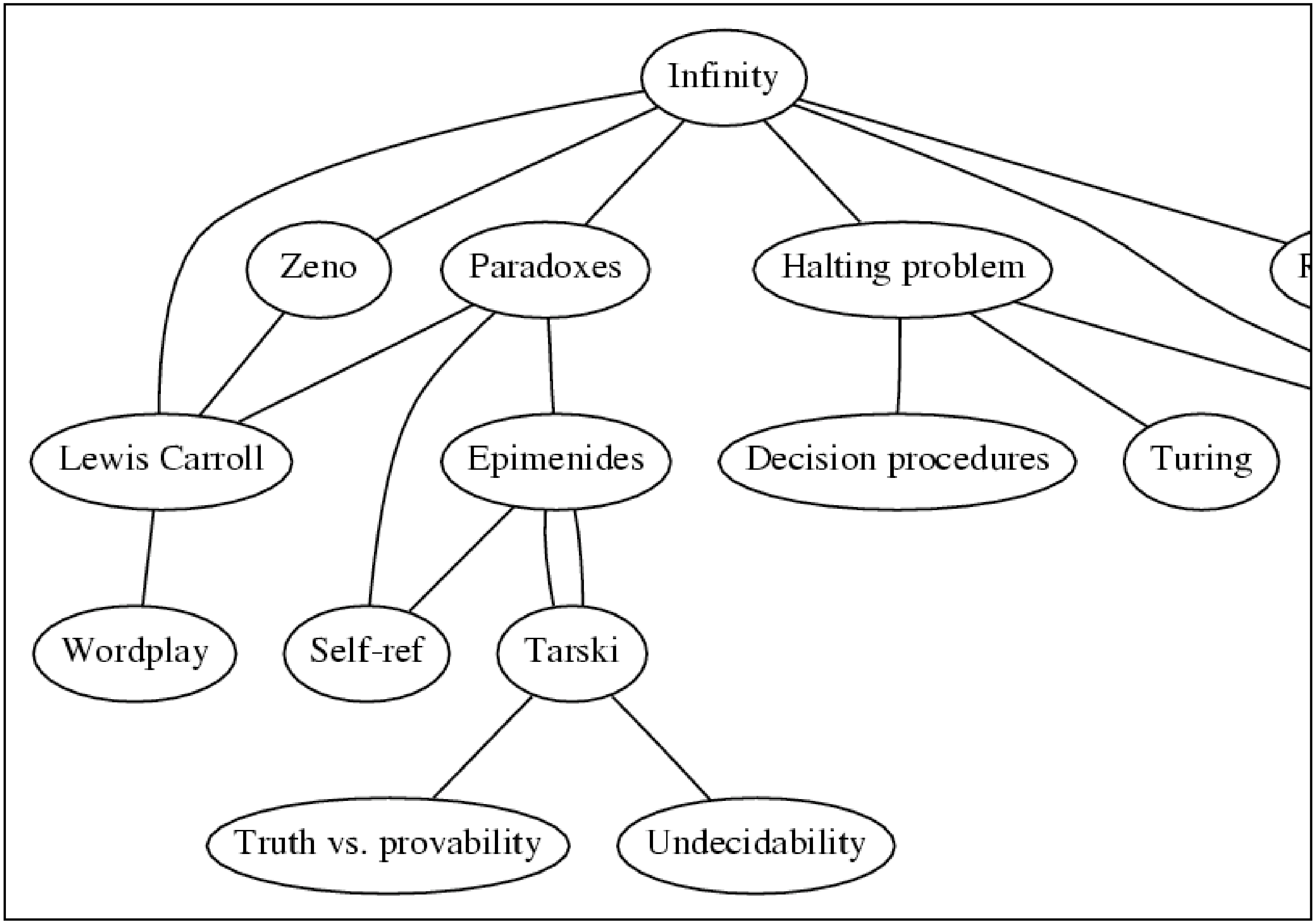
- hard to find topics two hops away from target

[Godel, Escher, Bach: The Eternal Golden Braid. Hofstadter 1979]

- **Paradoxes** - Lewis Carroll
- Turing - Halting problem
- Halting problem - Infinity
- Paradoxes - Infinity
- Infinity - Lewis Carroll
- Infinity - Unpredictably long searches
- Infinity - Recursion
- Infinity - Zeno
- Infinity - Paradoxes
- Lewis Carroll - Zeno
- Lewis Carroll - Wordplay
- Halting problem - Decision procedures
- BlooP and FlooP - AI
- Halting problem - Unpredictably long searches
- BlooP and FlooP - Unpredictably long searches
- BlooP and FlooP - Recursion
- Tarski - Truth vs. provability
- Tarski - Epimenides
- Tarski - Undecidability
- Paradoxes - Self-ref
- [...]

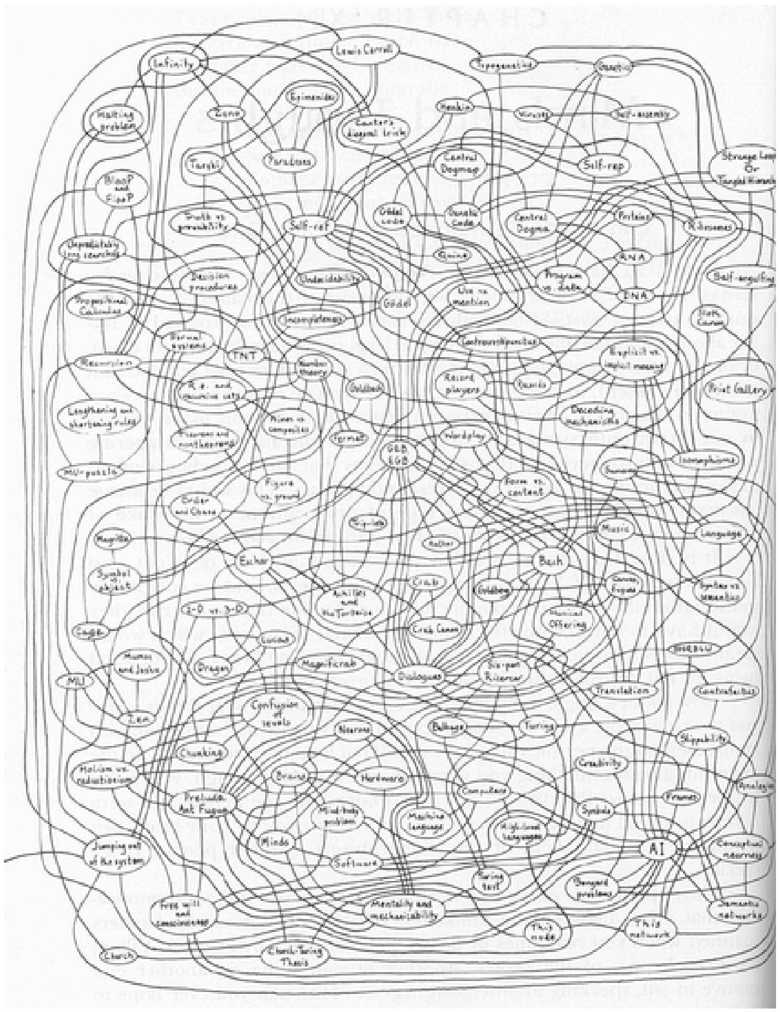
External Representation: Topic Graphs

- offload cognition to visual system



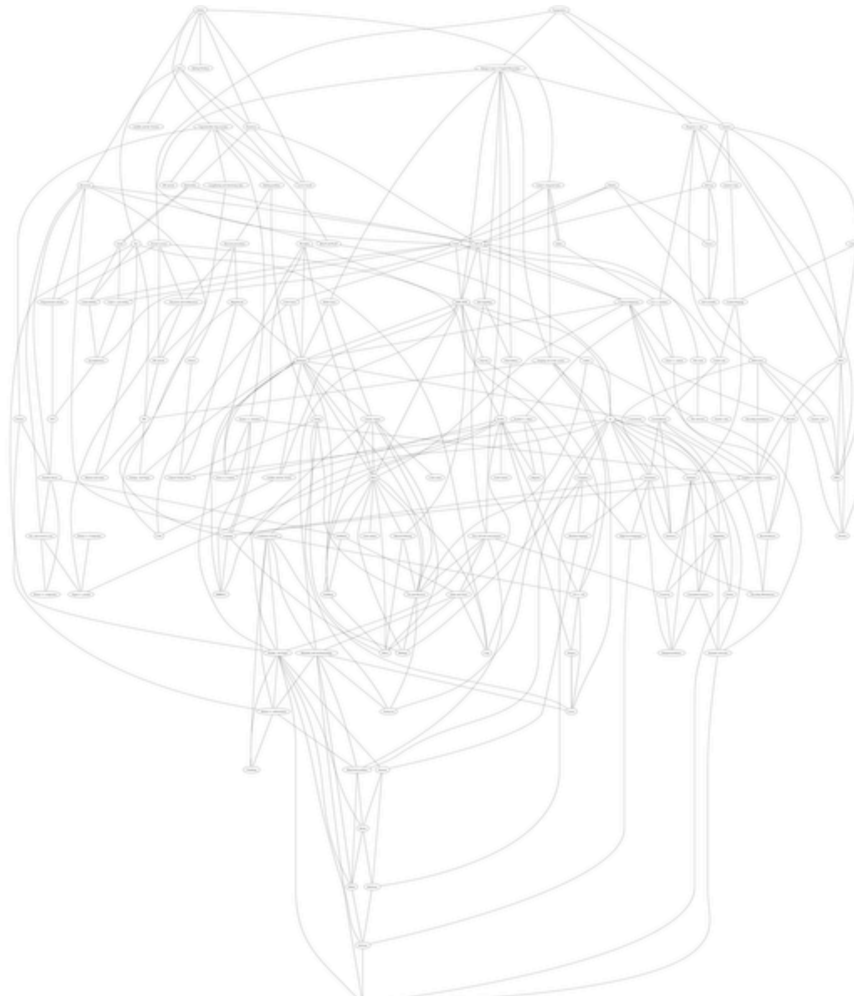
Automatic Node-Link Graph Layout

- manual: hours, days



[Godel, Escher, Bach. Hofstadter 1979]

- automatic: seconds



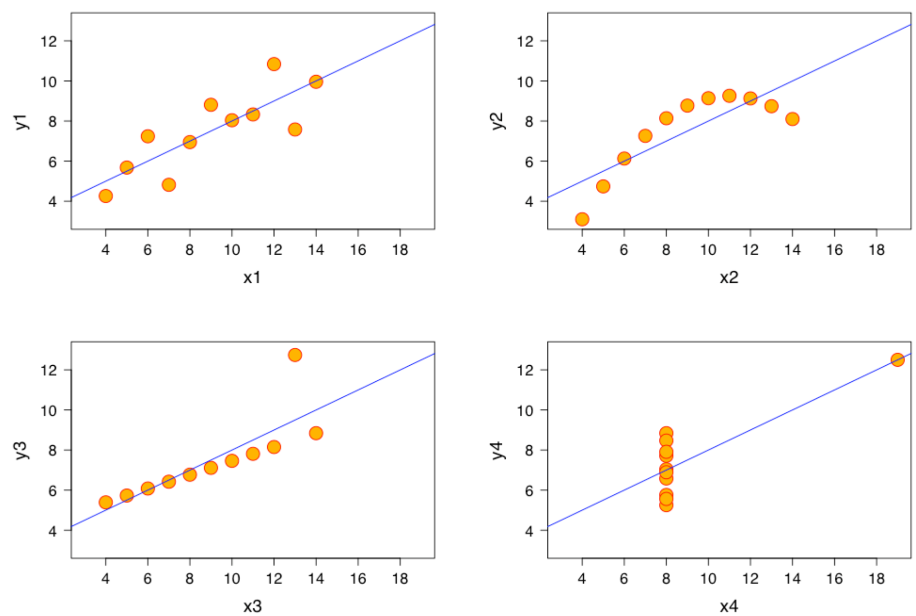
[dot, Gansner et al, 1973.]

When To Do Vis?

- need a human in the loop
  - augment, not replace, human cognition
  - for problems that cannot be (completely) automated
- simple summary not adequate
  - statistics may not adequately characterize complexity of dataset distribution

Anscombe's quartet: same

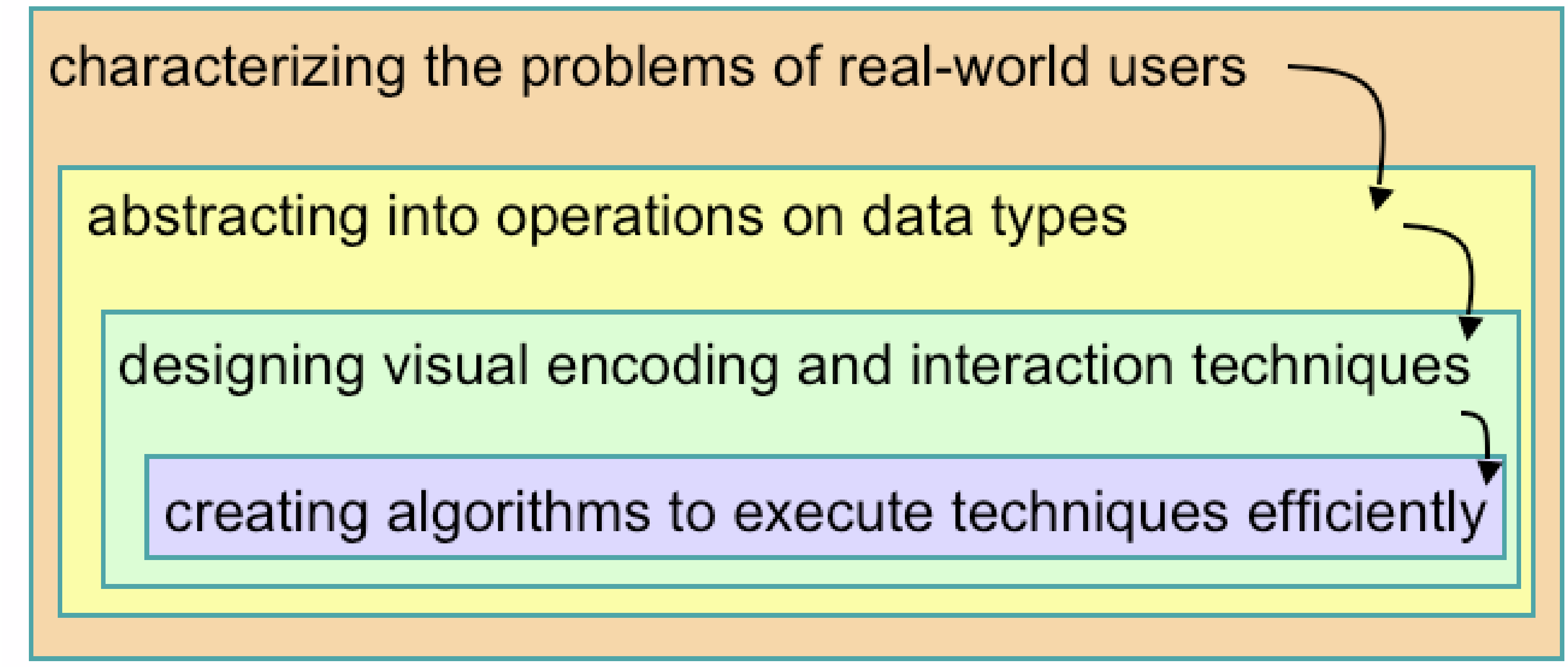
- mean
- variance
- correlation coefficient
- linear regression line



http://upload.wikimedia.org/wikipedia/commons/b/b6/Anscombe.svg

Visualization Design Layers

- depends on both data and task



Visual Encoding

marks: geometric primitives

points lines areas

attributes

position

size

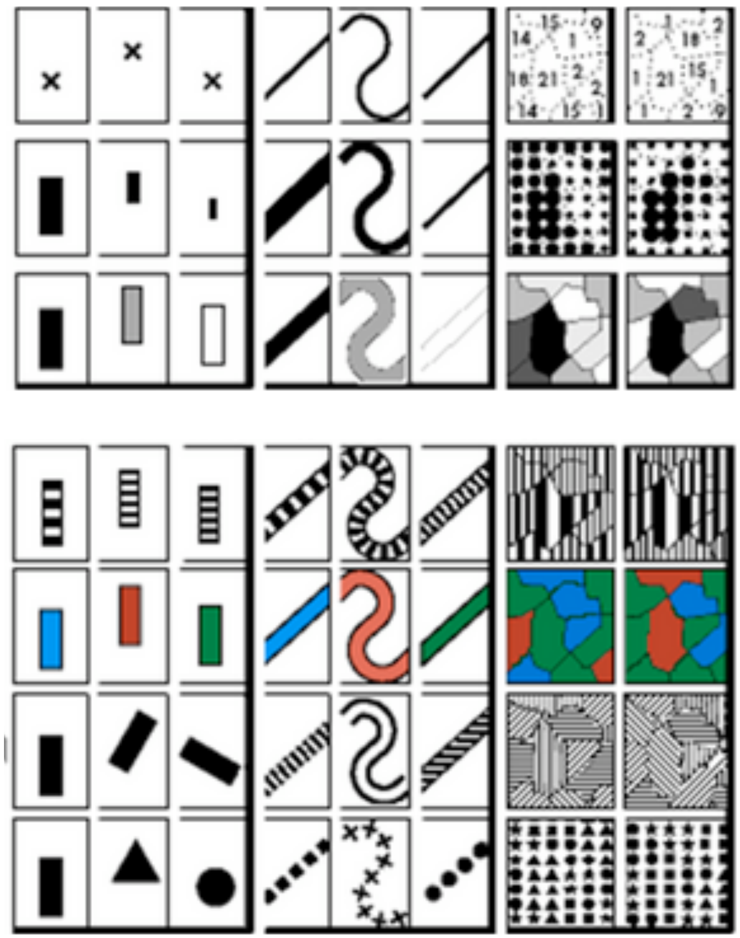
grey level

texture

color

orientation

shape



- attributes
  - parameters control mark appearance
  - separable channels flowing from retina to brain

Semiology of Graphics. Jacques Bertin, Gauthier-Villars 1967, EHESS 1998

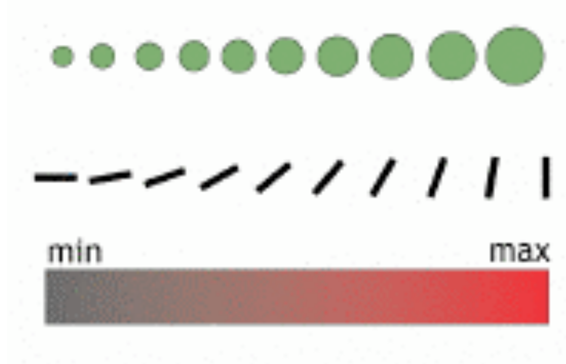
Visual Encoding Example: Scatterplot

- x position
- y position
- hue
- size

Robertson et al. Effectiveness of Animation in Trend Visualization. IEEE TVCG (Proc. InfoVis08) 14:6 (2008), 1325–1332.

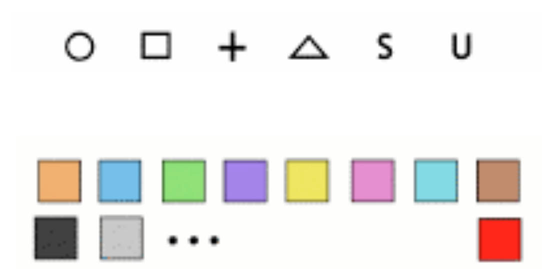
Data Types

- quantitative
  - lengths: 10 inches, 17 inches, 23 inches



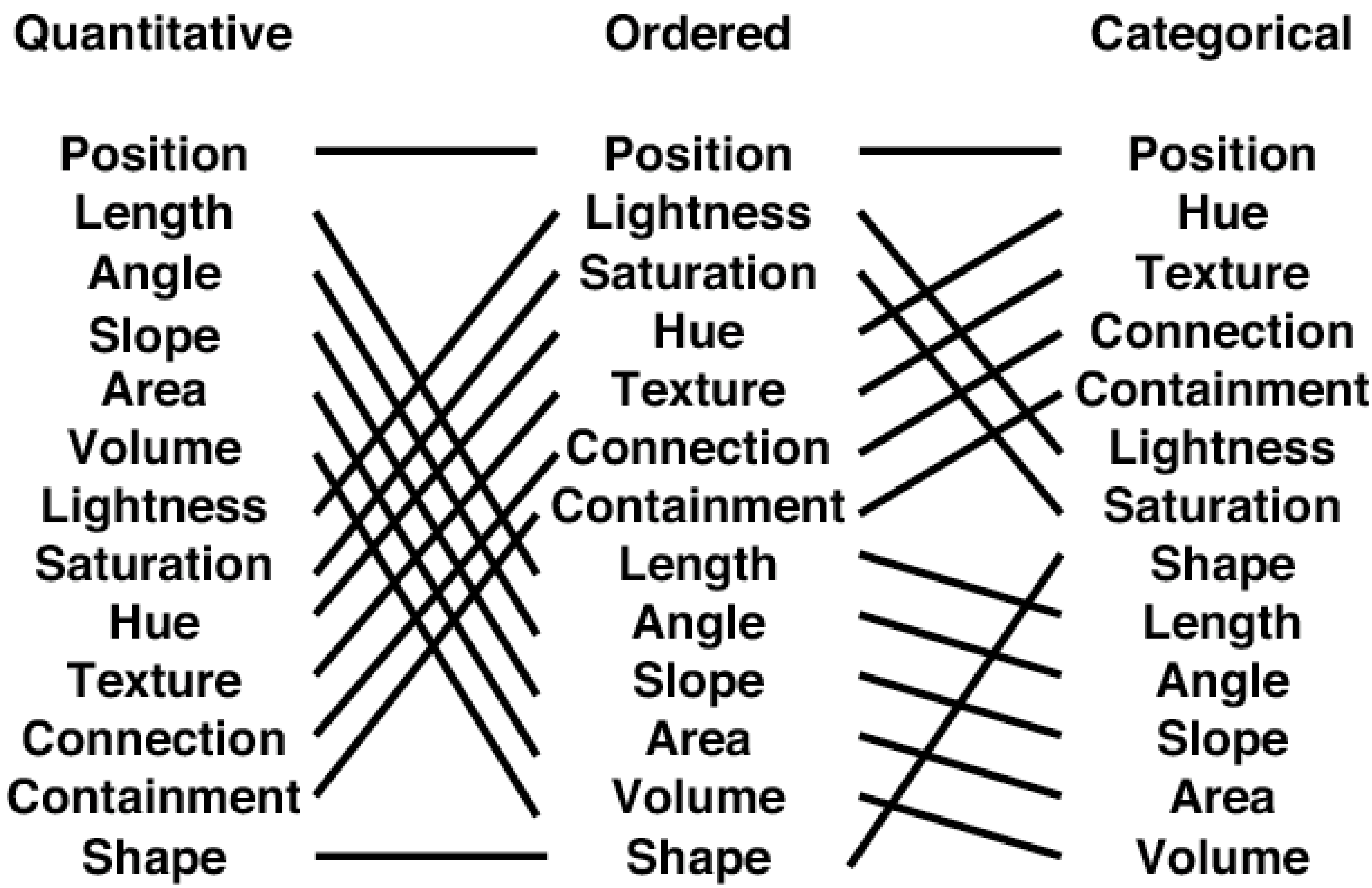
- ordered
  - sizes: small, medium, large
  - days: Mon, Tue, Wed, ...

- categorical
  - fruit: apples, oranges, bananas



[Stolte and Hanrahan. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Proc InfoVis 2000. graphics.stanford.edu/projects/polaris/]

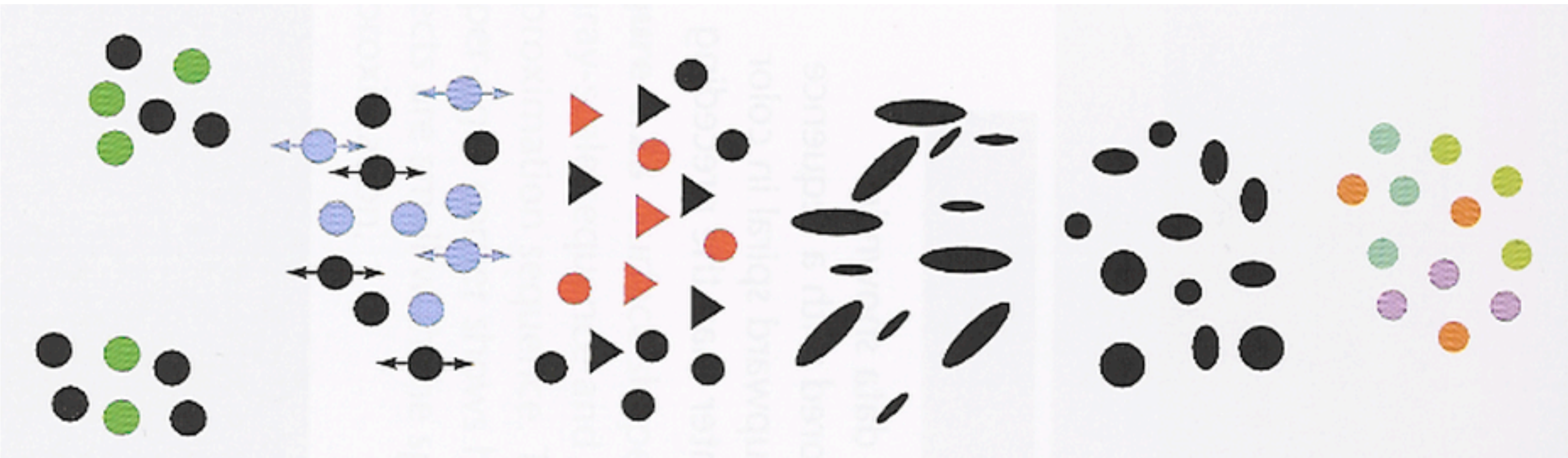
Channel Ranking Varies By Data Type



[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

Integral vs. Separable Dimensions

- not all dimensions separable

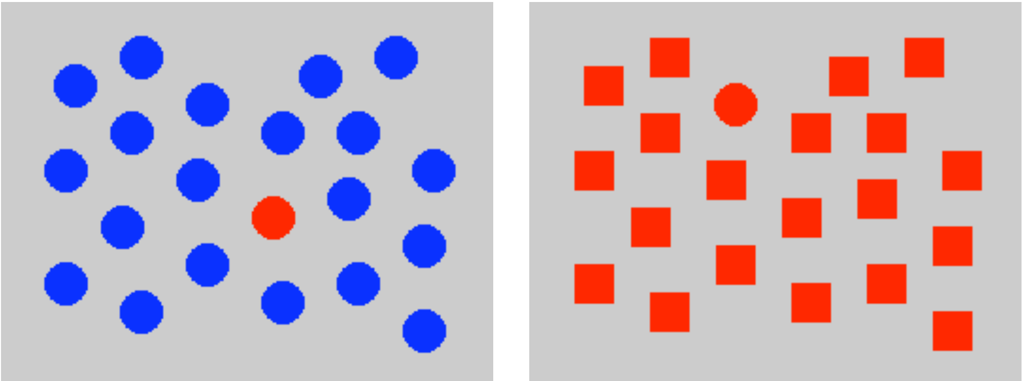


color location	color motion	color shape	size orientation	x-size y-size	red-green yellow-blue

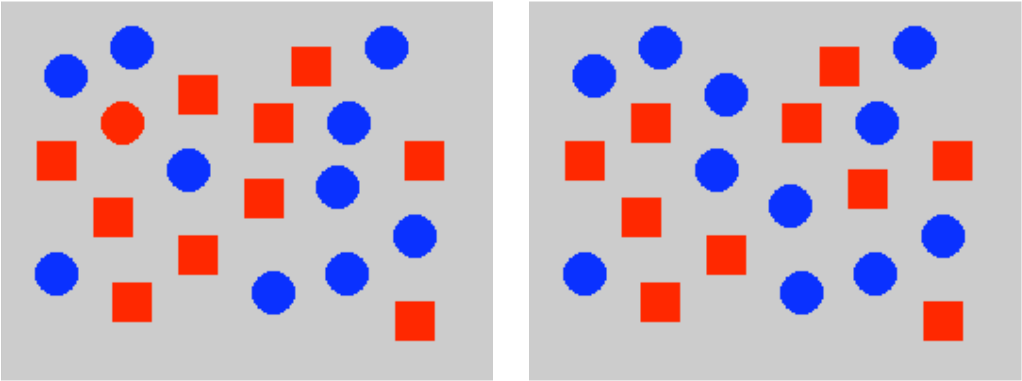
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Preattentive Visual Channels

- color alone, shape alone: preattentive



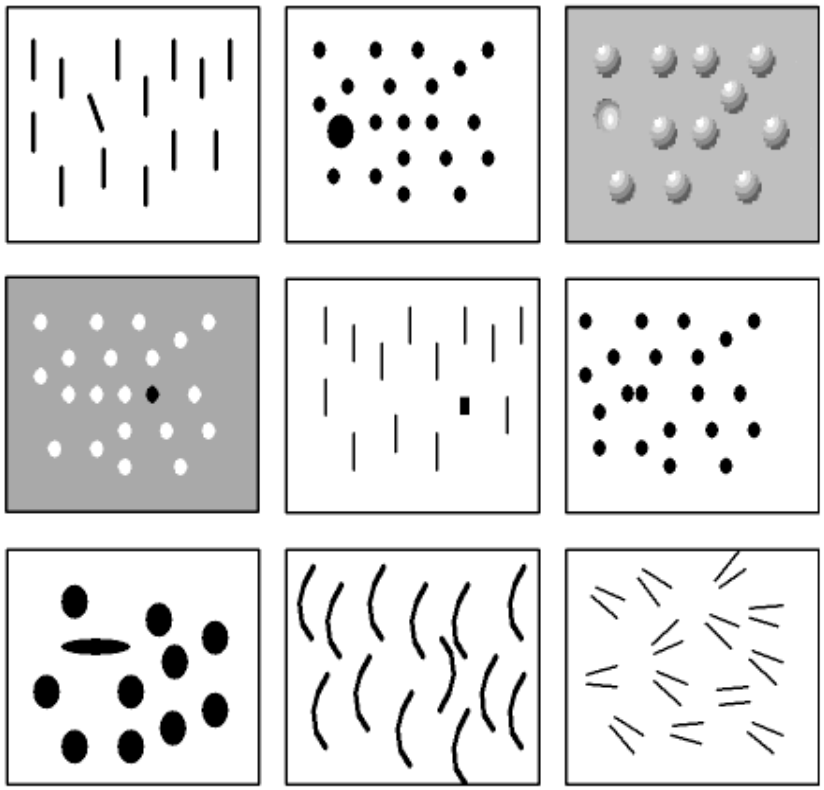
- combined color and shape: requires attention
  - search speed linear with distractor count



[Christopher Healey, [www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive Visual Channels

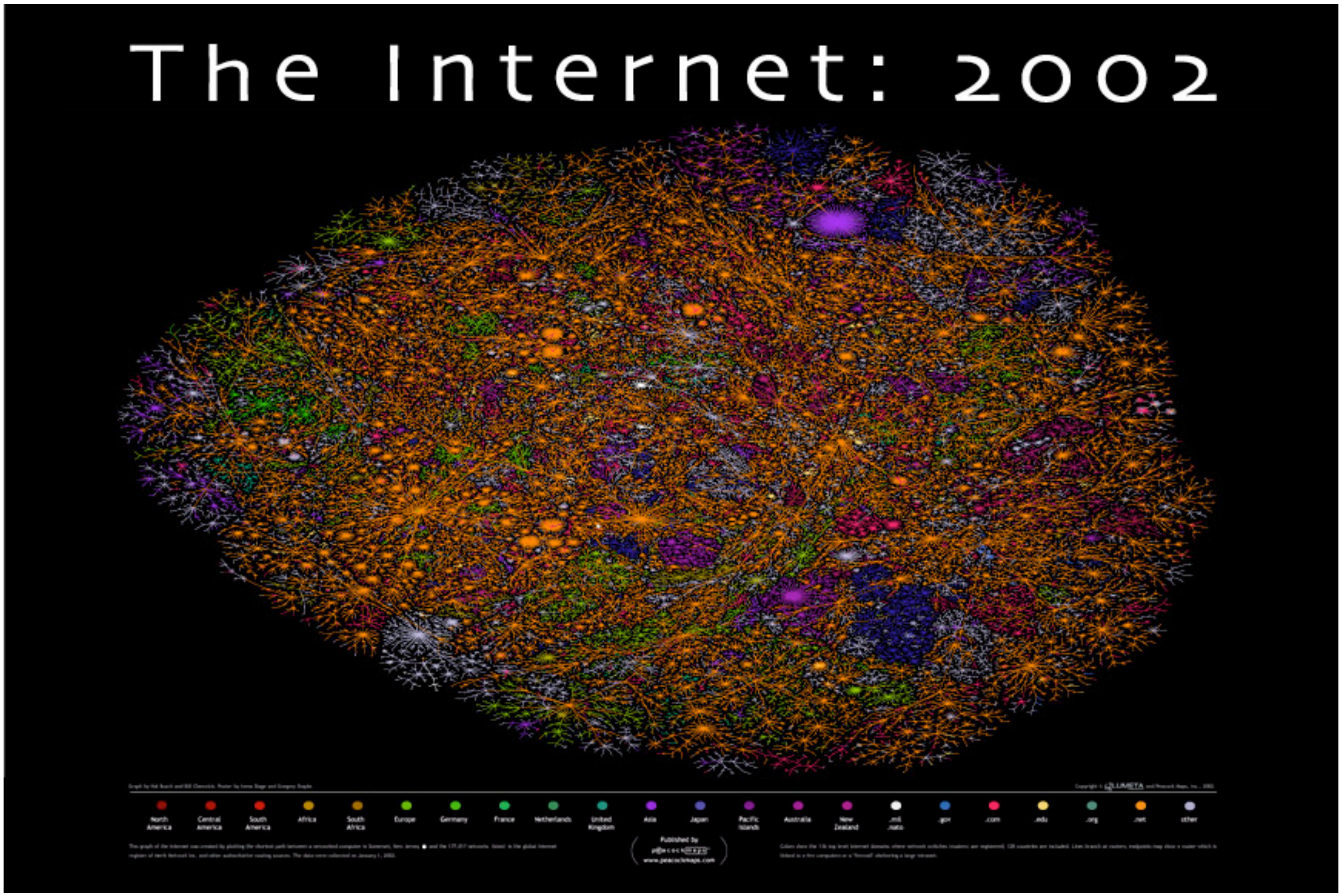
- preattentive channels include
  - hue
  - shape
  - texture
  - length
  - width
  - size
  - orientation
  - curvature
  - intersection
  - intensity
  - flicker
  - direction of motion
  - stereoscopic depth
  - lighting direction
  - many more...



[Healey, [www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Coloring Categorical Data

- 22 colors, but only ~8 distinguishable



[www.peacockmaps.com, research.lumeta.com/ches/map]

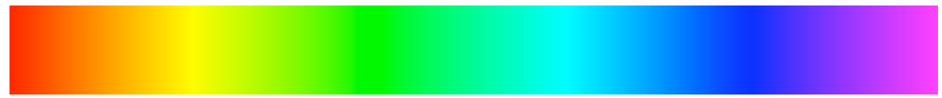
Coloring Categorical Data

- discrete small patches separated in space
- limited distinguishability: around 8-14
  - channel dynamic range low
  - best to choose bins explicitly
- maximal saturation for small areas

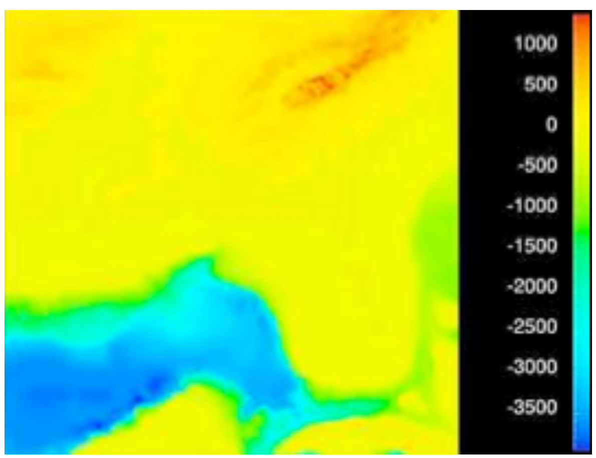
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

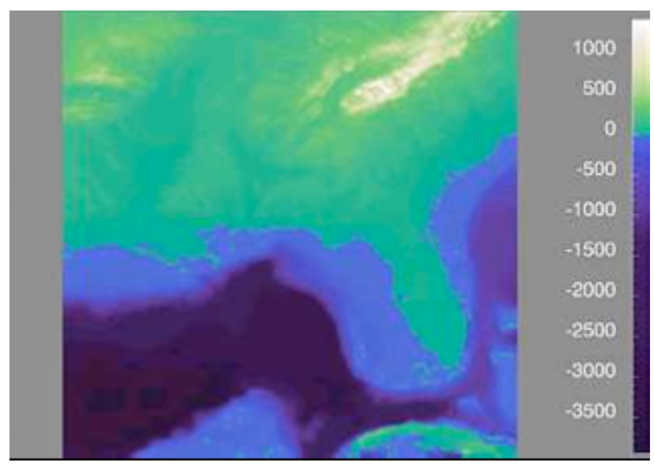
Quantitative Colormaps

- dangers of rainbows
  - perceptually nonlinear
  - arbitrary not innate ordering



- other approaches
  - explicitly segmented colormaps
  - monotonically increasing/(decreasing) luminance, plus hue to semantically distinguish regions

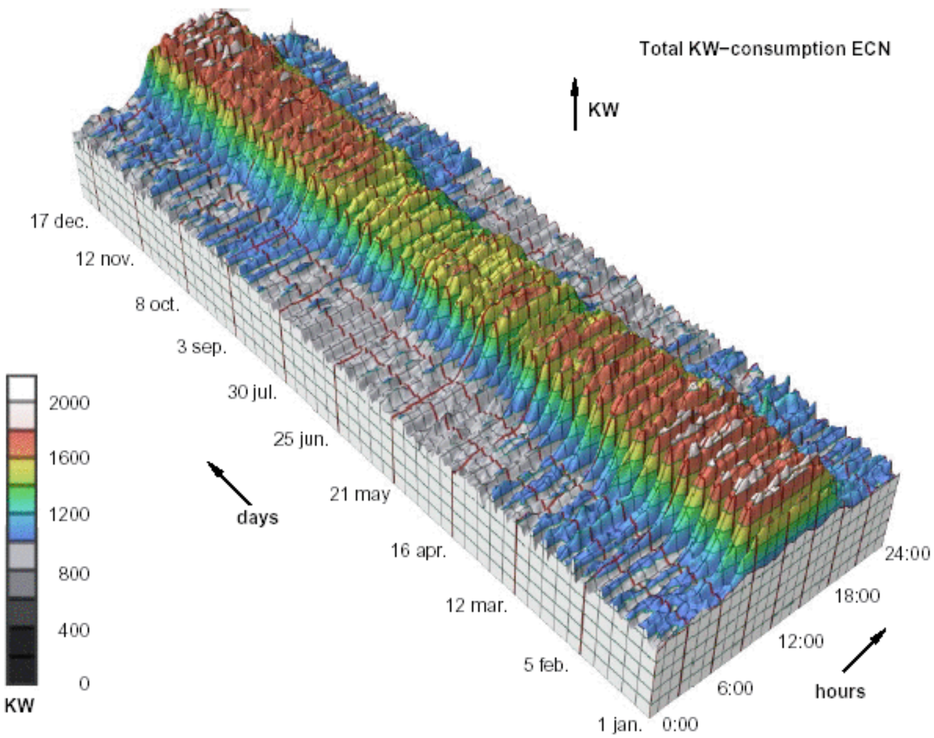


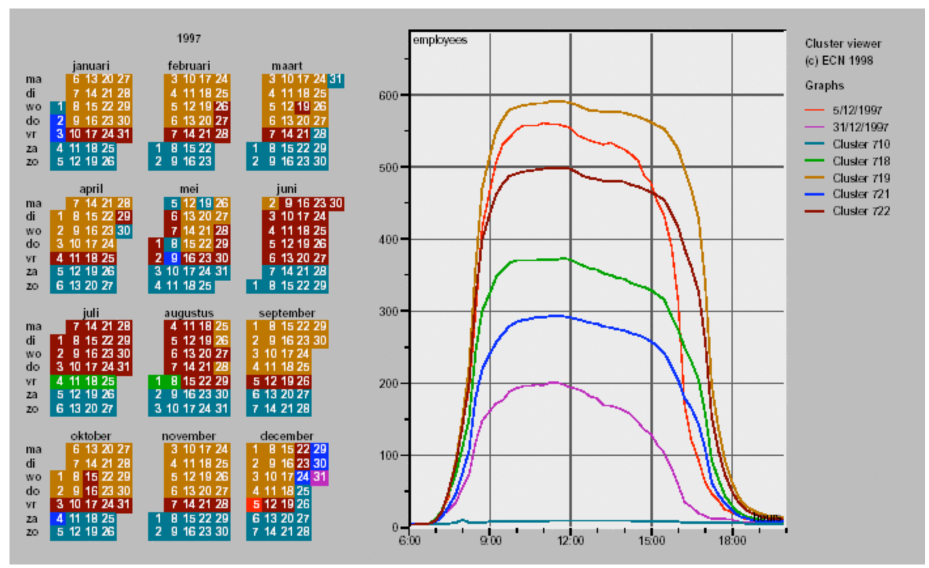


Rogowitz and Treinish. Data Visualization: The End of the Rainbow. IEEE Spectrum 35(12):52-59, Dec 1998.

3D vs 2D Representations

- curve comparison difficult: perspective distortion, occlusion
  - dataset is abstract, not inherently spatial
  - after data transformation to clusters, linked 2D views of representative curves show more

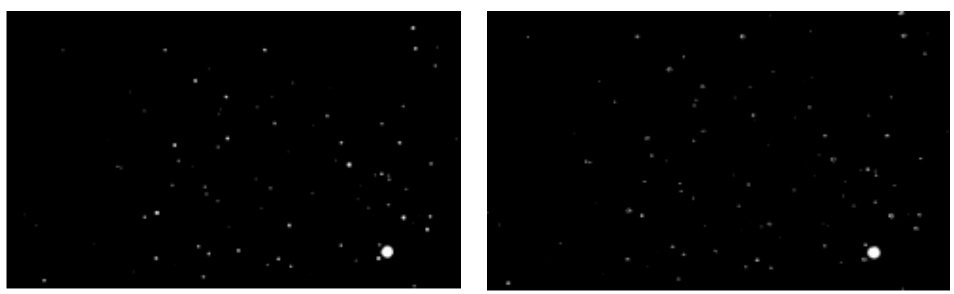




[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99

Space vs Time: Showing Change

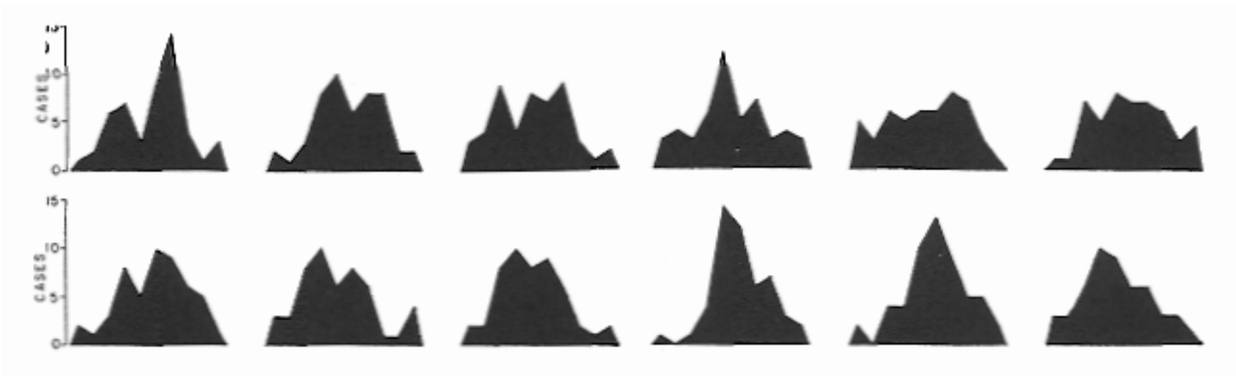
- animation: show time using temporal change
  - good: show process
  - good: flip between two things
  - bad: flip between between many things
    - interference between intermediate frames



[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
[www.astroshow.com/ccdpho/pluto.gif]
[Edward Tufte. The Visual Display of Quantitative Information, p 172]

Space vs Time: Showing Change

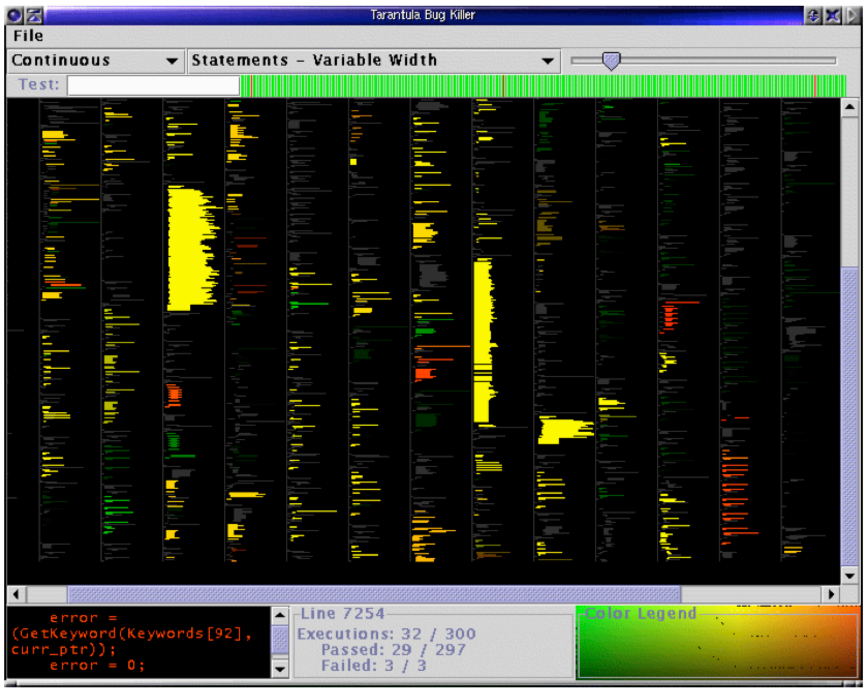
- small multiples: show time using space
  - overview: show each time step in array
  - compare: side by side easier than temporal
    - external cognition vs internal memory
  - general technique, not just for temporal changes



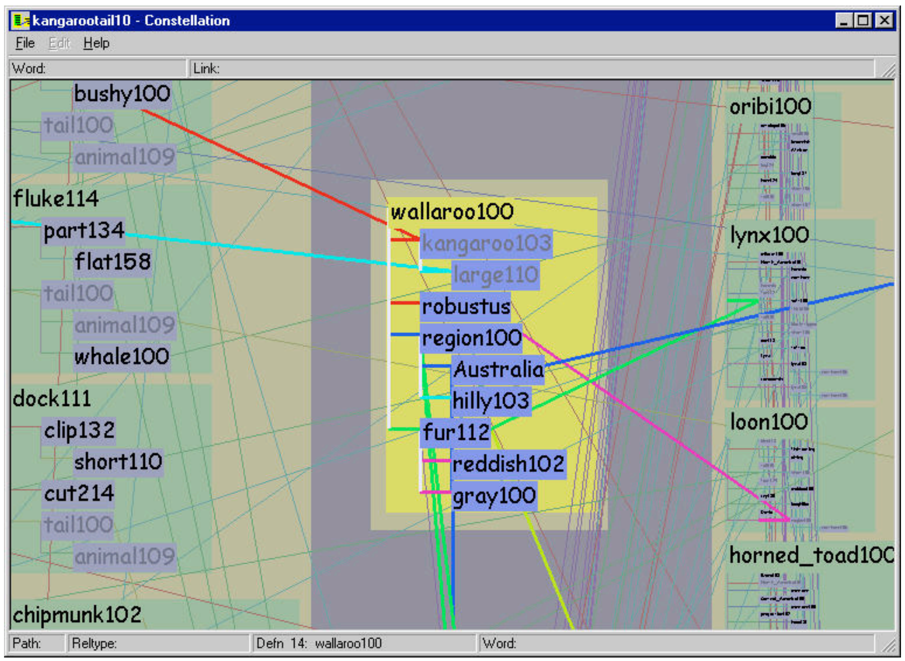
[Edward Tufte. The Visual Display of Quantitative Information, p 172]

Composite Views

- pixel-oriented views
  - overviews with high information density
- superimposing/layering
  - shared coordinate frame
  - redundant visual encoding



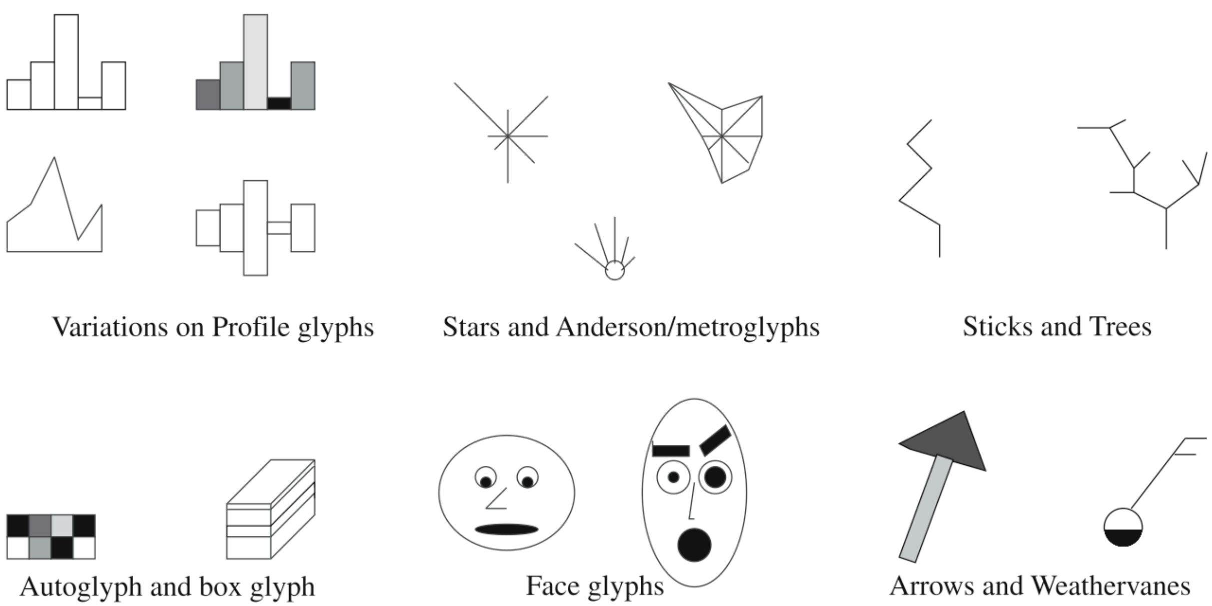
[Jones, Harrold, and Stasko. Visualization of Test Information to Assist Fault Localization. Proc. ICSE 2002, p 467-477.]

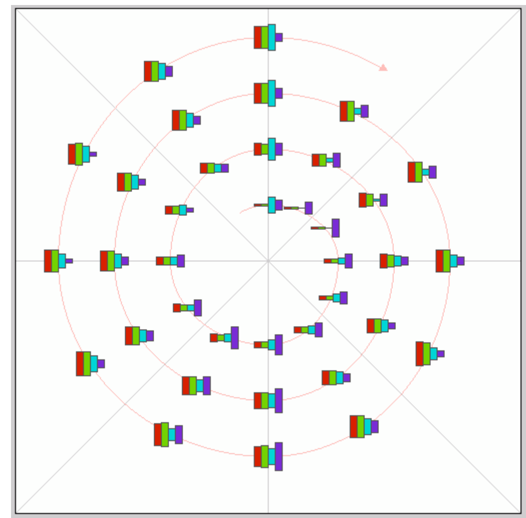


[Munzner. Interactive Visualization of Large Graphs and Networks. Stanford CS, 2000]

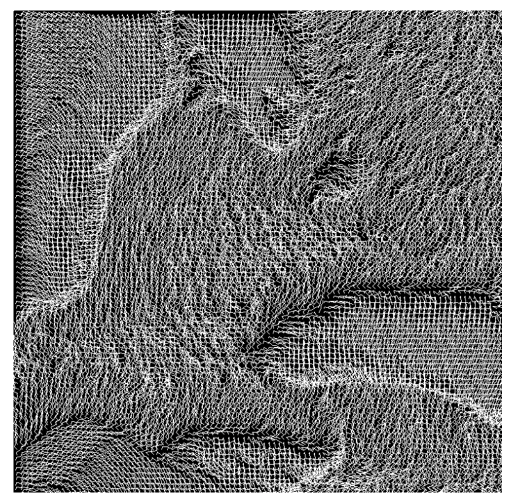
Composite Views: Glyphs

- internal structure where subregions have different visual channel encodings





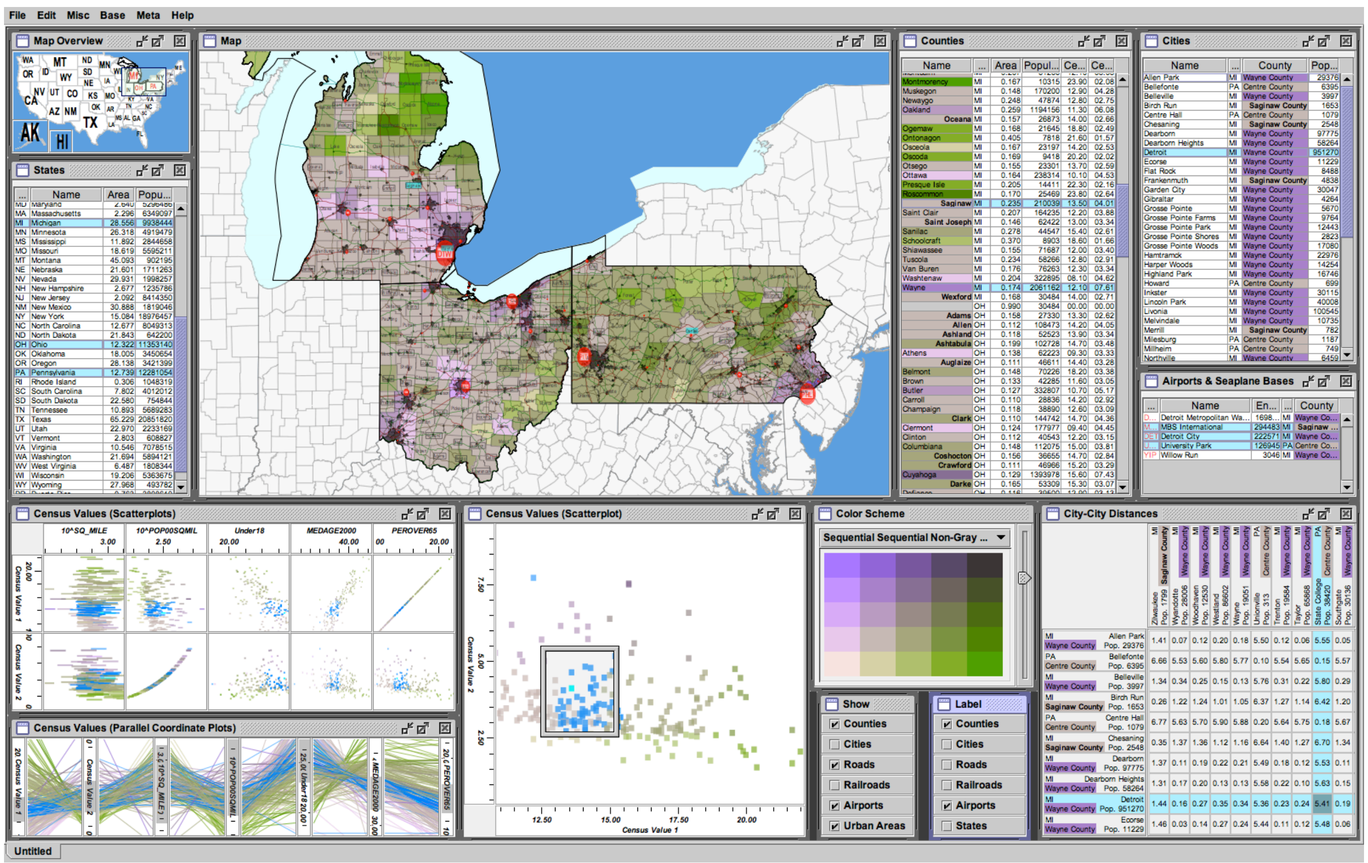
[Ward. A Taxonomy of Glyph Placement Strategies for Multidimensional Data Visualization. Information Visualization Journal 1:3-4 (2002), 194--210.]



[Smith, Grinstein, and Bergeron. Interactive data exploration with a supercomputer. Proc. IEEE Visualization, p 248-254, 1991.]

Adjacent: Multiple Views

- different visual encodings show different aspects of the data
- linked highlighting to show where contiguous in one view distributed within another



[Weaver. http://www.personal.psu.edu/cew15/improvise/examples/census]

Adjacent Views

- overview and detail
  - same visual encoding, different resolutions
- small multiples
  - same visual encoding, different data