University of British Columbia
CPSC 314 Computer Graphics
May-June 2005

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Scientific Visualization, Information Visualization I/II

Week 5, Thu Jun 9

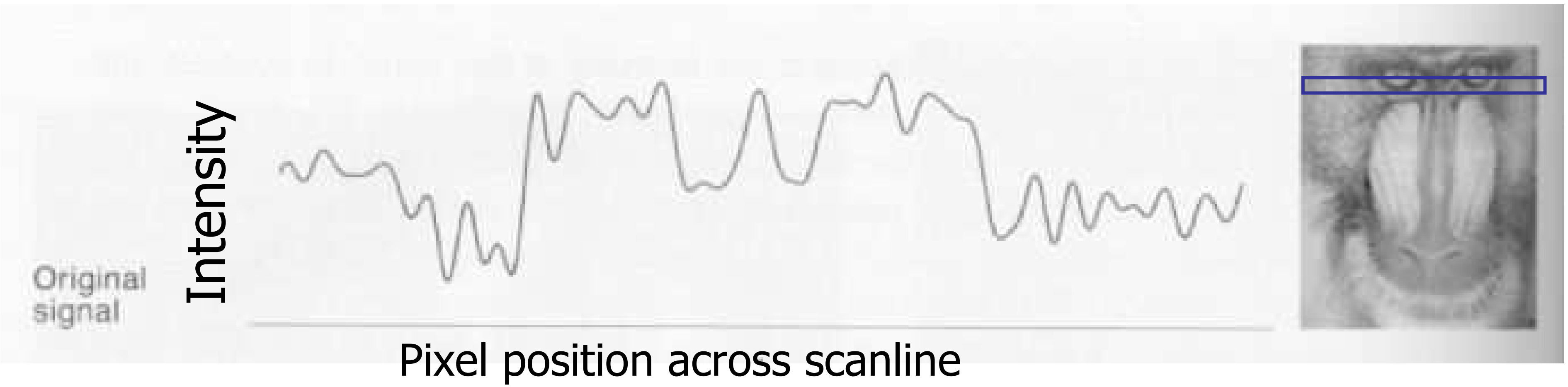
http://www.ugrad.cs.ubc.ca/~cs314/Vmay2005

News

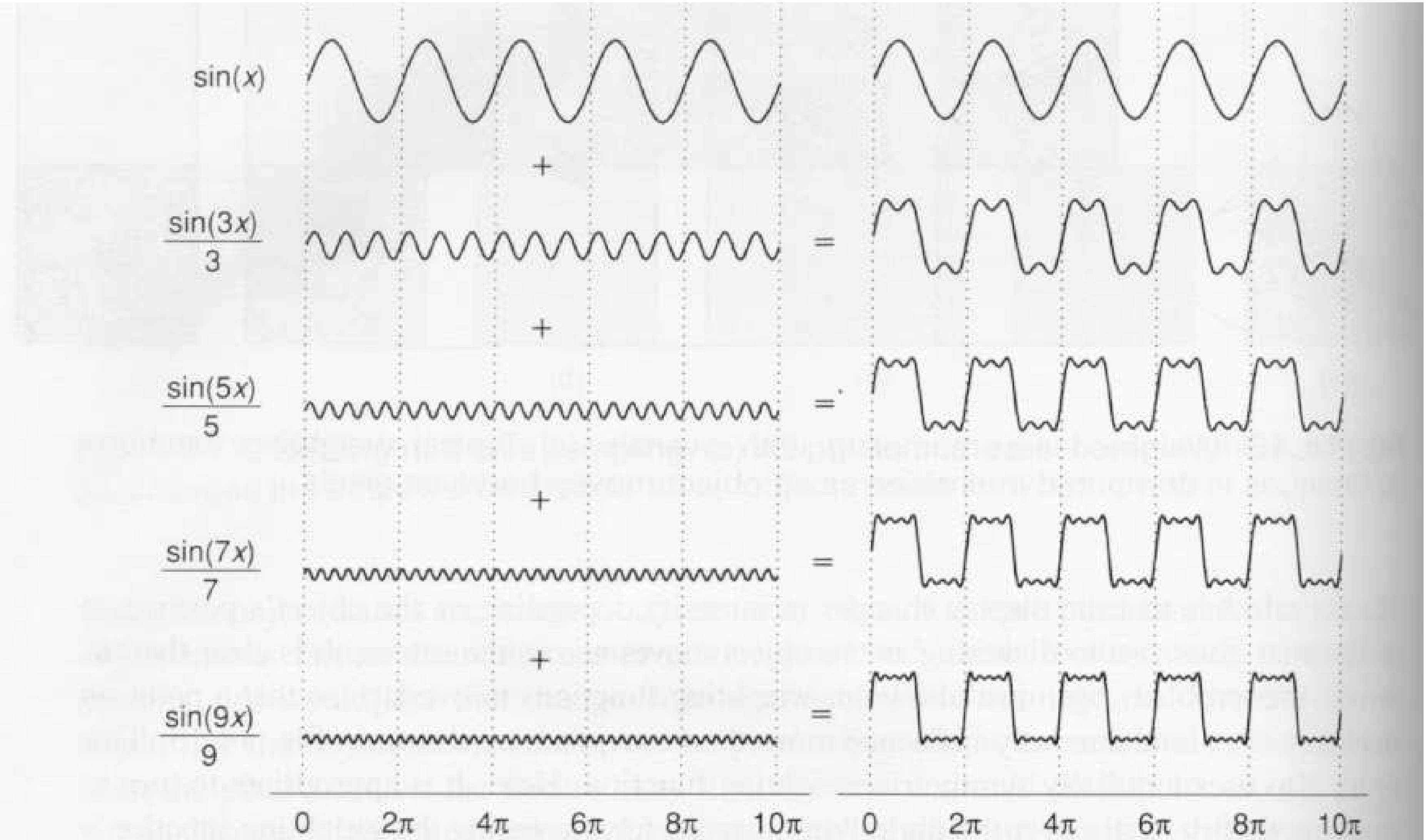
- P1 Hall of Fame take 2
- P4 grading signup
  - 12-4 Mon Jun 20

Review: Image As Signal

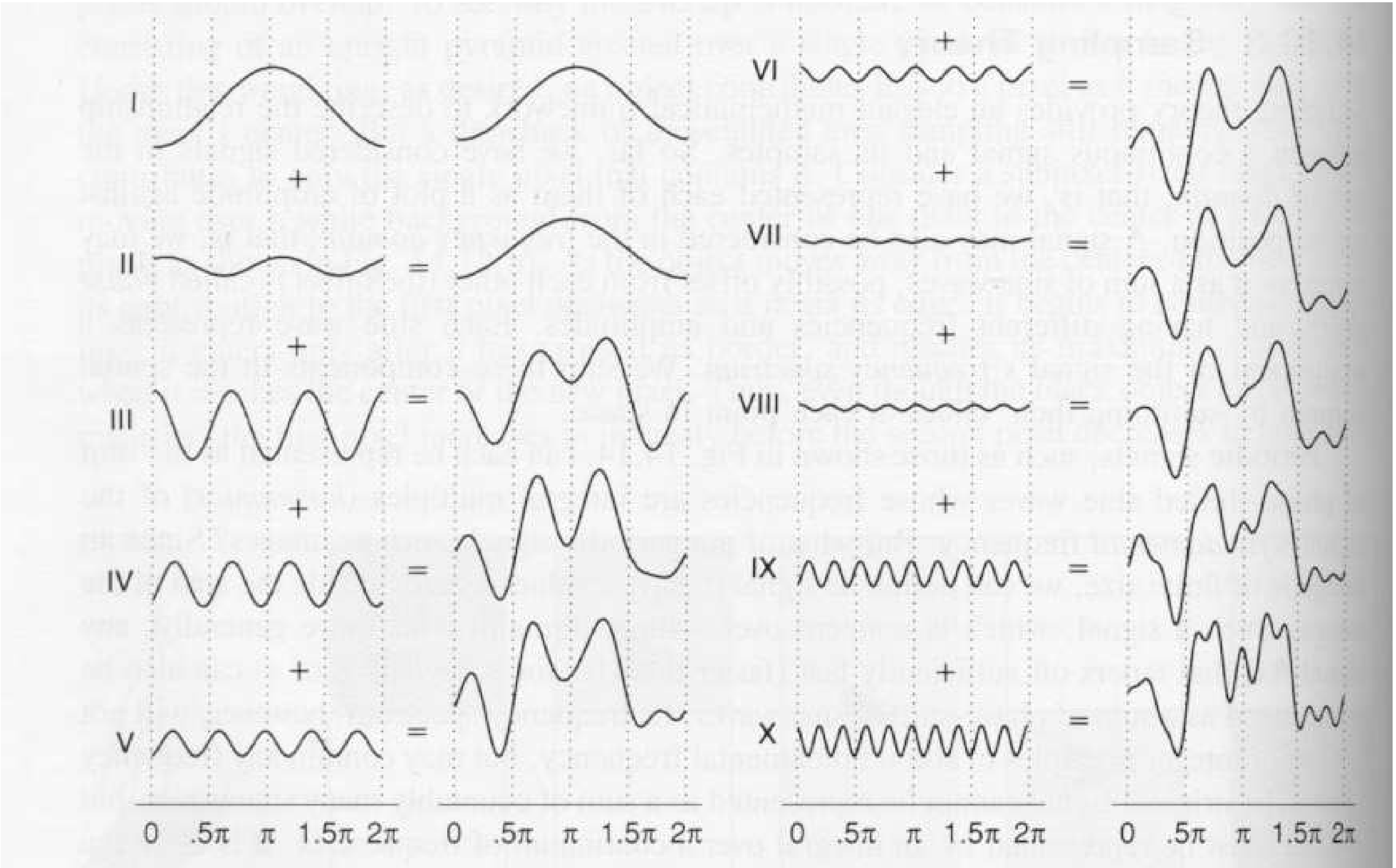
- 1D slice of raster image
  - discrete sampling of 1D spatial signal
- theorem
  - any signal can be represented as an (infinite) sum of sine waves at different frequencies



Review: Summing Waves I

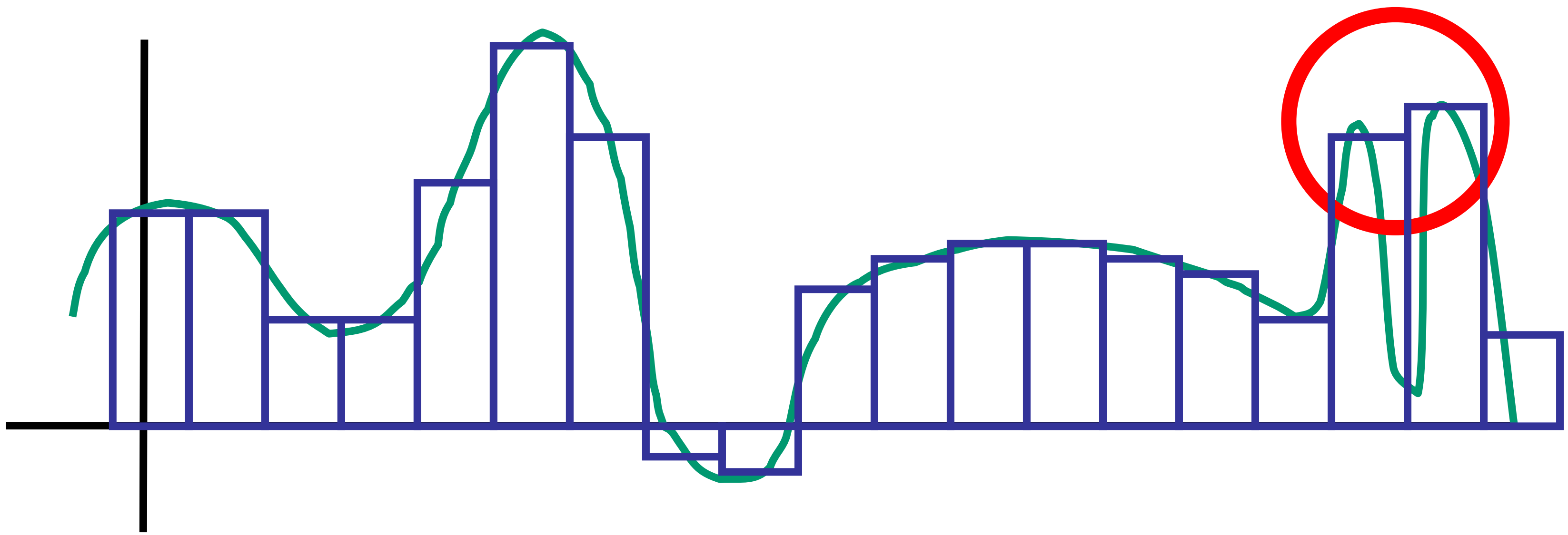


Review: Summing Waves II



Review: 1D Sampling and Reconstruction

- problems
  - jaggies – abrupt changes
  - lose data



Review: Sampling Theorem and Nyquist Rate

- Shannon Sampling Theorem
  - continuous signal can be completely recovered from its samples iff sampling rate greater than twice maximum frequency present in signal
- sample past Nyquist Rate to avoid aliasing
  - twice the highest frequency component in the image's spectrum

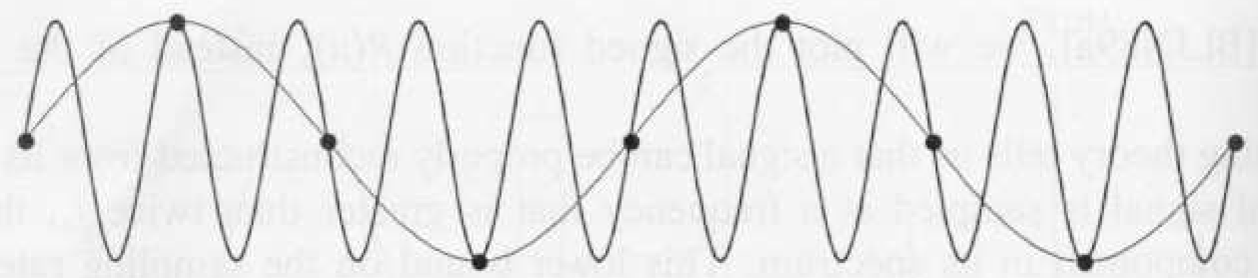
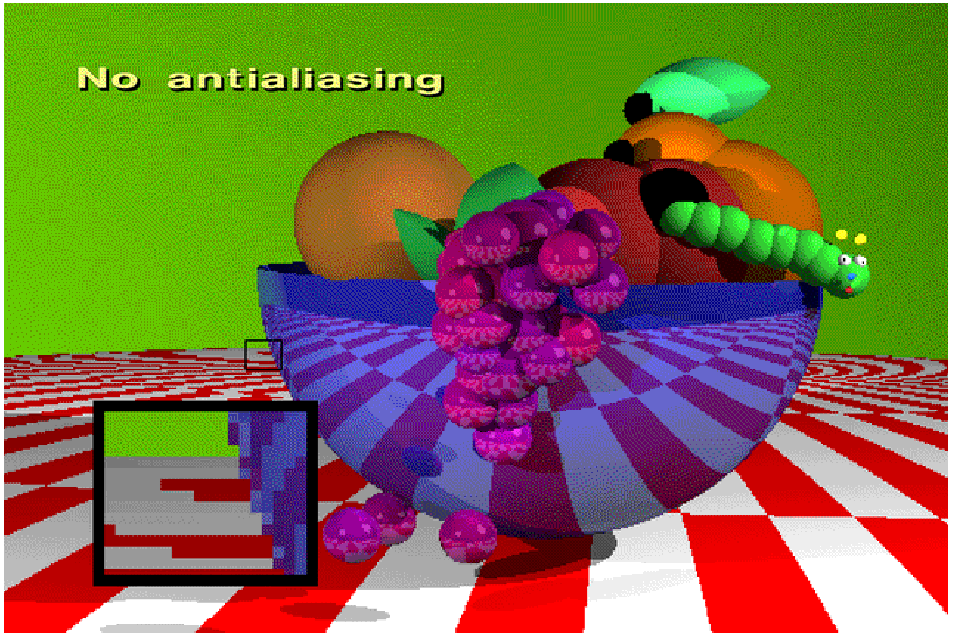


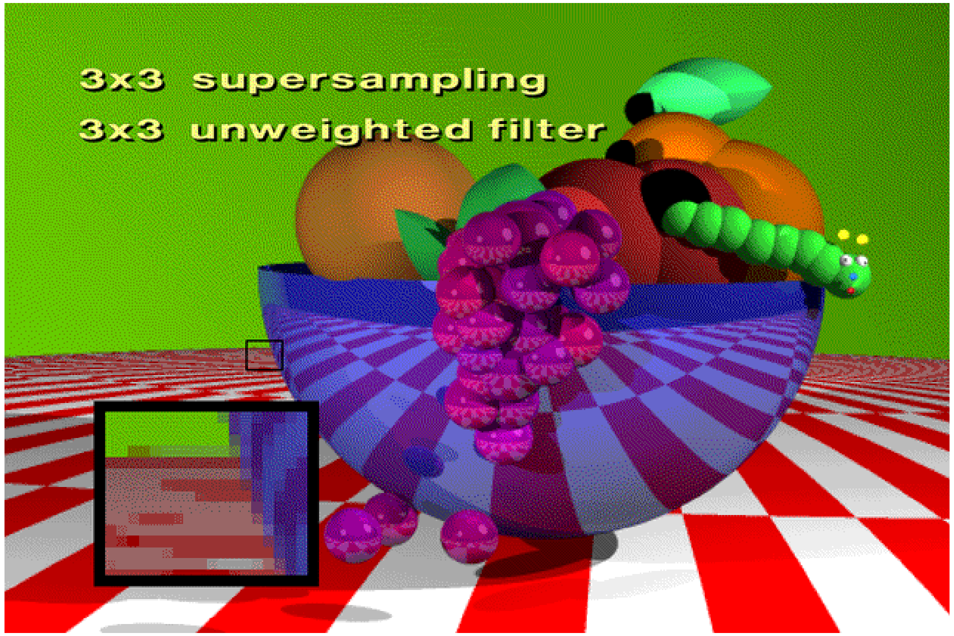
Fig. 14.17 Sampling below the Nyquist rate. (Courtesy of George Wolberg, Columbia University.)

Review: Aliasing

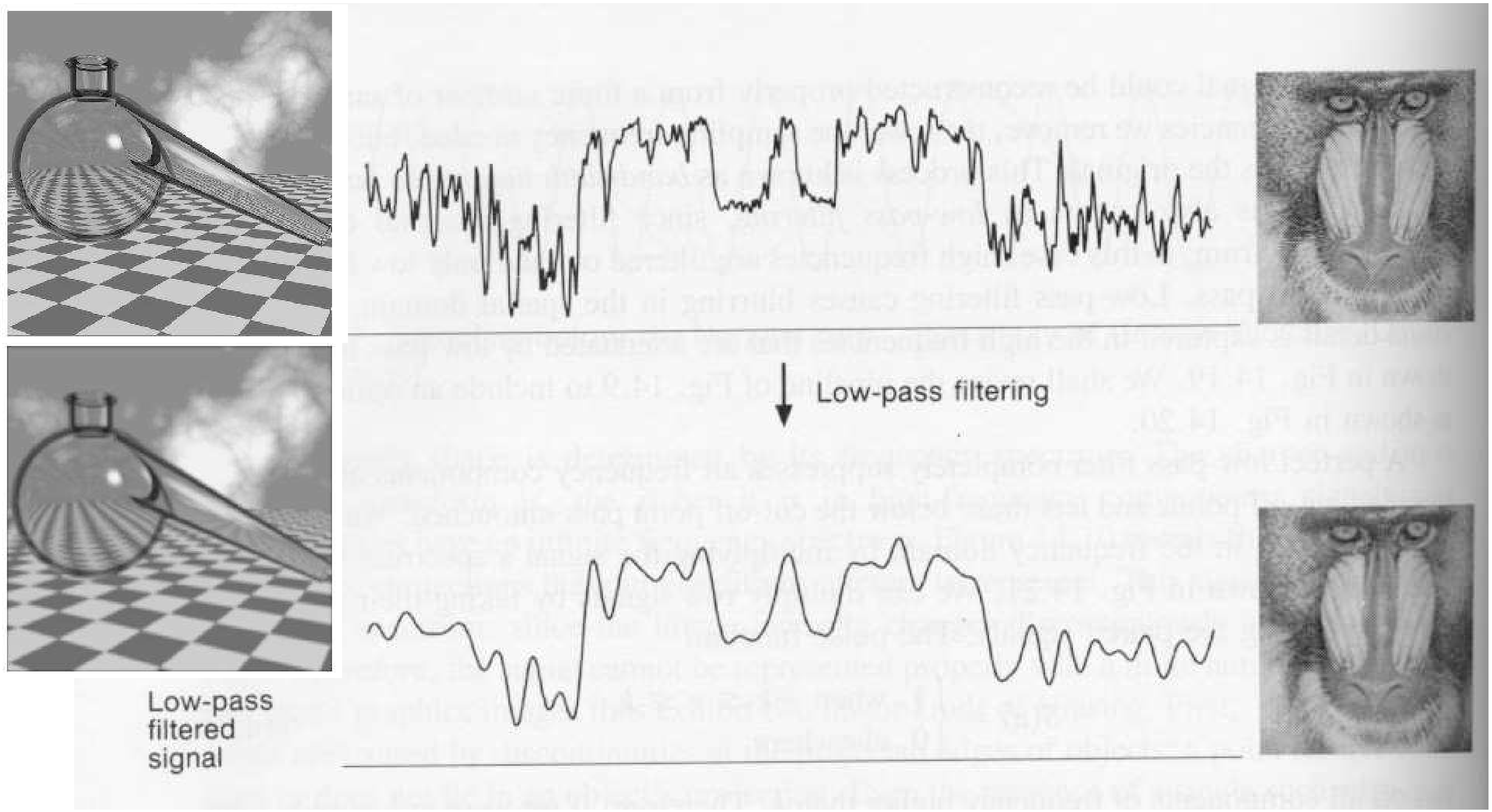
- incorrect appearance of high frequencies as low frequencies
- to avoid: antialiasing
  - supersample
    - sample at higher frequency
  - low pass filtering
    - remove high frequency function parts
    - aka prefiltering, band-limiting

Review: Supersampling





Review: Low-Pass Filtering

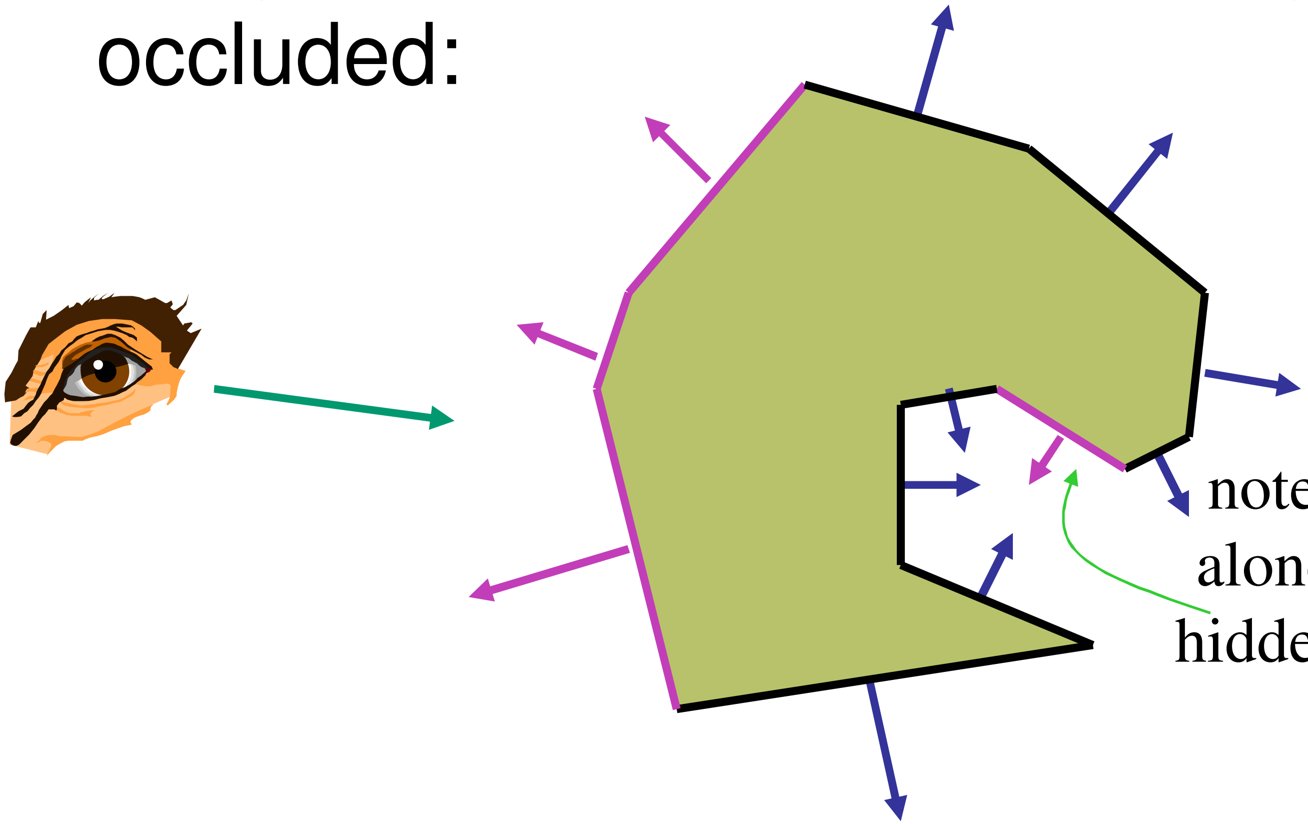


Review: Invisible Primitives

- *why might a polygon be invisible?*
  - polygon outside the *field of view / frustum*
    - solved by clipping
  - polygon is *backfacing*
    - solved by backface culling
  - polygon is *occluded* by object(s) nearer the viewpoint
    - solved by hidden surface removal

Review: Back-Face Culling

- on the surface of a closed orientable manifold, polygons whose normals point away from the camera are always occluded:



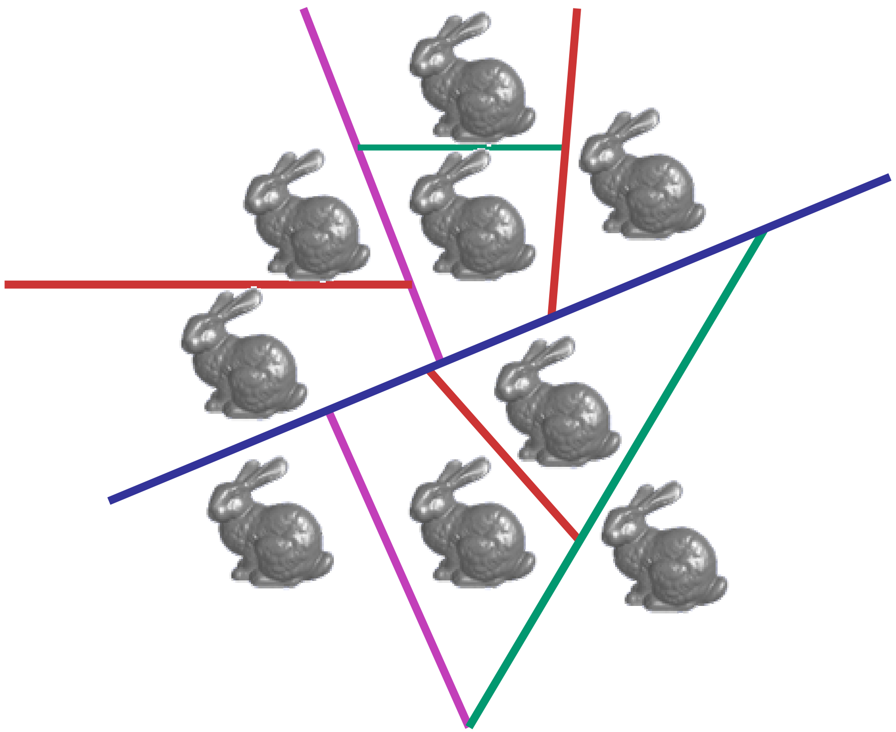
note: backface culling alone doesn't solve the hidden-surface problem!

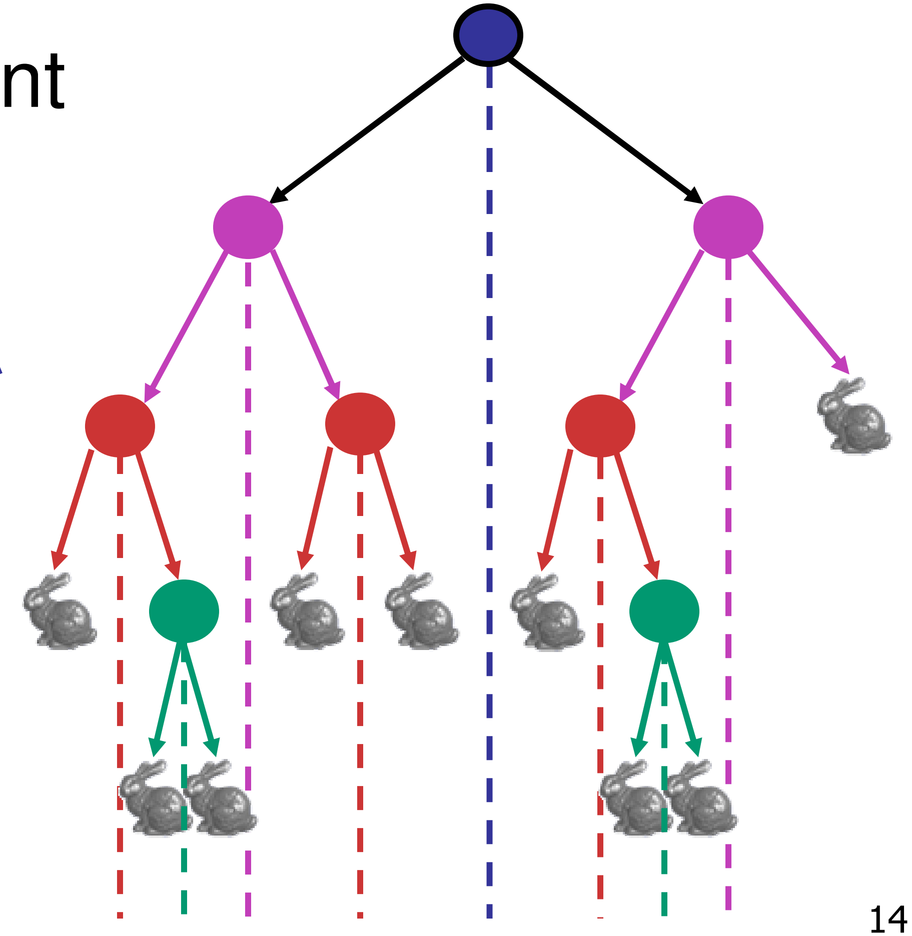
Review: Painter's Algorithm

- draw objects from back to front
- problems: no valid visibility order for
  - intersecting polygons
  - cycles of non-intersecting polygons possible

Review: BSP Trees

- preprocess: create binary tree
  - recursive spatial partition
  - viewpoint independent



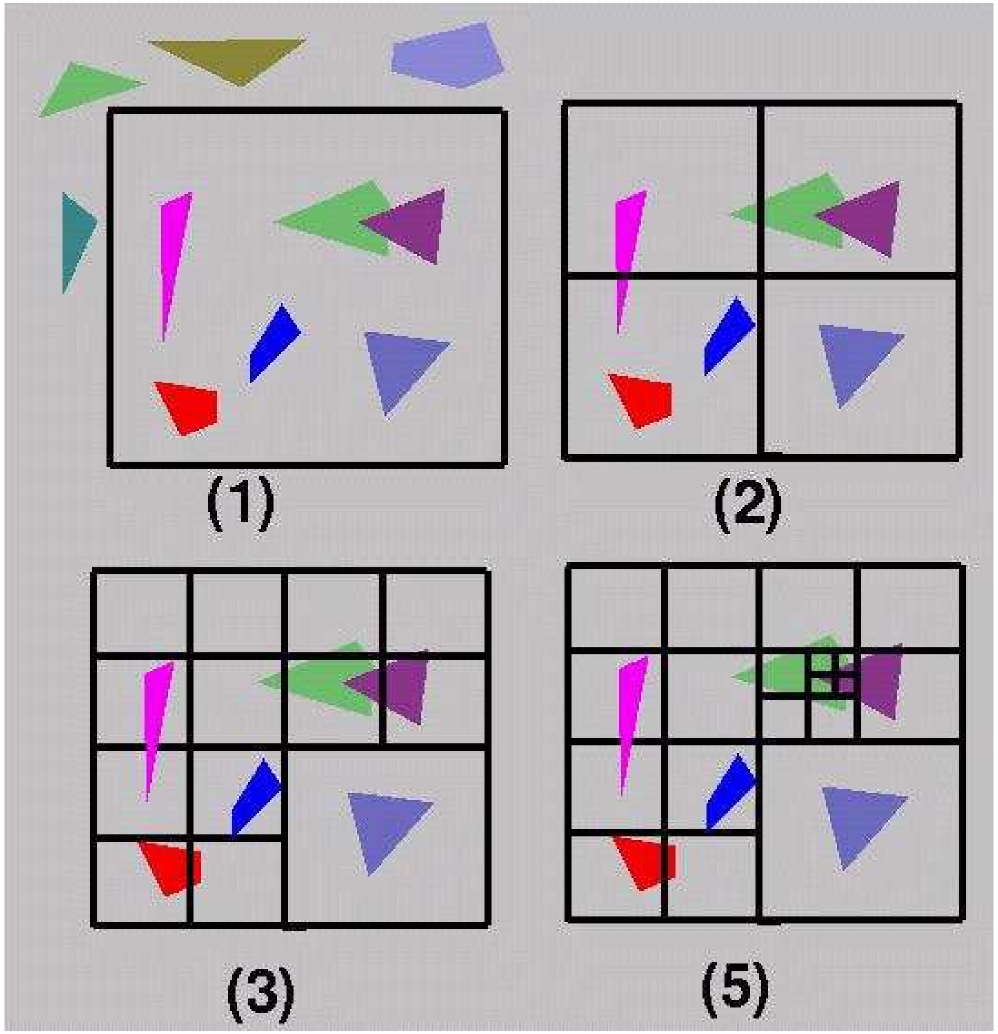


Review: BSP Trees

- runtime: correctly traversing this tree enumerates objects from back to front
  - viewpoint dependent
    - check which side of plane viewpoint is on at each node
  - draw far, draw object in question, draw near
- pros
  - simple, elegant scheme
  - works at object or polygon level
- cons
  - computationally intense preprocessing stage restricts algorithm to static scenes

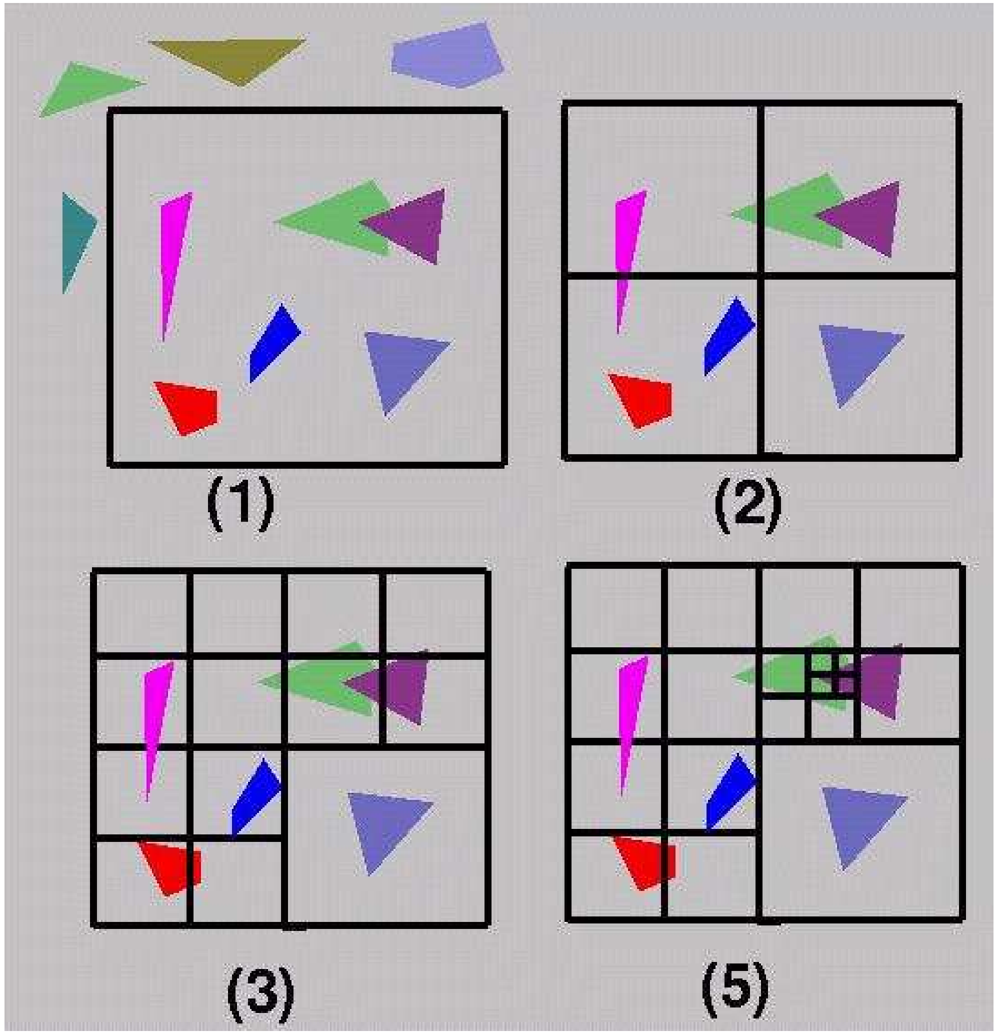
Review: Warnock's Algorithm

- start with root viewport and list of all objects
- recursion:
  - clip objects to viewport
  - if only 0 or 1 objects
    - done
  - else
    - subdivide to new smaller viewports
    - distribute objects to new viewpoints
    - recurse



Review: Warnock's Algorithm

- termination
  - viewport is single pixel
  - explicitly check for object occlusion
- single-pixel case common in high depth complexity scenes



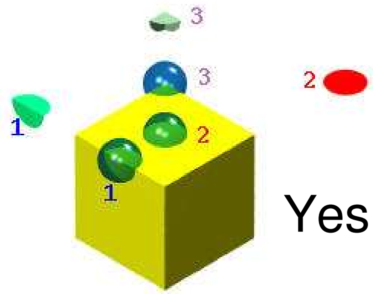
Review: Z-Buffer Algorithm

- augment color framebuffer with Z-buffer or depth buffer which stores Z value at each pixel
  - at frame beginning, initialize all pixel depths to ∞
  - when rasterizing, interpolate depth (Z) across polygon
  - check Z-buffer before storing pixel color in framebuffer and storing depth in Z-buffer
  - don’t write pixel if its Z value is more distant than the Z value already stored there

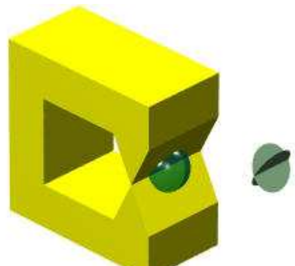
Review: Back-Face Culling

- most objects in scene are typically “solid”
- rigorously: orientable closed manifolds
  - orientable: must have two distinct sides
    - cannot self-intersect
    - sphere is orientable
      - boundary partitions space into interior & exterior
    - Mobius strip or Klein bottle is not orientable
      - do not partition space into interior & exterior
  - closed: cannot “walk” from one side to other
    - sphere is closed manifold, plane is not
  - manifold: local neighborhood of all points isomorphic to disc

No



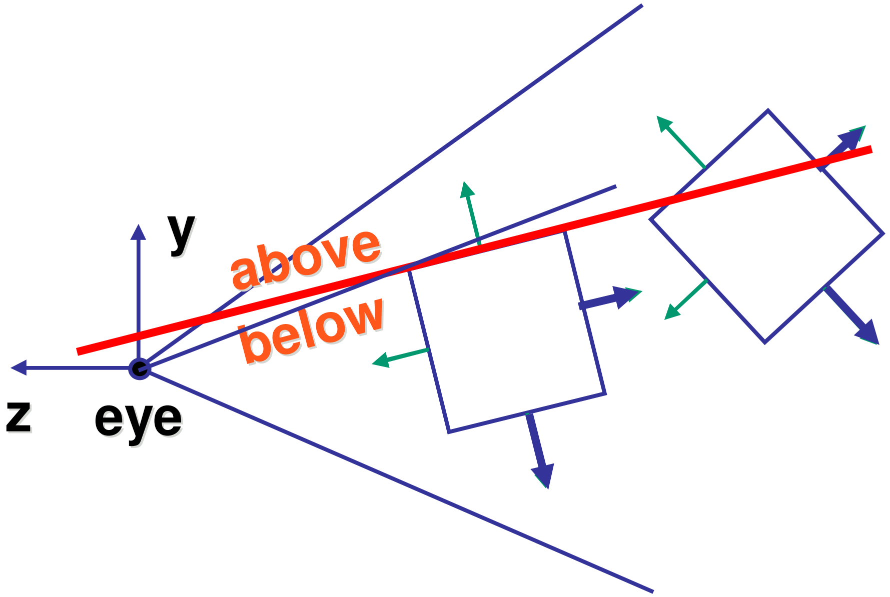
Yes



No

Review: Back-face Culling

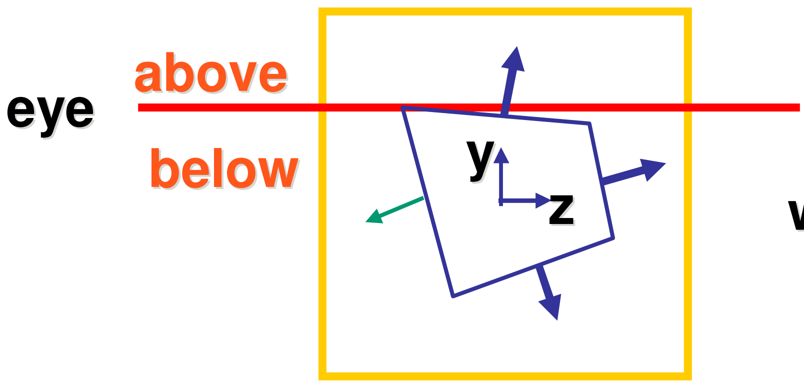
VCS



culling $N_Z < 0$
sometimes
misses polygons that
should be culled

instead, cull if eye is
below polygon plane

NDCS



works to cull if $N_Z > 0$

Clarification/Review: Depth Test Precision

- reminder: projective transformation maps eye-space *z* to generic *z*-range (NDC)

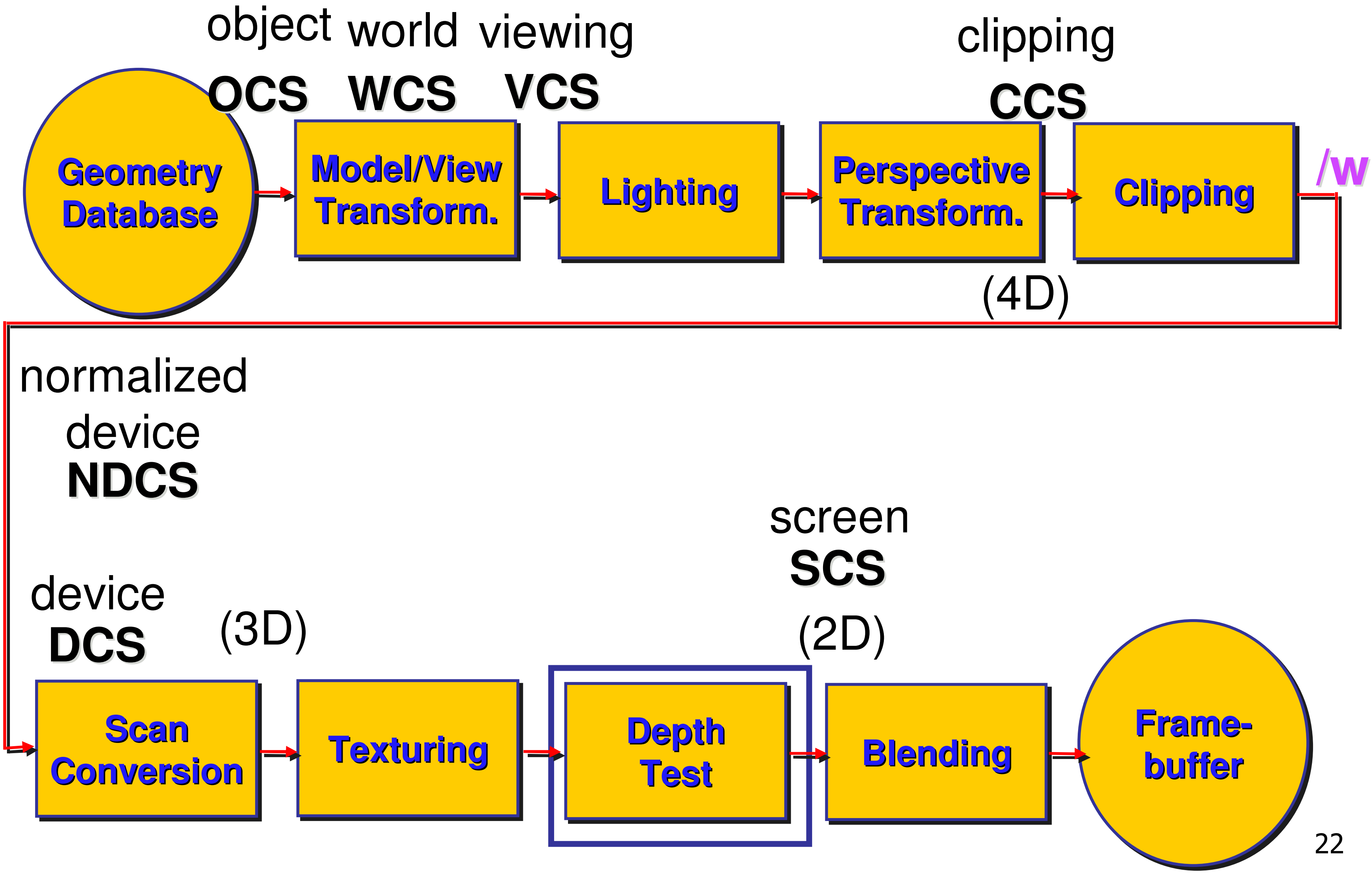
$$\begin{bmatrix} x_N \\ y_N \\ z_N \\ w_N \end{bmatrix} = \begin{bmatrix} \frac{2n}{r-l} & 0 & \frac{r+l}{r-l} & 0 \\ 0 & \frac{2n}{t-b} & \frac{t+b}{t-b} & 0 \\ 0 & 0 & \frac{-(f+n)}{f-n} & \frac{-2fn}{f-n} \\ 0 & 0 & -1 & 0 \end{bmatrix} \cdot \begin{bmatrix} x_E \\ y_E \\ z_E \\ w_E \end{bmatrix}$$

- thus $z_N \sim= 1/z_E$

$$z_N = \frac{-(f+n)}{f-n} z_E + \frac{-2fn}{f-n} w_E, w_N = -z_E$$

$$\frac{z_N}{w_N} = \frac{f+n}{f-n} + \frac{2fn}{f-n} \frac{w_E}{z_E}$$

Review: Rendering Pipeline



Scientific Visualization

Reading

- FCG Chapter 23

Surface Graphics

- objects explicitly defined by surface or boundary representation
  - mesh of polygons

200 polys 1000 polys 15000 polys

Surface Graphics

- pros
  - fast rendering algorithms available
  - hardware acceleration cheap
  - OpenGL API for programming
  - use texture mapping for added realism
- cons
  - discards interior of object, maintaining only the shell
  - operations such cutting, slicing & dissection not possible
  - no artificial viewing modes such as semi-transparencies, X-ray
  - surface-less phenomena such as clouds, fog & gas are hard to model and represent

Volume Graphics

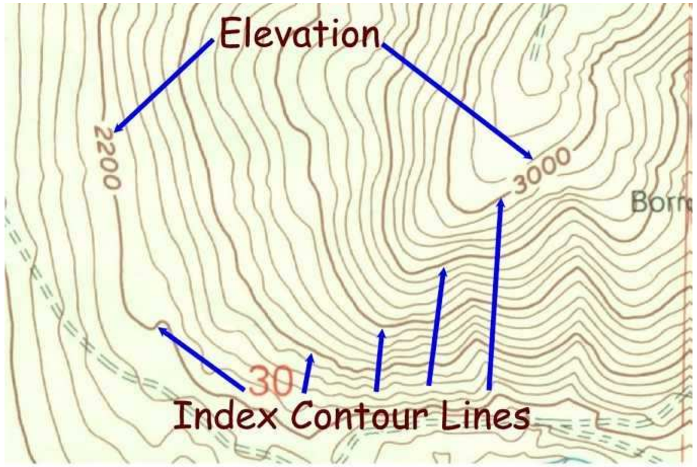
- for some data, difficult to create polygonal mesh
- voxels: discrete representation of 3D object
  - volume rendering: create 2D image from 3D object
- translate raw densities into colors and transparencies
  - different aspects of the dataset can be emphasized via changes in transfer functions

Volume Graphics

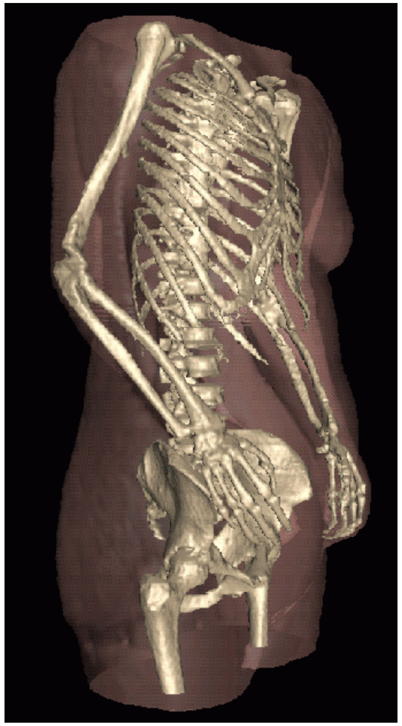
- pros
  - formidable technique for data exploration
- cons
  - rendering algorithm has high complexity!
  - special purpose hardware costly (~$3K-$10K)

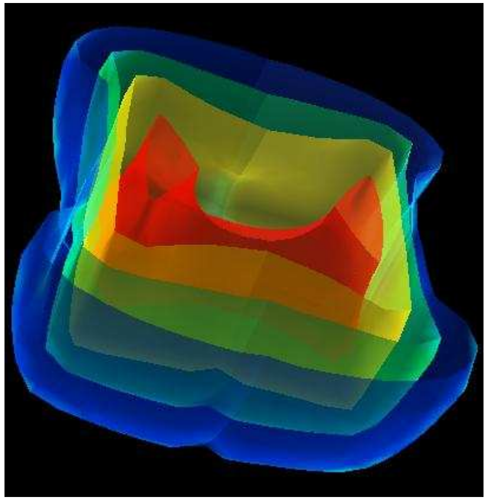
volumetric human head (CT scan)

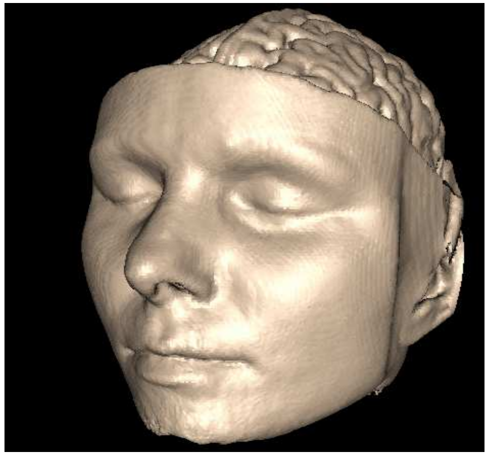
Isosurfaces



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

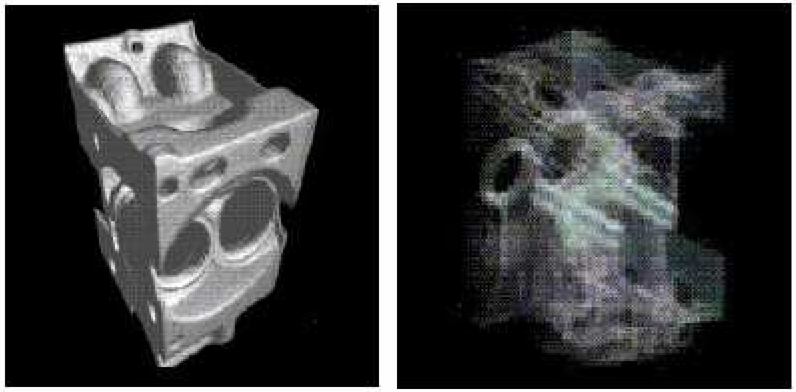




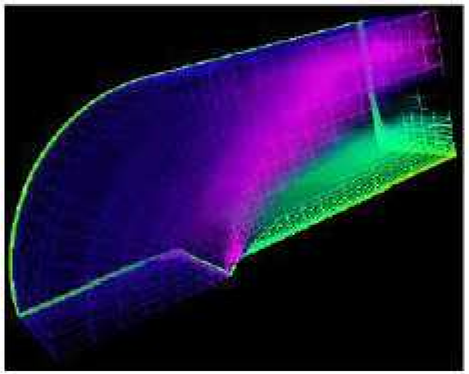


Volume Graphics: Examples

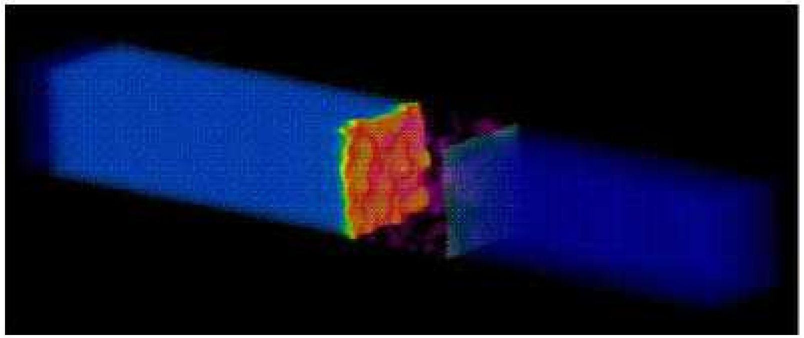
anatomical atlas from visible human (CT & MRI) datasets



industrial CT - structural failure, security applications



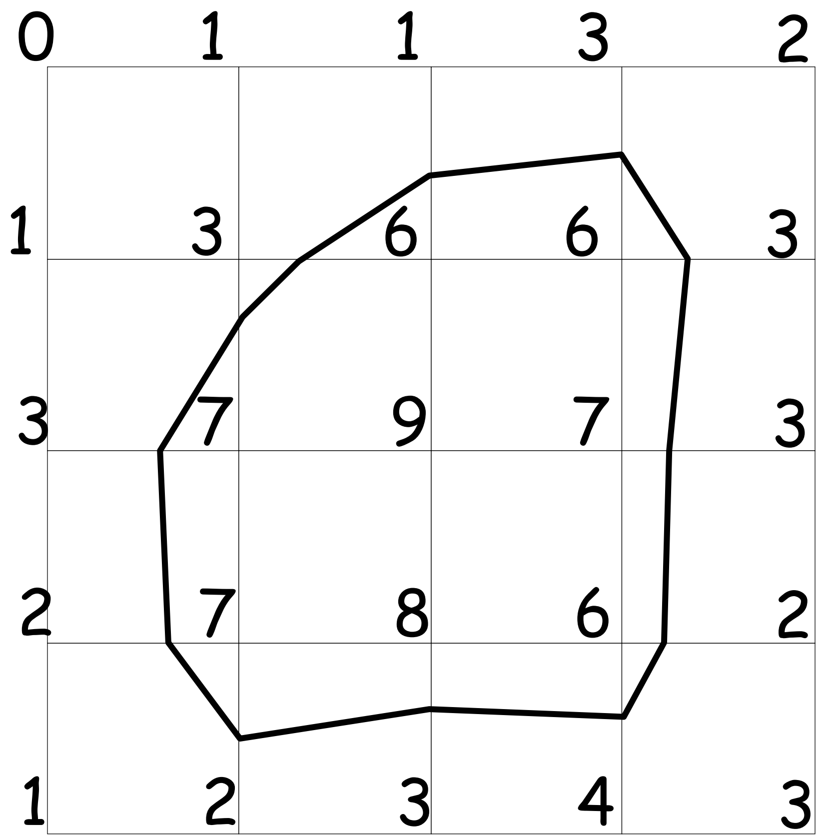
flow around airplane wing



shockwave visualization: simulation with Navier-Stokes PDEs

Isosurface Extraction

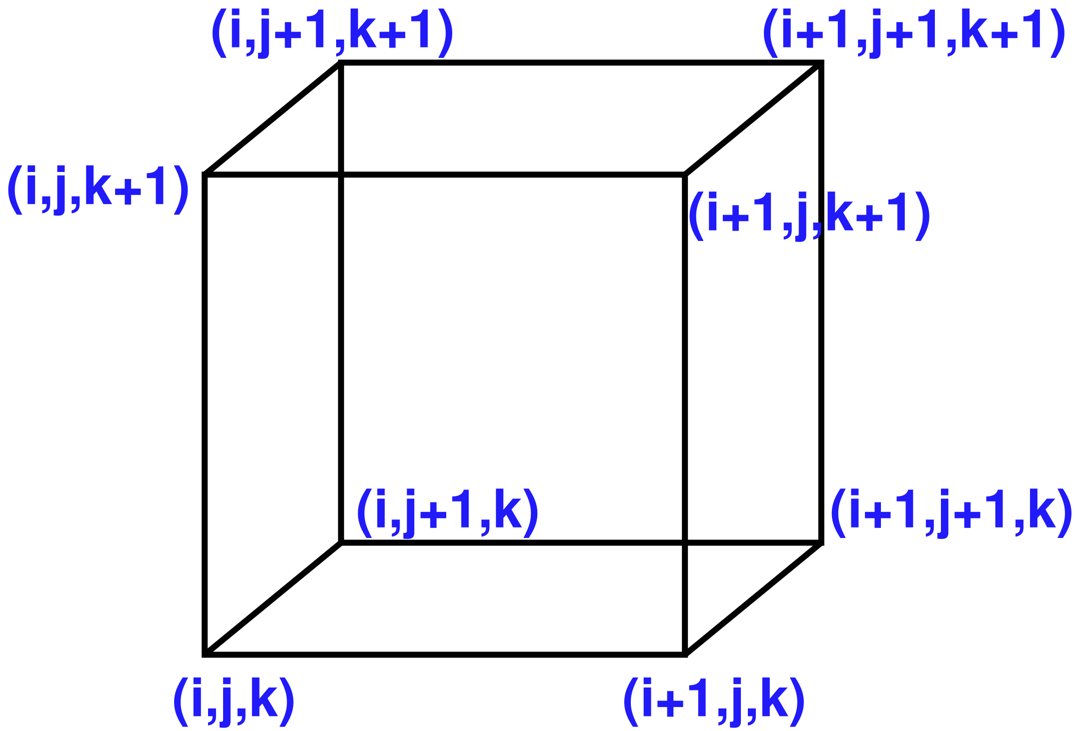
- array of discrete point samples at grid points
  - 3D array: voxels
- find contours
  - closed, continuous
  - determined by iso-value
- several methods
  - marching cubes is most common



Iso-value = 5

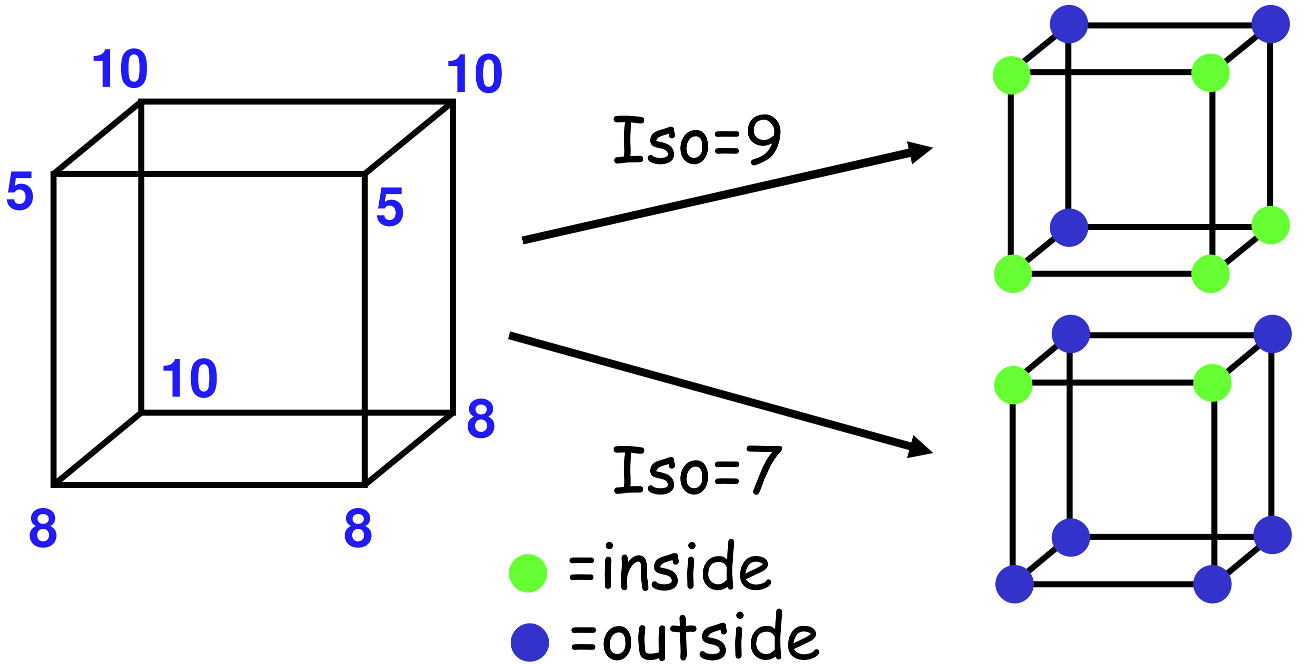
MC 1: Create a Cube

- consider a cube defined by eight data values



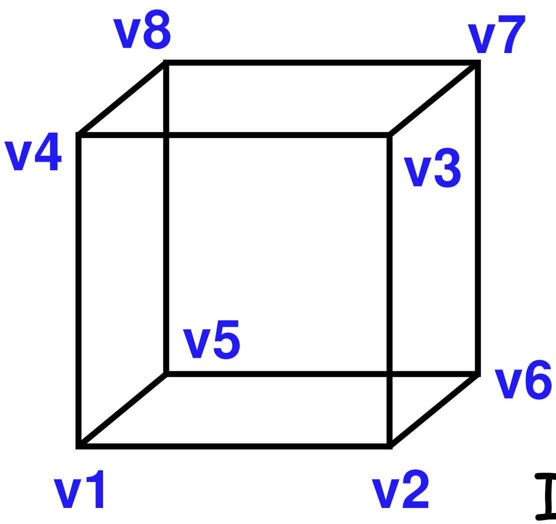
MC 2: Classify Each Voxel

- classify each voxel according to whether lies
  - outside the surface (value > iso-surface value)
  - inside the surface (value <= iso-surface value)

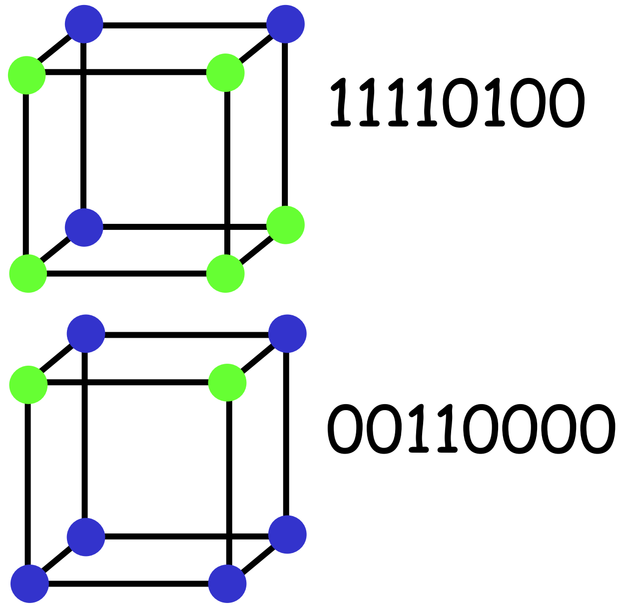


MC 3: Build An Index

- binary labeling of each voxel to create index



- inside =1
- outside=0

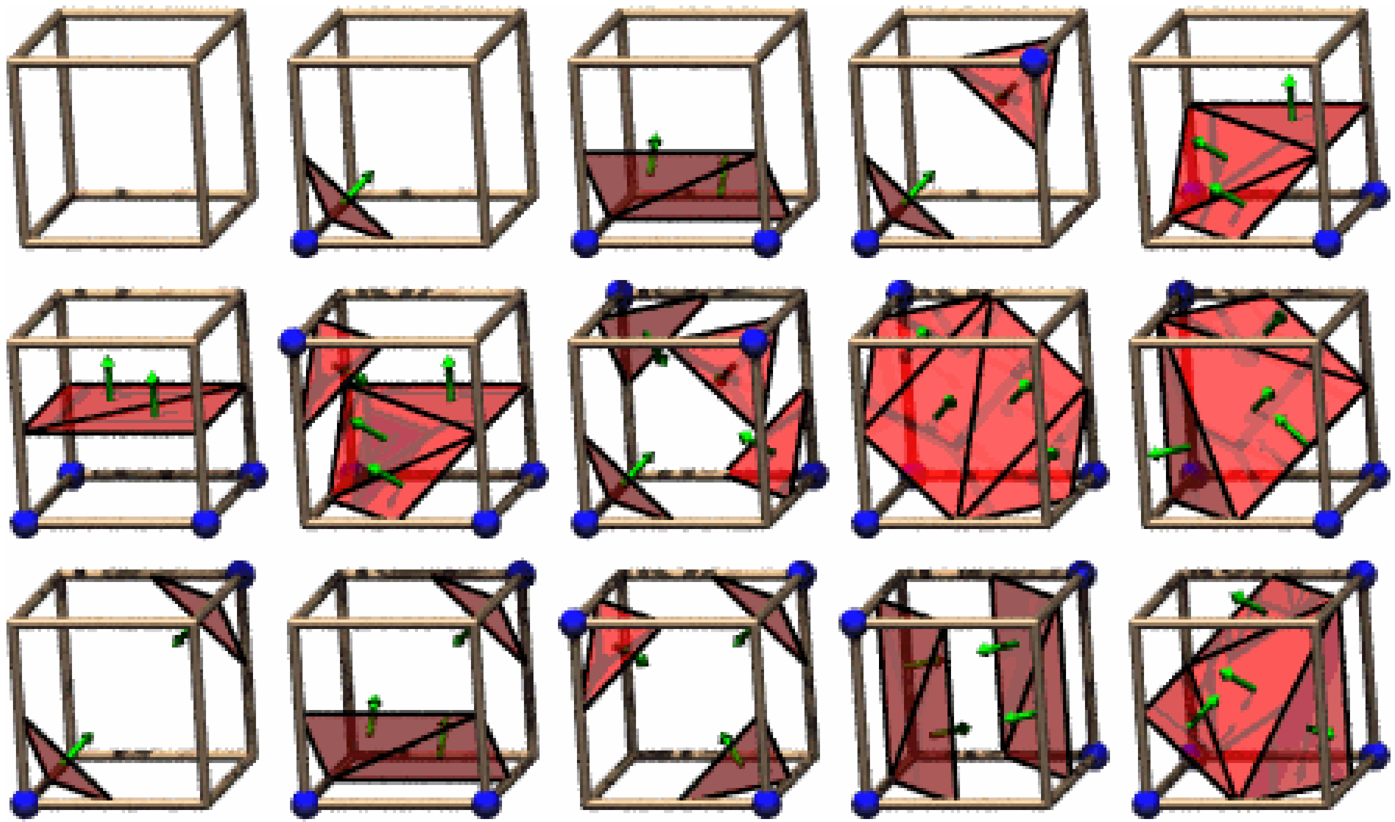


Index:

v1	v2	v3	v4	v5	v6	v7	v8

MC 4: Lookup Edge List

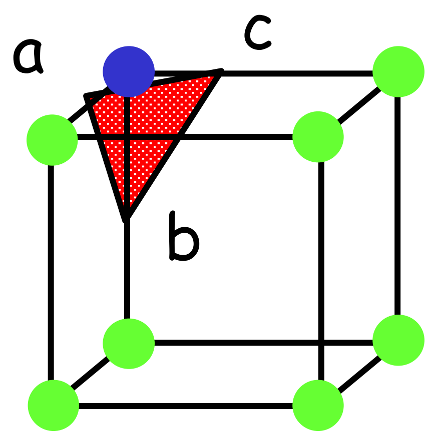
- use index to access array storing list of edges
  - all 256 cases can be derived from 15 base cases



The 15 Cube Combinations

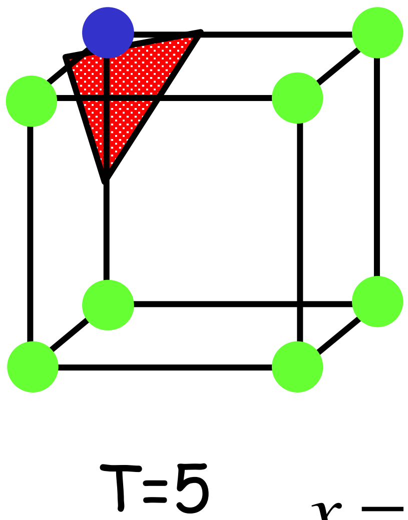
MC 4: Example

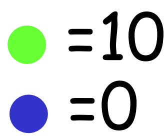
- index = 00000001
- triangle 1 = a, b, c

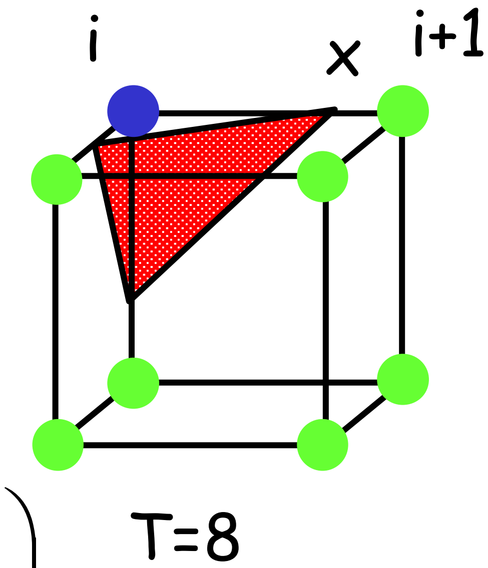


MC 5: Interpolate Triangle Vertex

- for each triangle edge
  - find vertex location along edge using linear interpolation of voxel values







$$x = i + \left(\frac{T - v[i]}{v[i+1] - v[i]} \right)$$

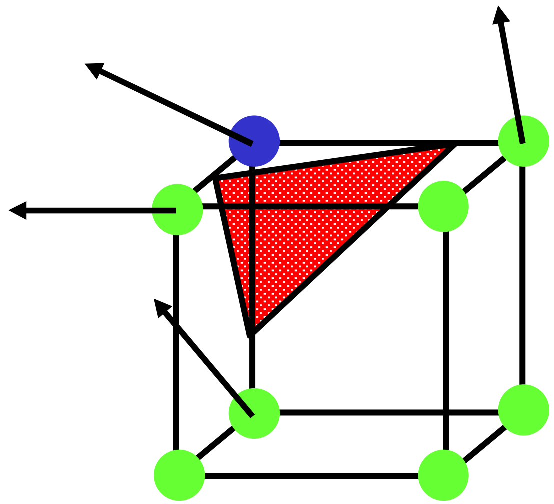
MC 6: Compute Normals

- calculate the normal at each cube vertex
  - use linear interpolation to compute the polygon vertex normal

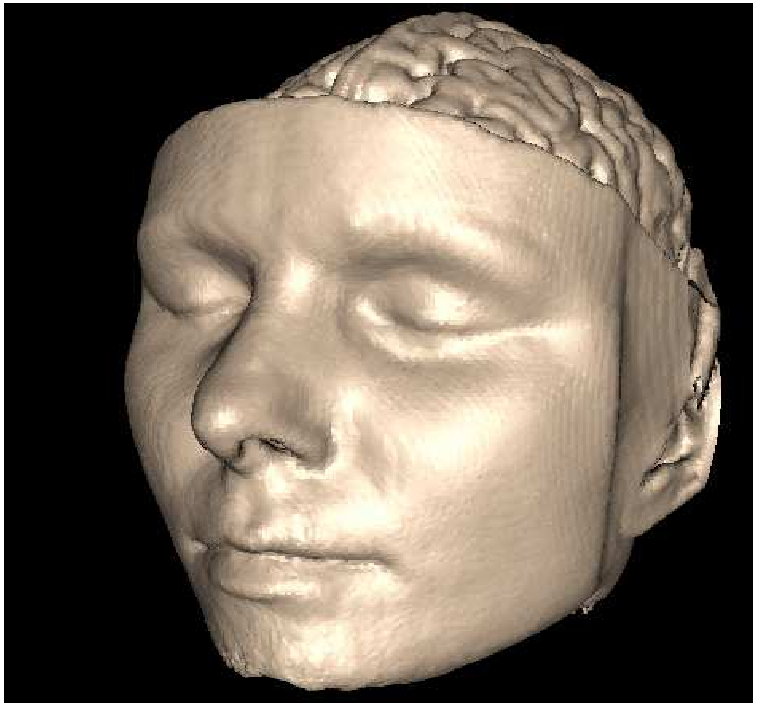
$$G_x = v_{i+1,j,k} - v_{i-1,j,k}$$

$$G_y = v_{i,j+1,k} - v_{i,j-1,k}$$

$$G_z = v_{i,j,k+1} - v_{i,j,k-1}$$

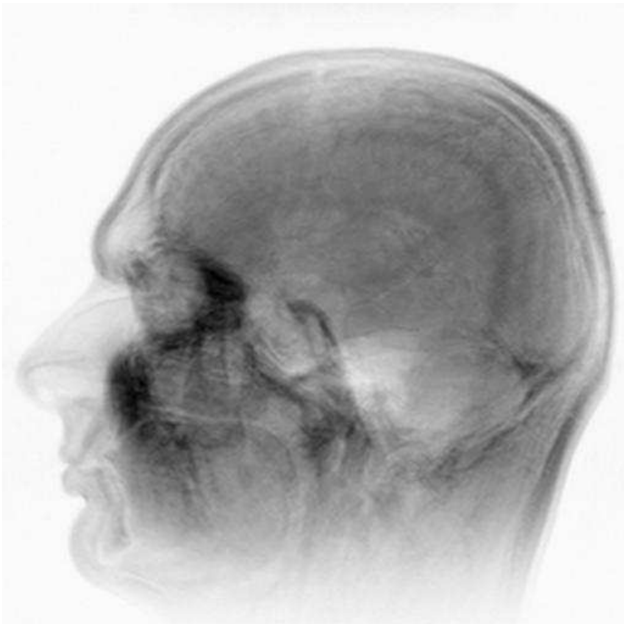


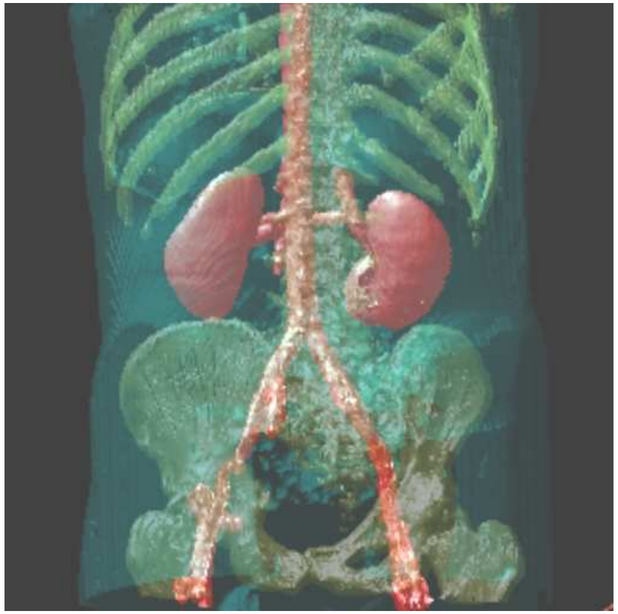
MC 7: Render!



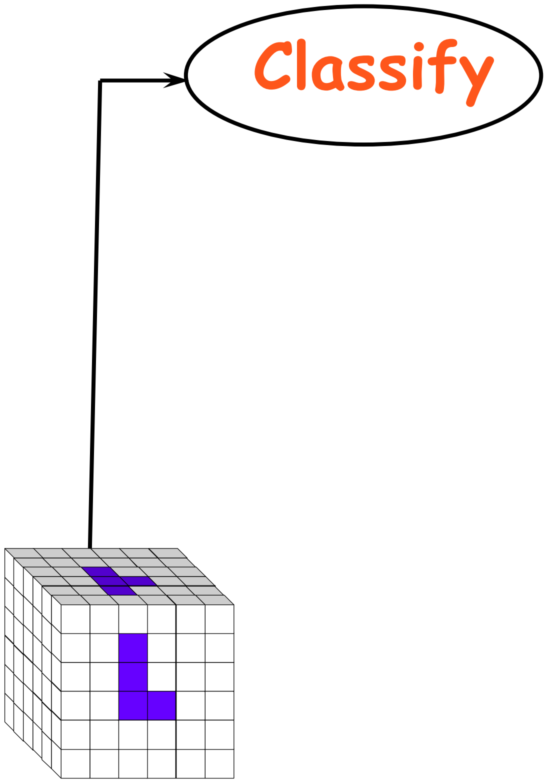
Direct Volume Rendering

- do not compute surface



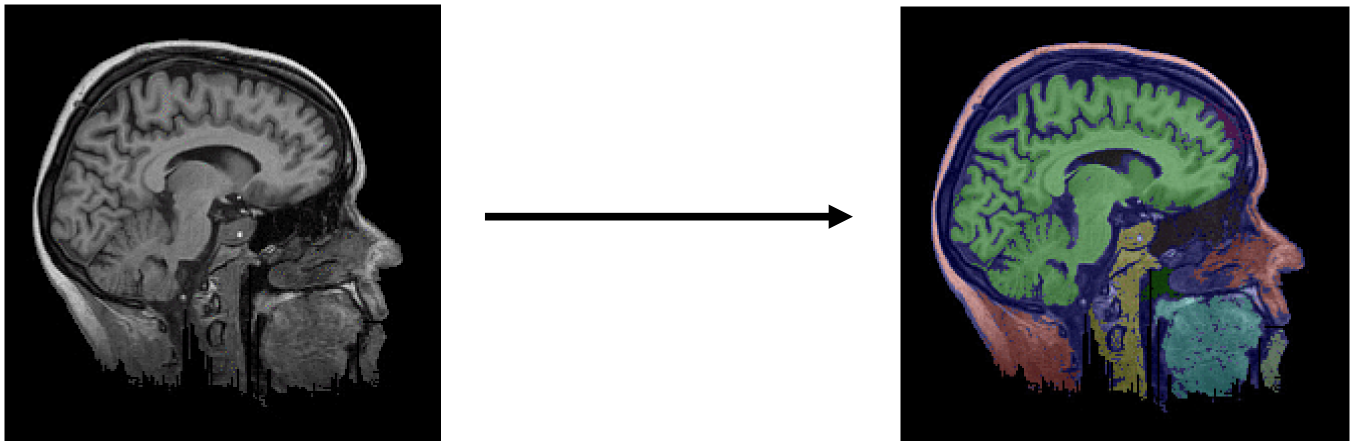


Rendering Pipeline



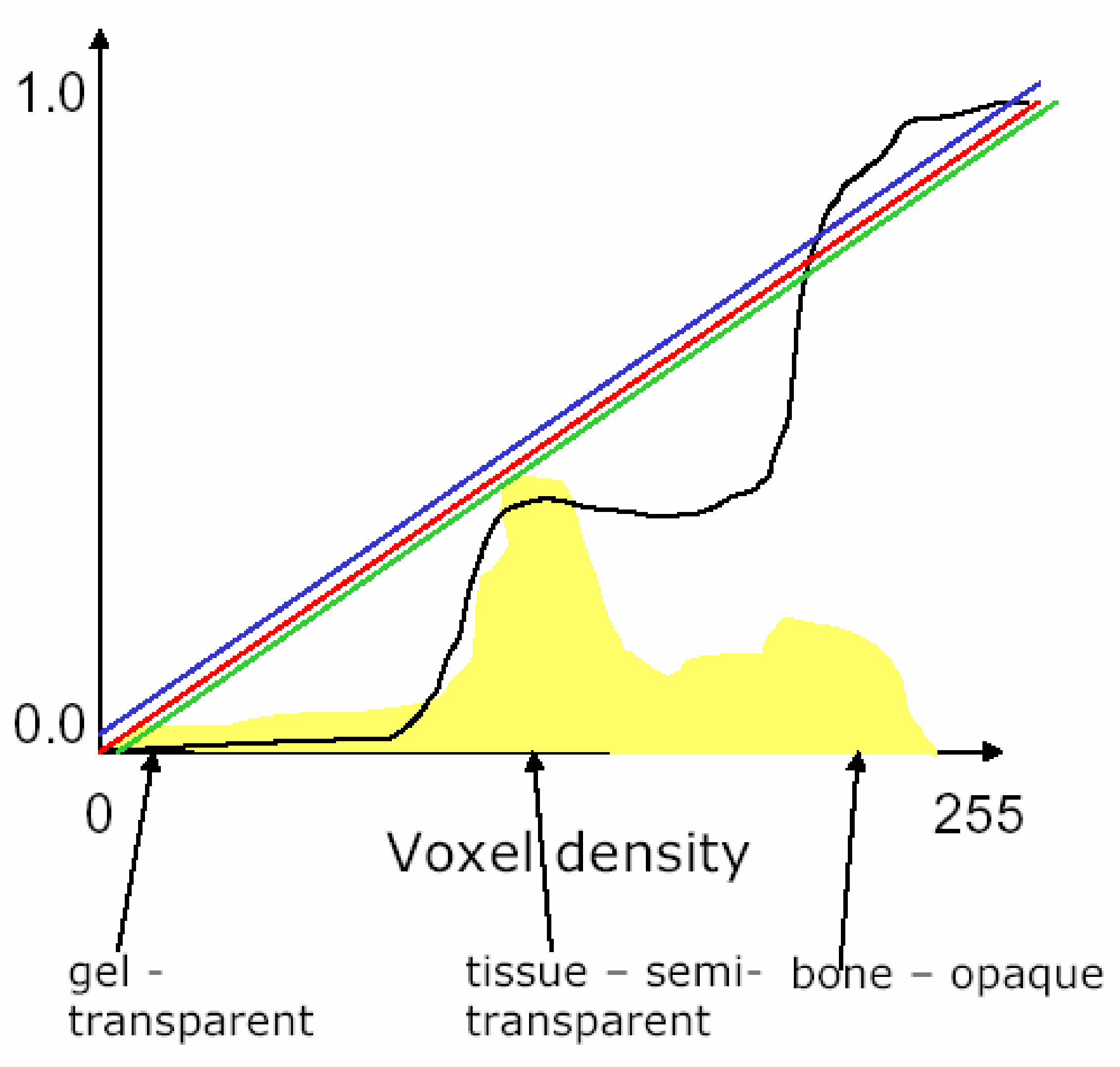
Classification

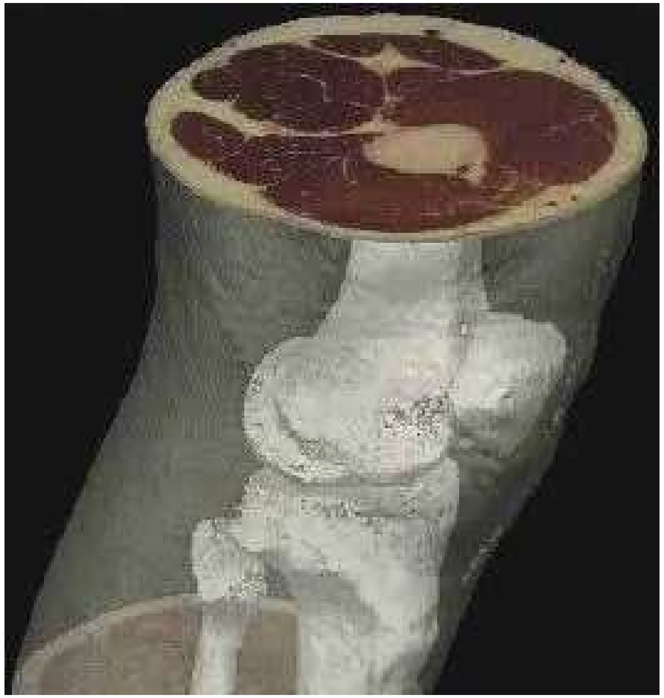
- data set has application-specific values
  - temperature, velocity, proton density, etc.
- assign these to color/opacity values to make sense of data
- achieved through transfer functions



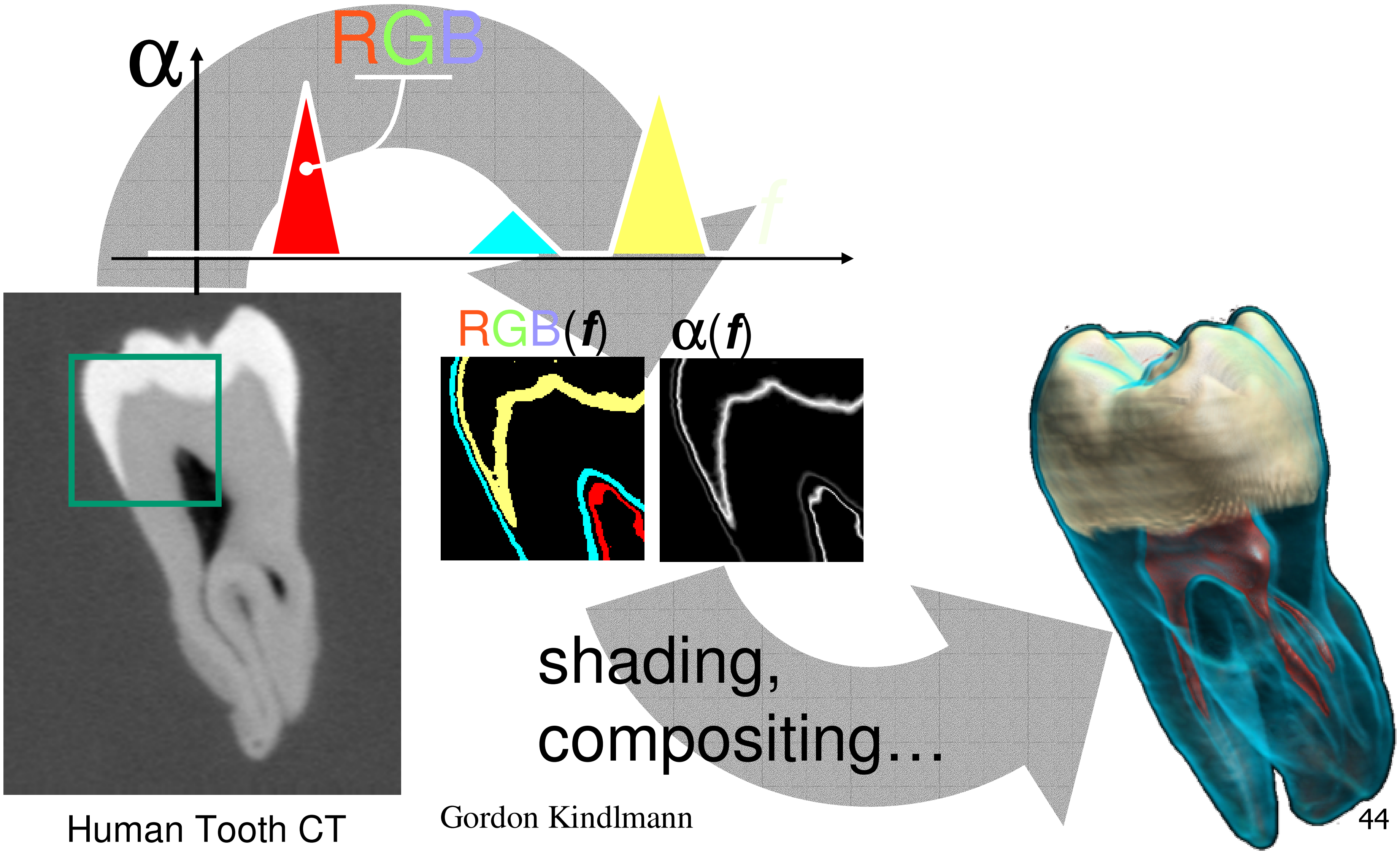
Transfer Functions

- map data value to color and opacity





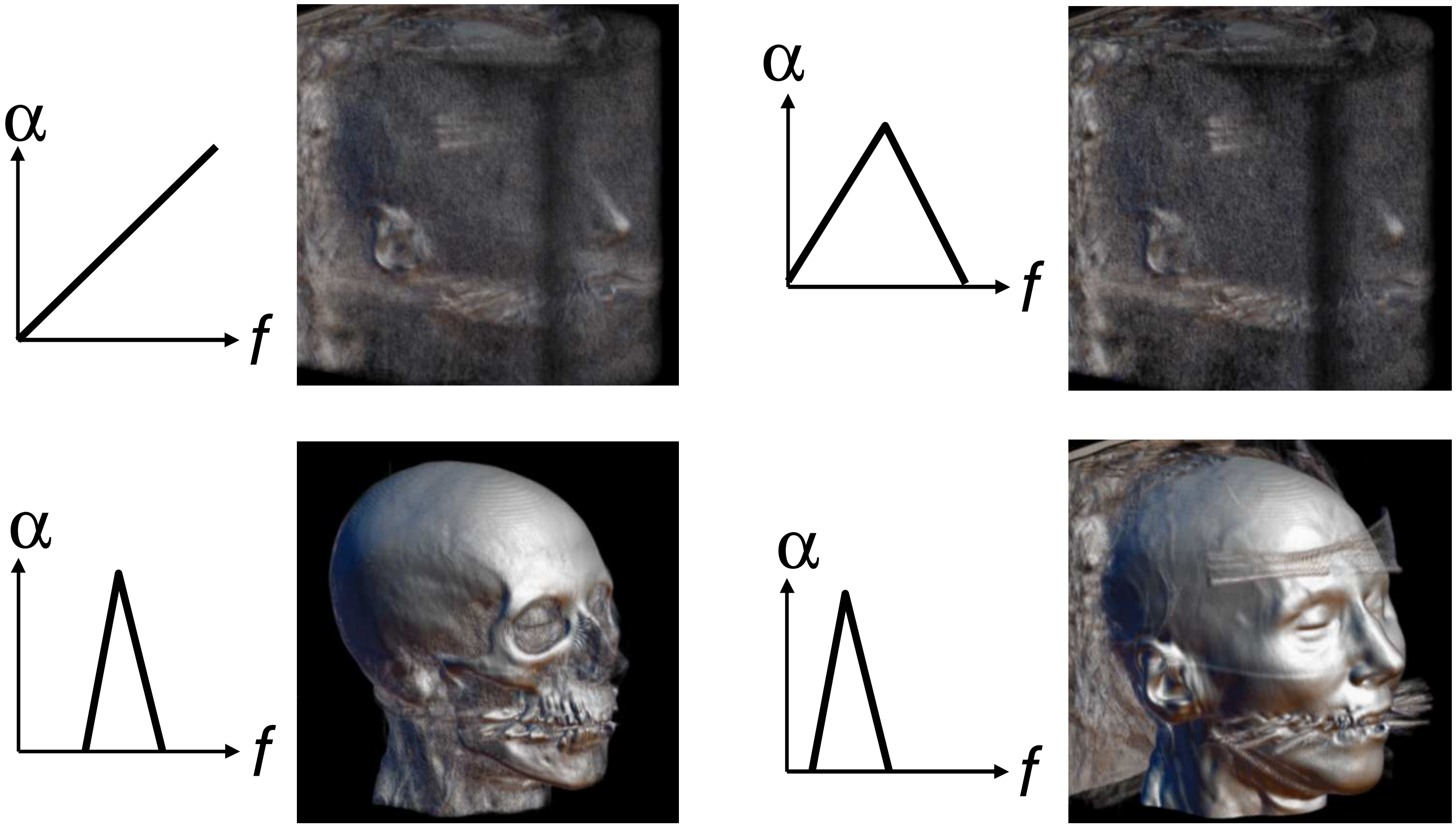
Transfer Functions



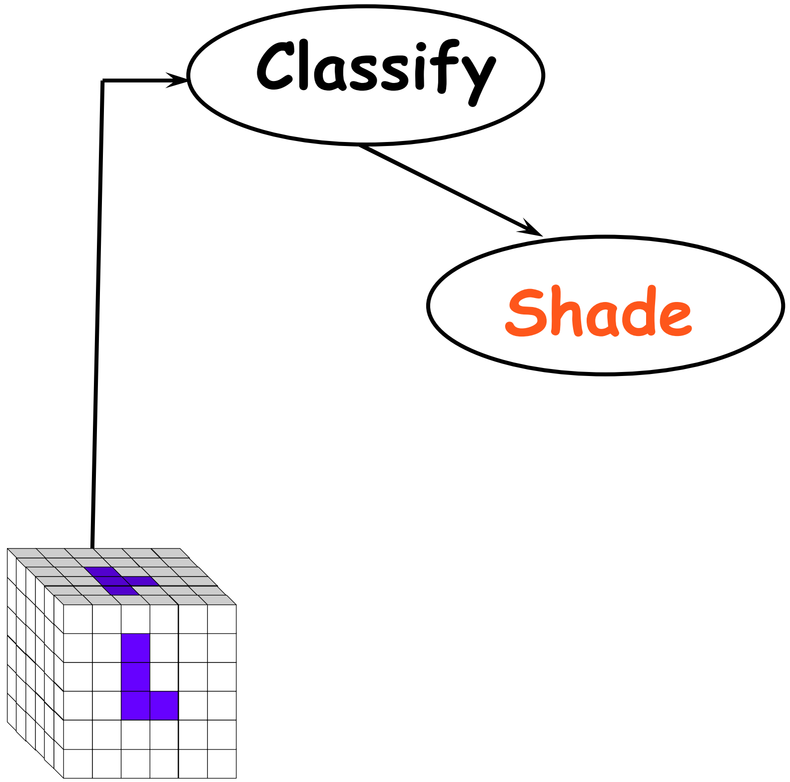
Human Tooth CT

Setting Transfer Functions

- can be difficult, unintuitive, and slow

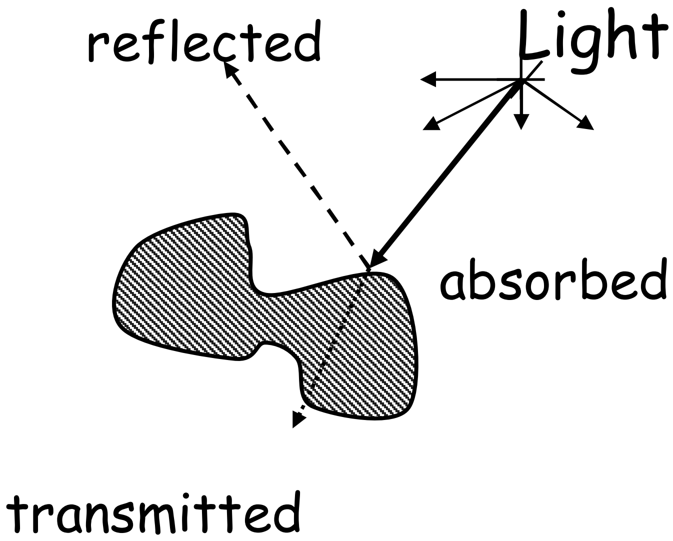


Rendering Pipeline

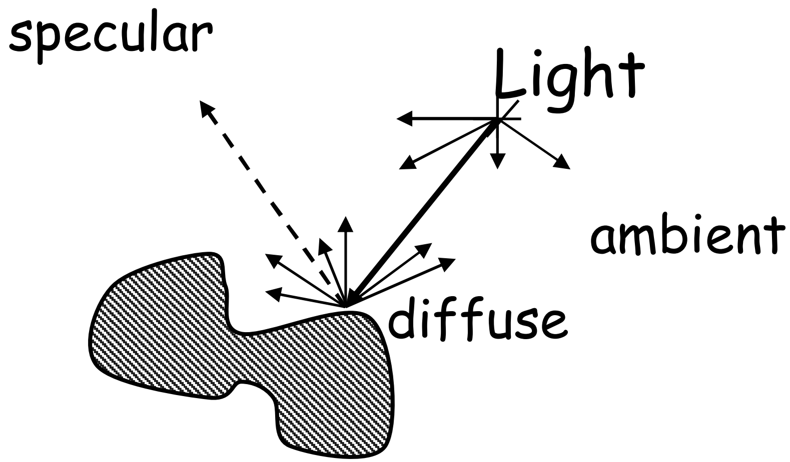


Light Effects

- usually only consider reflected part



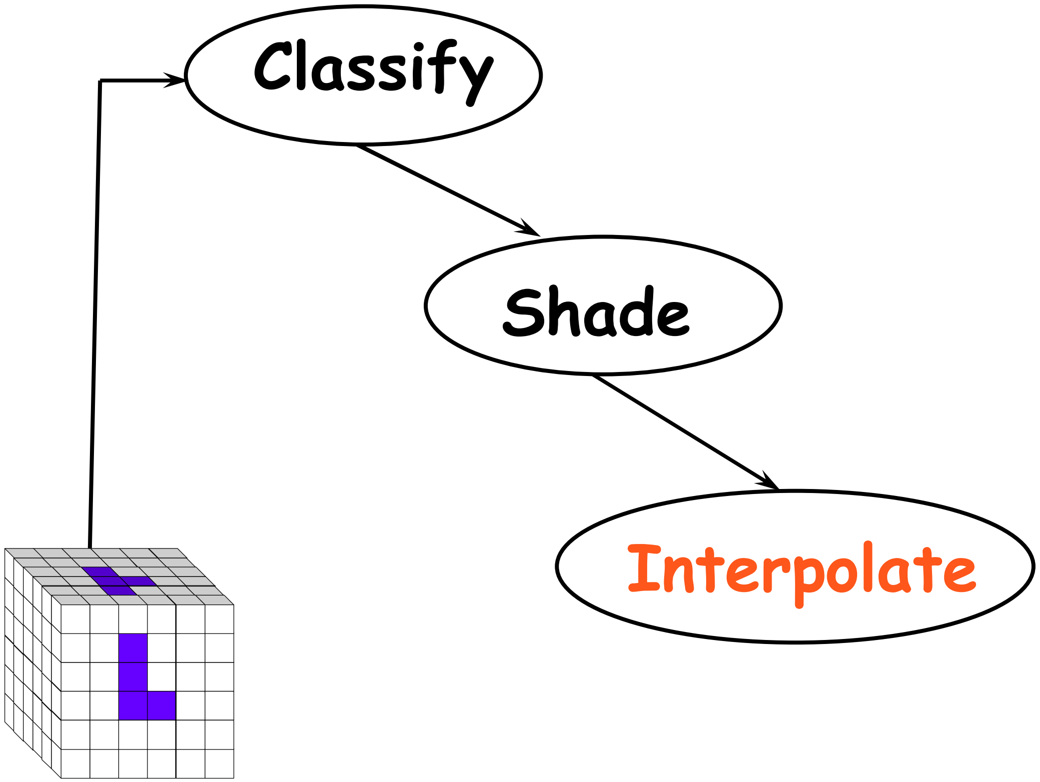
Light=refl.+absorbed+trans.



Light=ambient+diffuse+specular

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

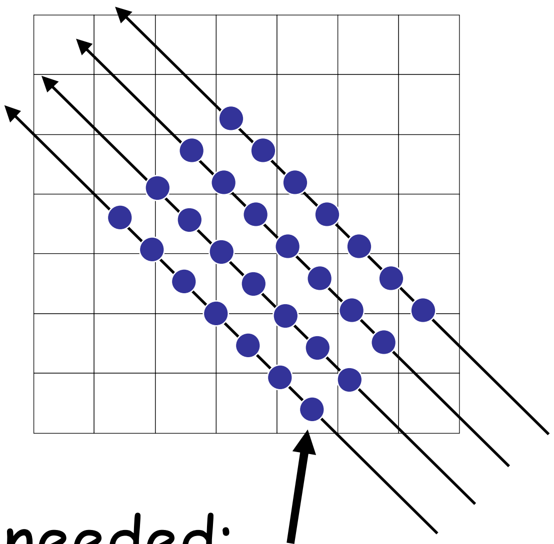
Rendering Pipeline



Interpolation

2D

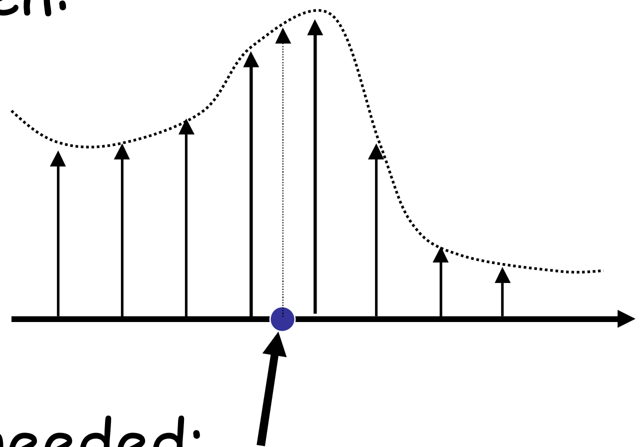
- given:



- needed:

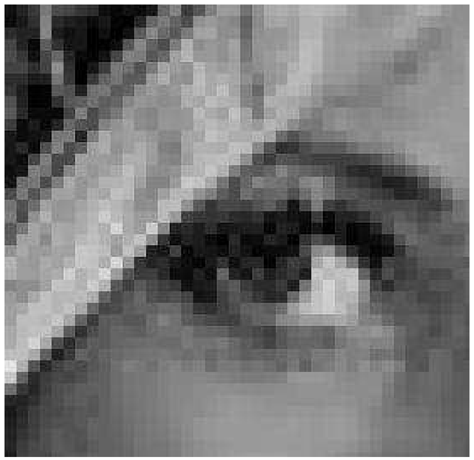
1D

- given:



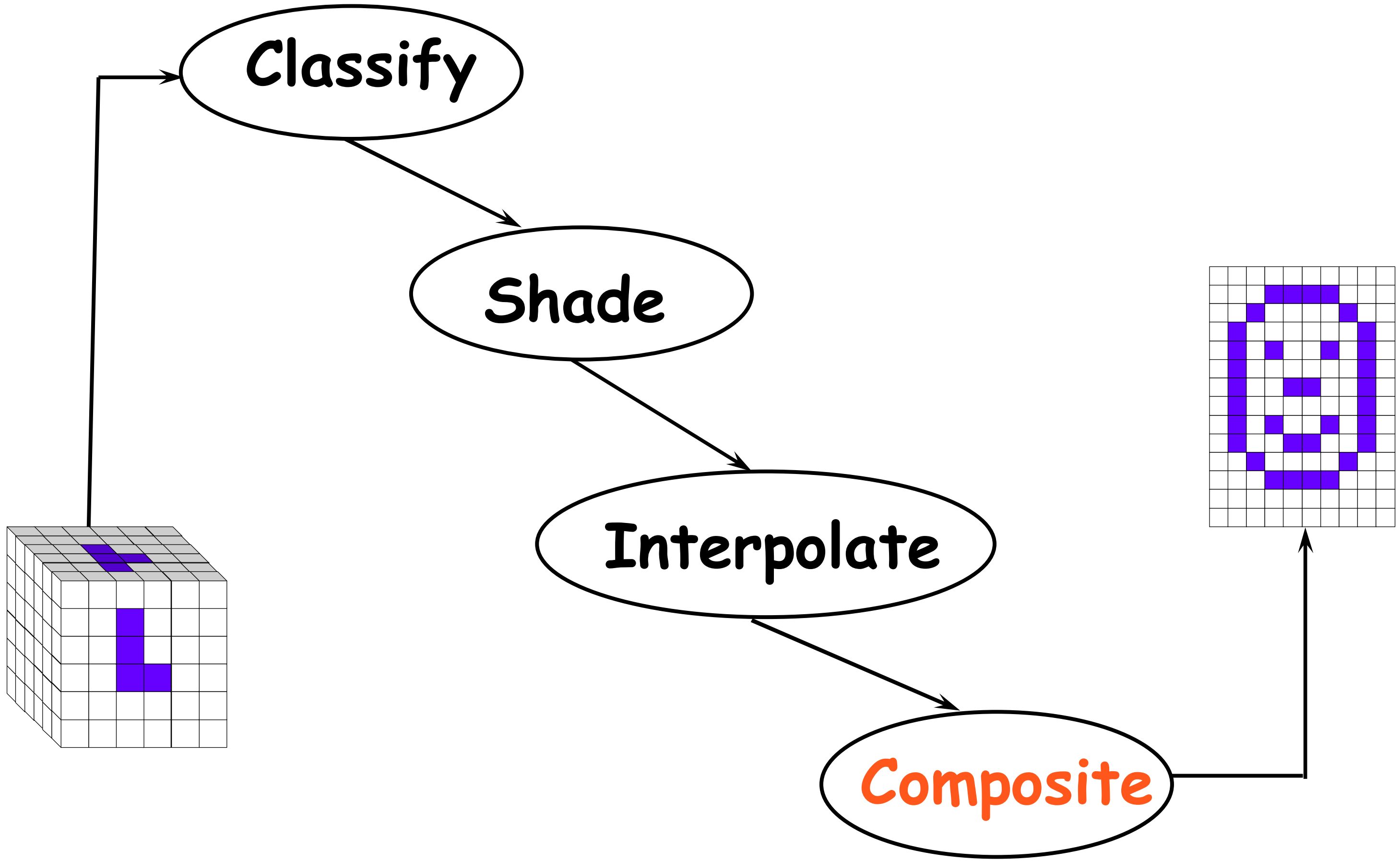
- needed:

nearest neighbor



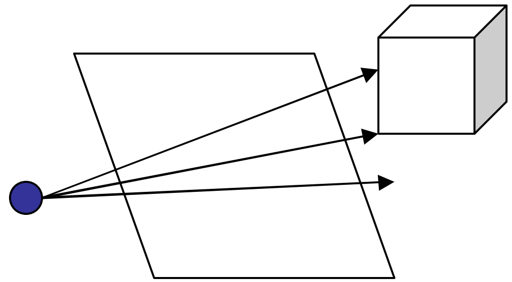
linear

Rendering Pipeline

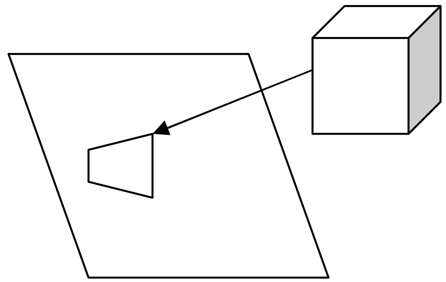


Volume Rendering Algorithms

- ray casting
  - image order, forward viewing

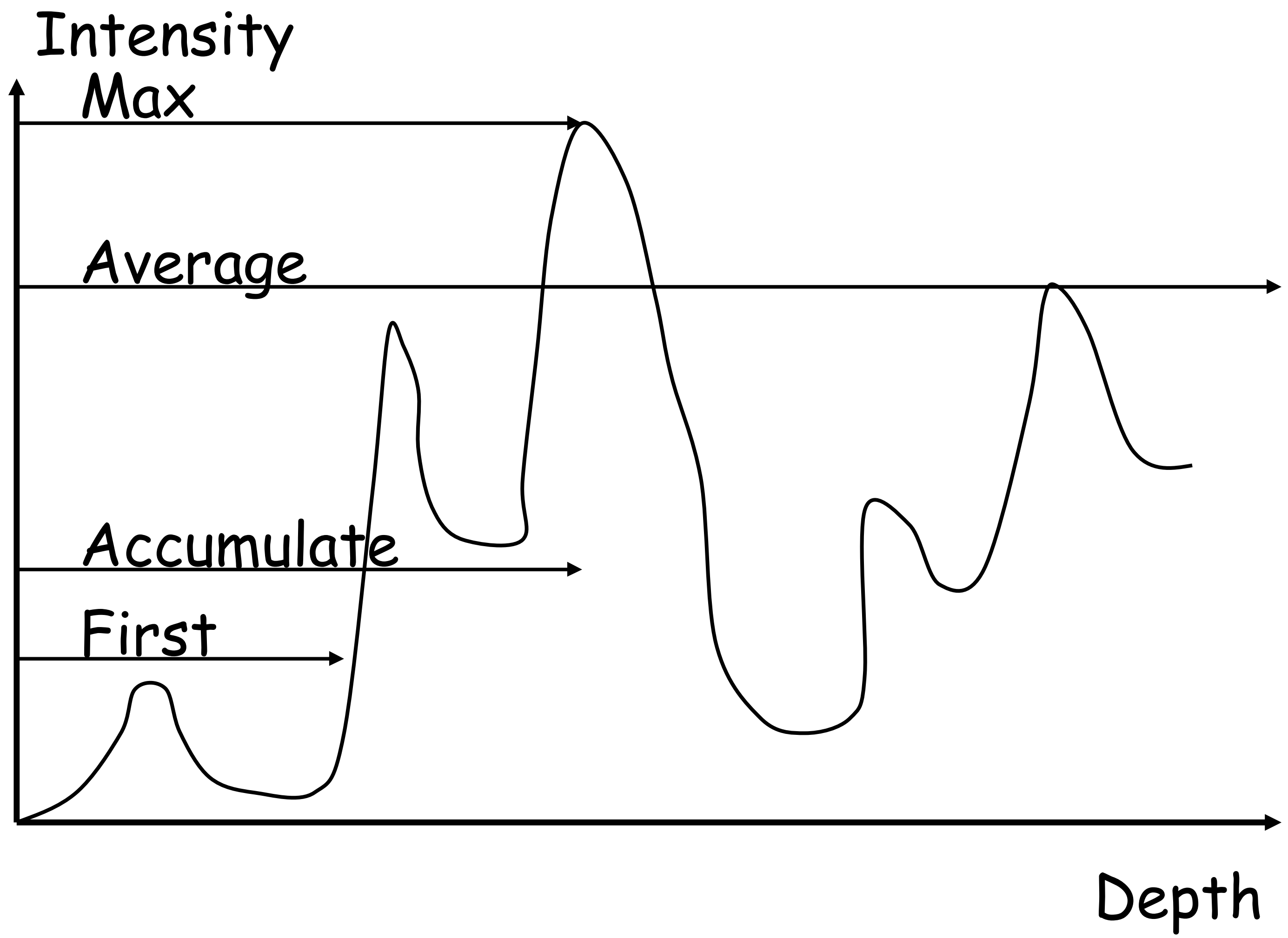


- splatting
  - object order, backward viewing



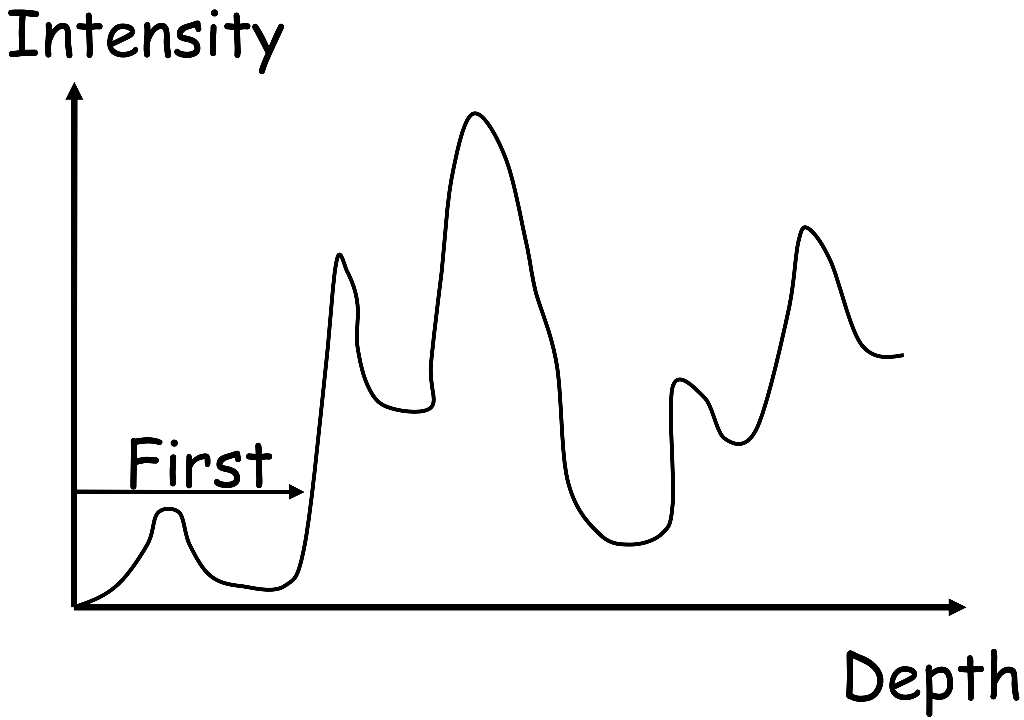
- texture mapping
  - object order
  - back-to-front compositing

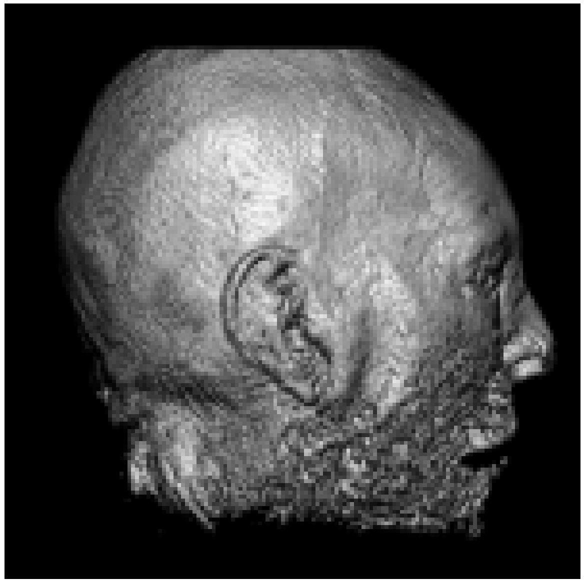
Ray Traversal Schemes



Ray Traversal - First

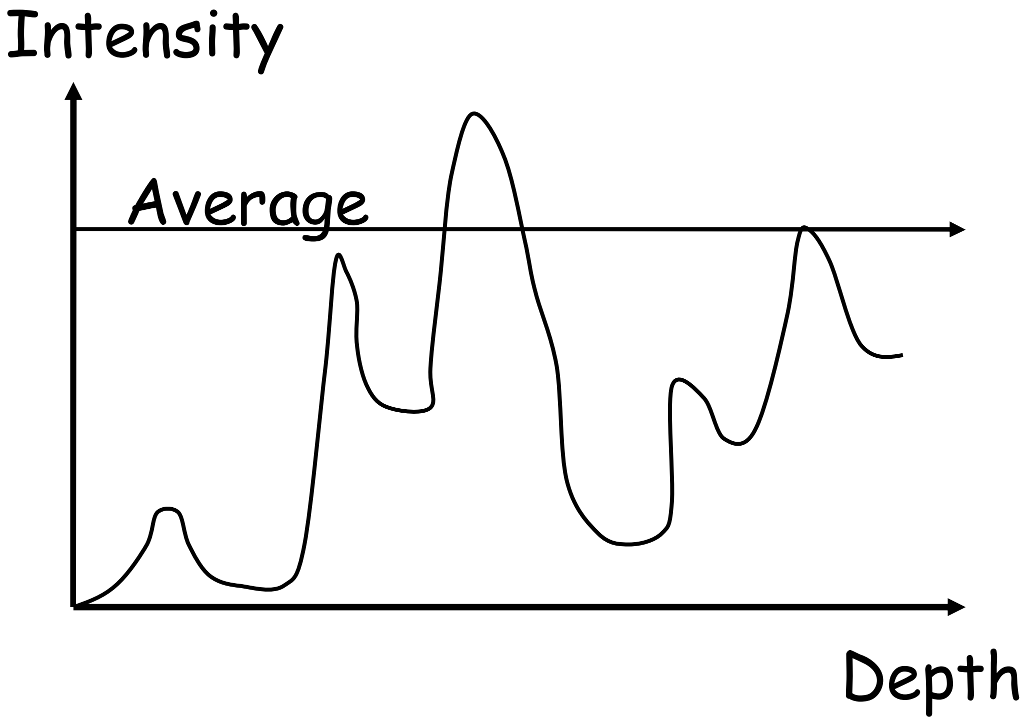
- first: extracts iso-surfaces (again!)

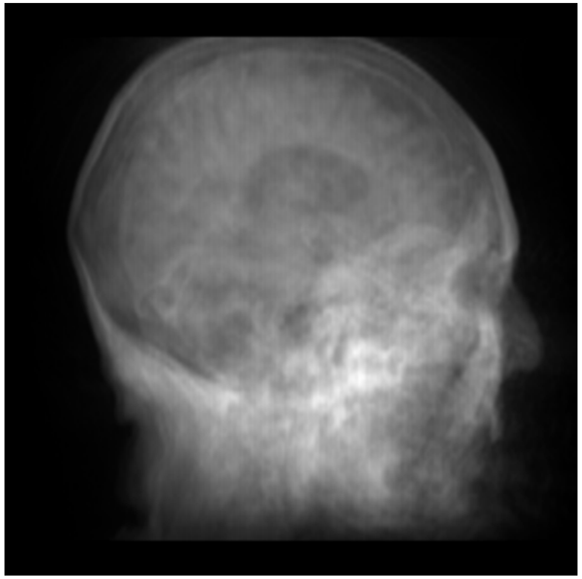




Ray Traversal - Average

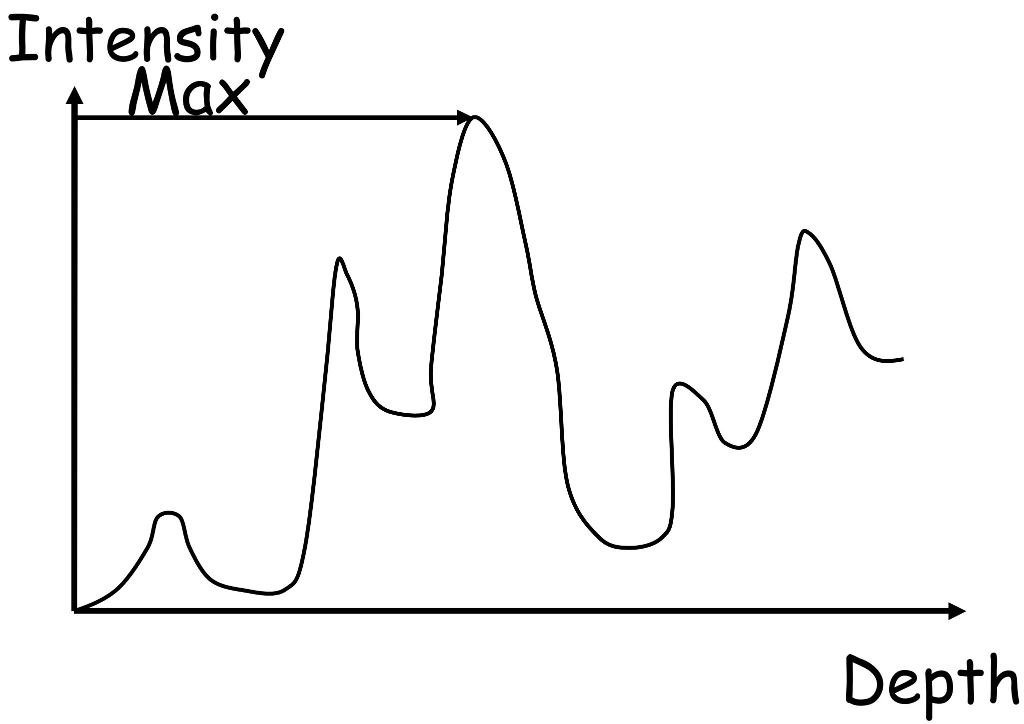
- average: looks like X-ray

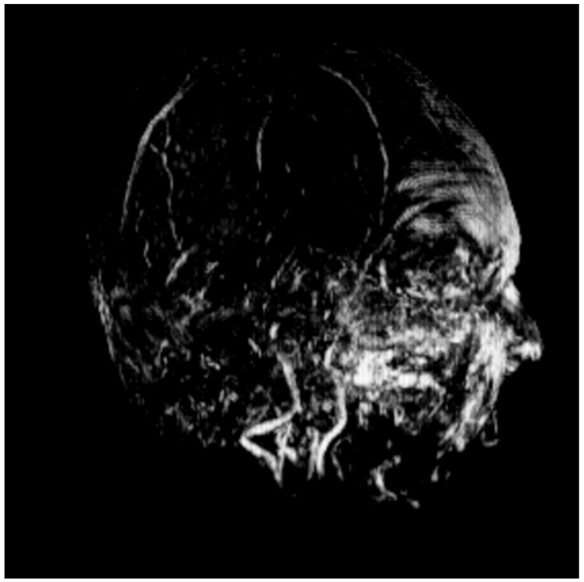




Ray Traversal - MIP

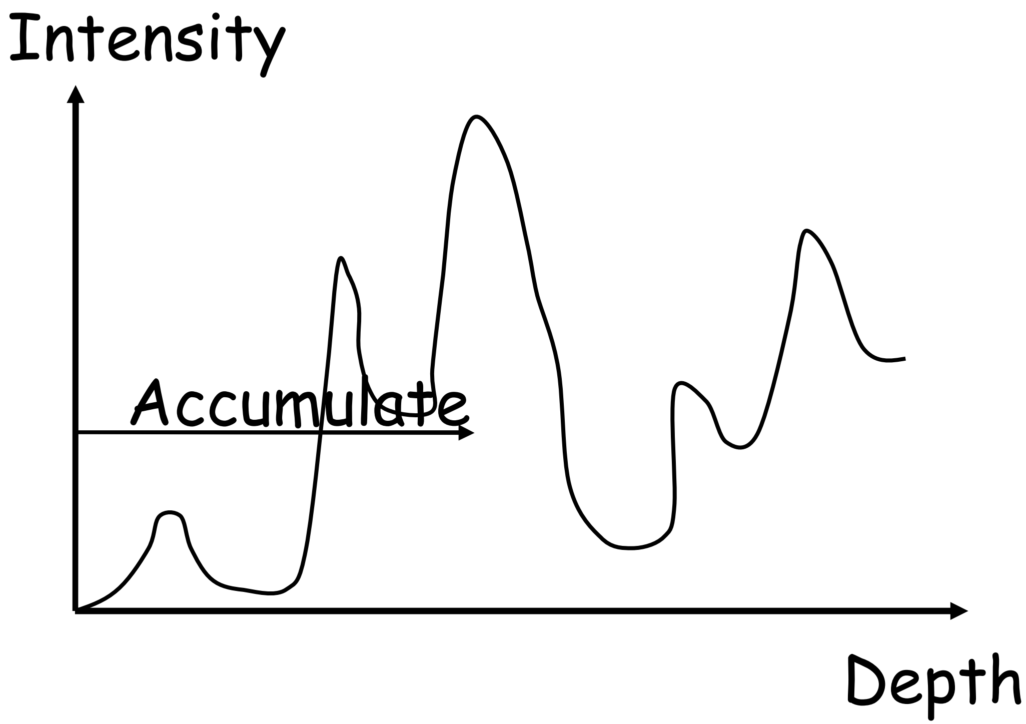
- max: Maximum Intensity Projection
  - used for Magnetic Resonance Angiogram

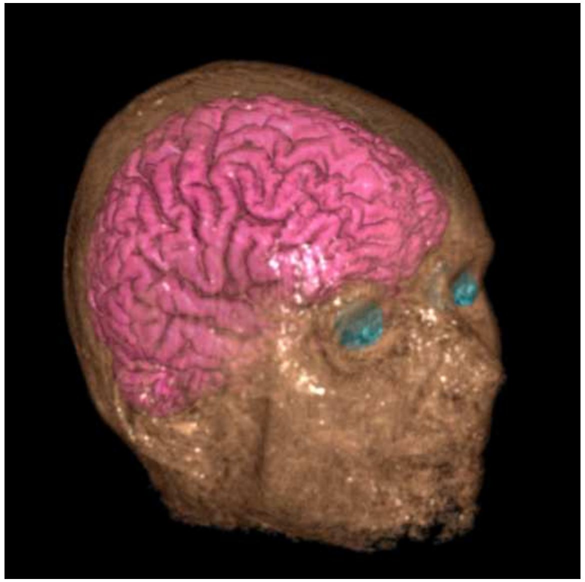




Ray Traversal - Accumulate

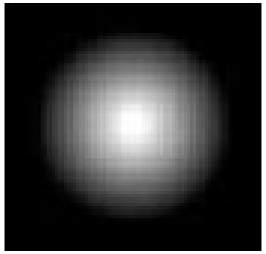
- accumulate: make transparent layers visible



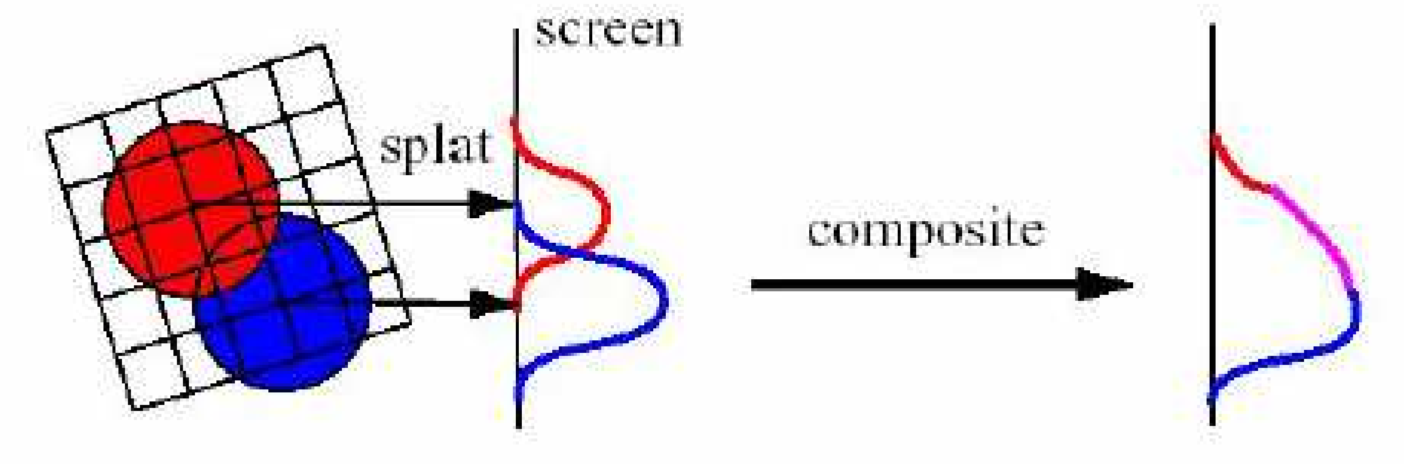


Splatting

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

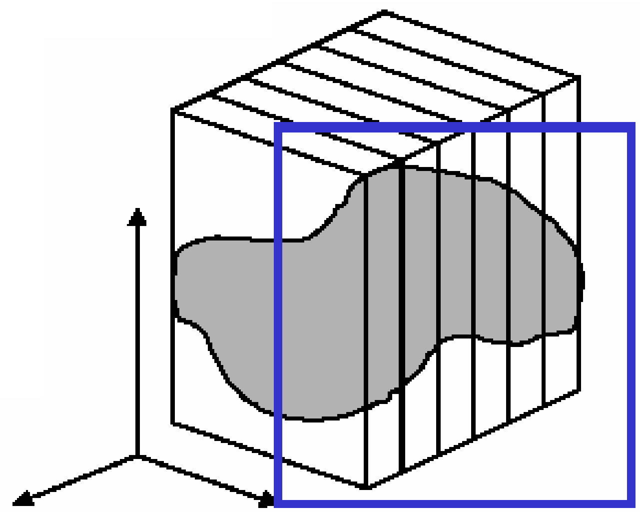


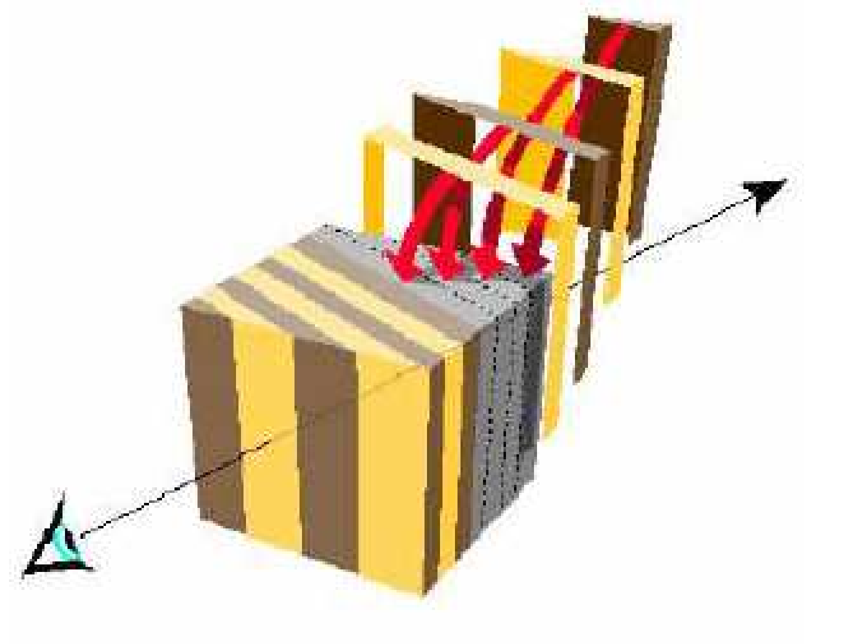
- fuzzy balls projected on screen, leaving footprint called splat
  - composite front to back, in object order



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





Information Visualization

interactive visual representation of abstract data

Interactivity

static images

- 10,000 years
- art, graphic design

moving images

- 100 years
- cinematography

interactive graphics

- 20 years
- computer graphics, human–computer interaction

Information Visualization

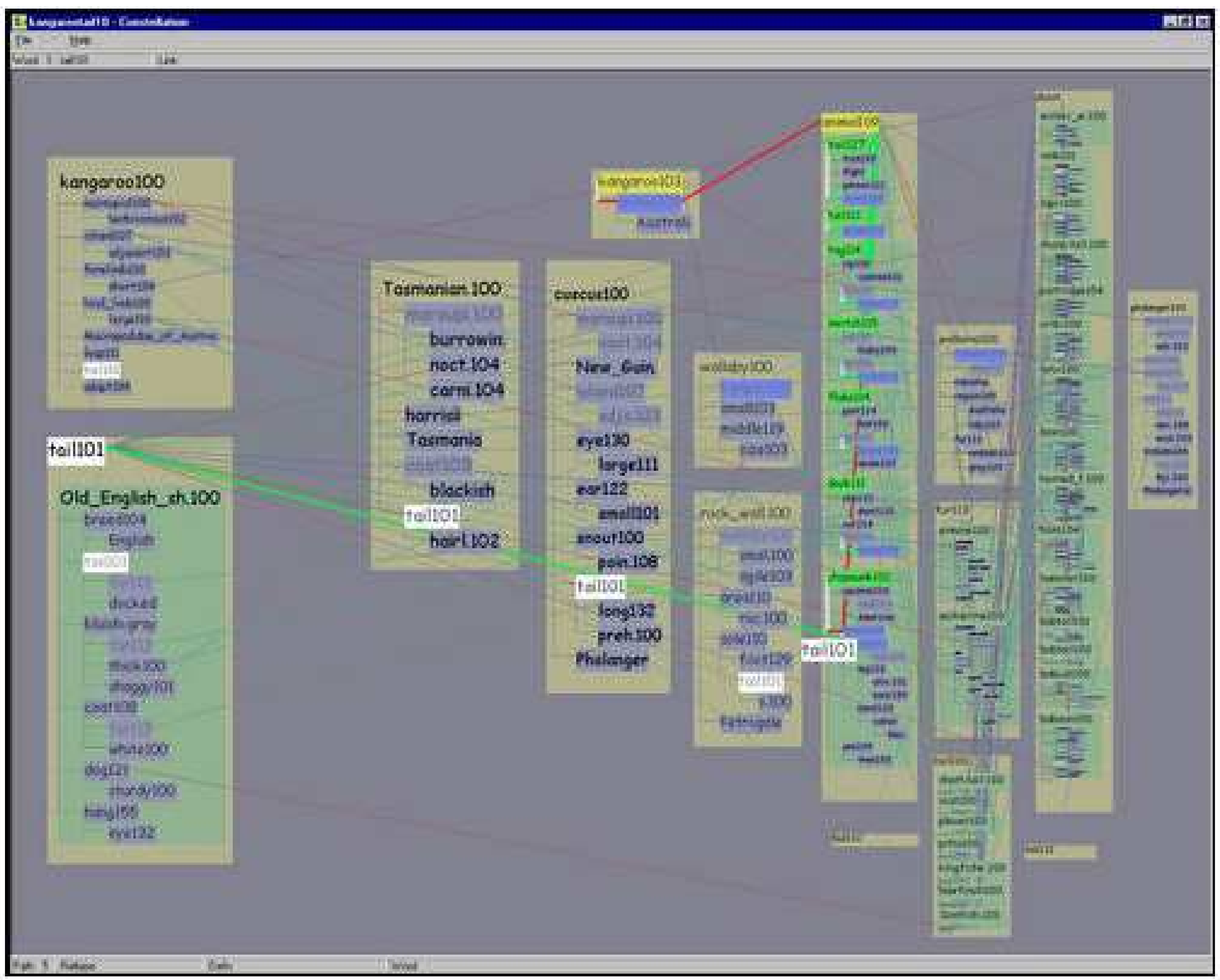
interactive visual representation of abstract data

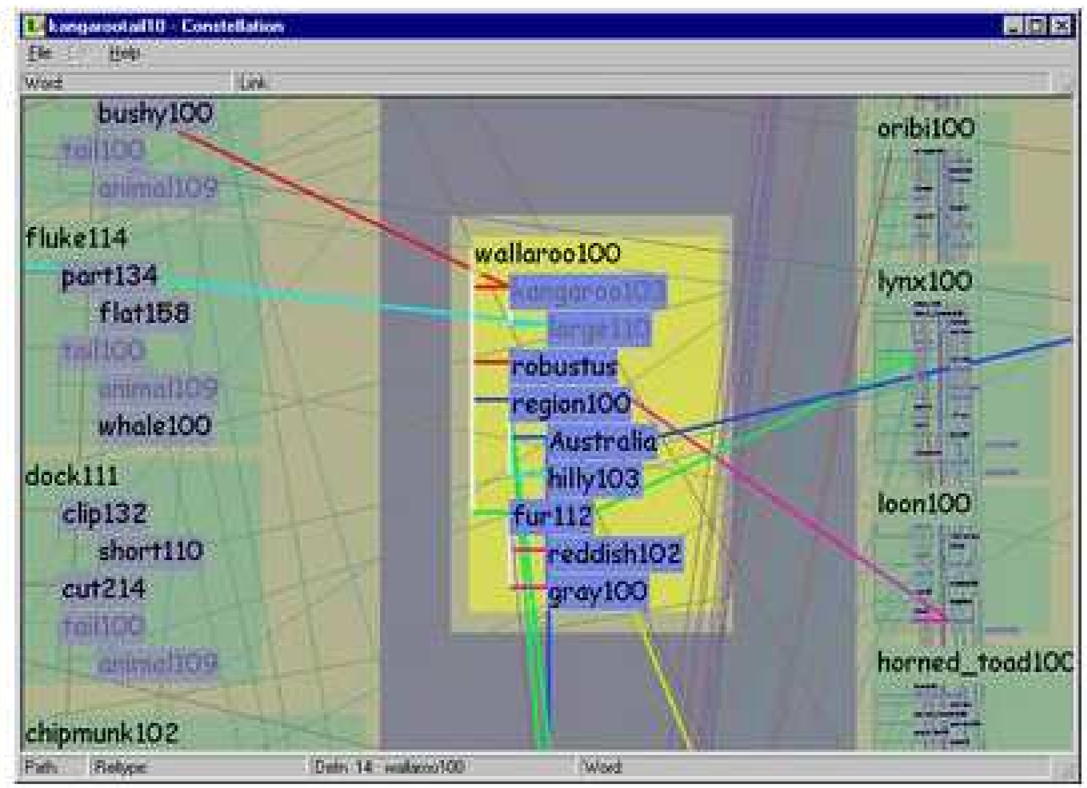
- help human perform some task more effectively

Task-Oriented Design: Constellation

custom design for checking semantic networks

- reading definition subgraph labels
- following paths through network

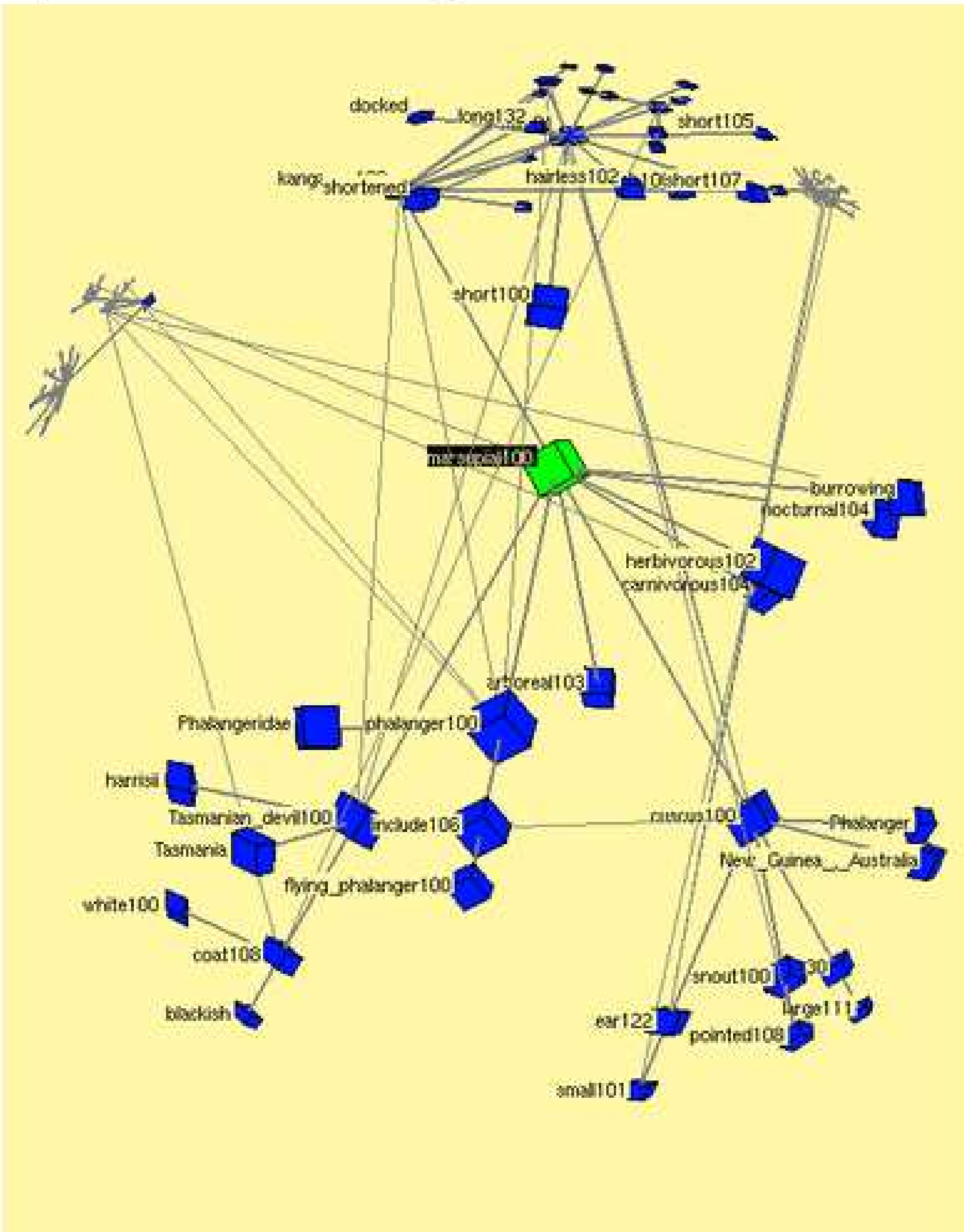


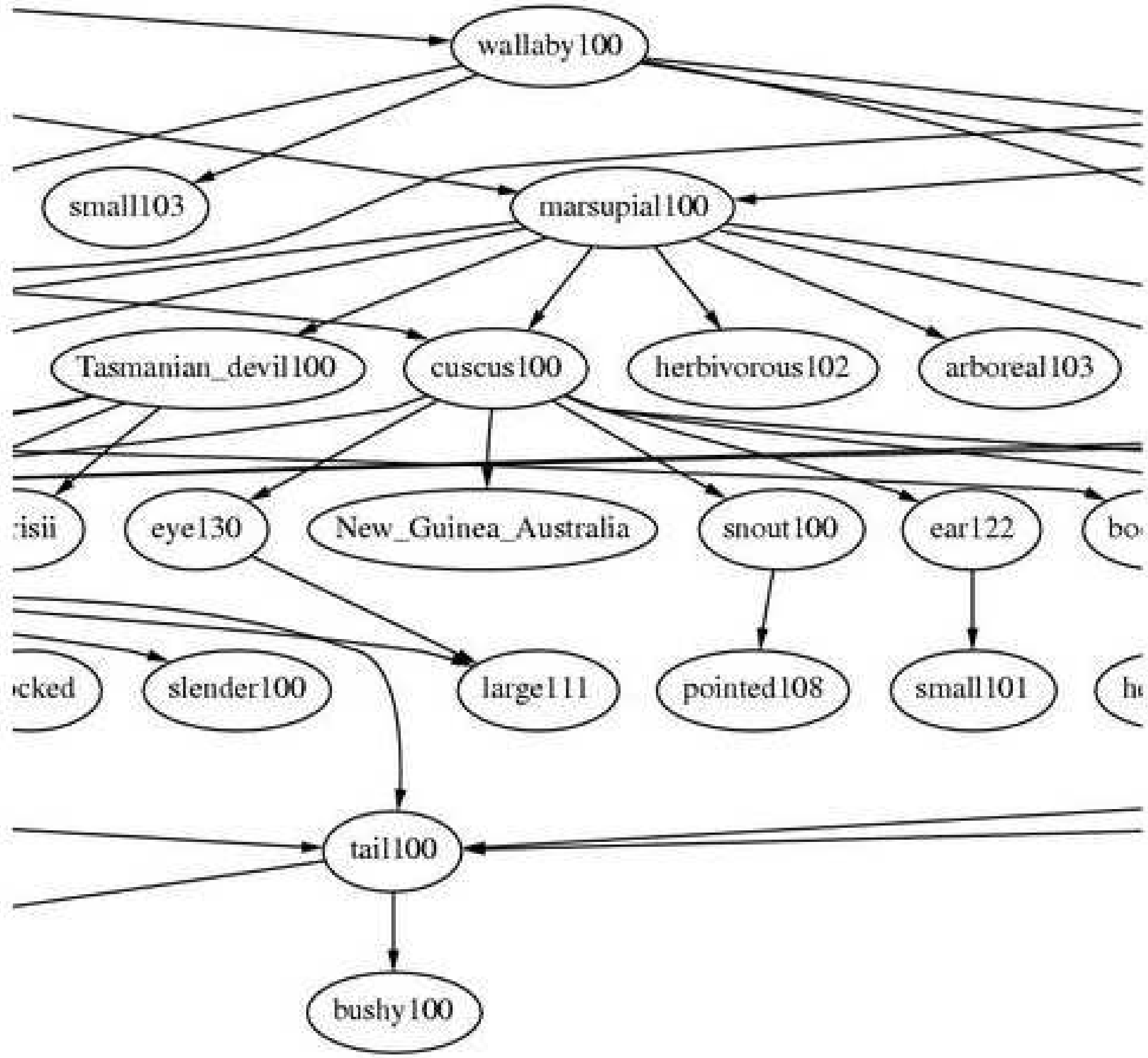


[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#layoutefffig]

Task-Oriented Design

previous general methods





[graphics.stanford.edu/papers/munzner_thesis/html/node10.html#dotconstfig]

Information Visualization

interactive visual representation of abstract data

- help human perform some task more effectively

bridging many fields

- graphics: interacting in realtime
- cognitive psych: finding appropriate representation
- HCI: using task to guide design and evaluation

external representation

- reduces load on working memory
- offload cognition

- familiar example: multiplication/division

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \underline{\times\ 48} \end{array}$$

External Representation: multiplication

paper | mental buffer

```
  57
x 48
----
```

[7*8=56]

External Representation: multiplication

paper | mental buffer

```
  5
 57
x 48
----

  6
```

[7*8=56]

External Representation: multiplication

paper mental buffer

```
   5
  57
x 48
----

   6
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper	mental buffer

```
  57
x 48
----

 456
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper	mental buffer
57
x 48 | [7*4=28]
---- |
456 |

External Representation: multiplication

paper mental buffer

```
   2
  57
x 48
----

 456
  8
```

[7*4=28]

External Representation: multiplication

paper

mental buffer

```
   2
  57
x 48
----

 456
  8
```

[5*4=20 + 2 =22]

External Representation: multiplication

paper | mental buffer

```
  57
x 48
----

 456
228
```

[5*4=20 + 2 =22]

External Representation: multiplication

paper   mental buffer

```
  57
x 48
----

 456
228
----
   6
```

External Representation: multiplication

paper	mental buffer

```
   57
 x 48
 ----

  456
 228_
 ----
    6
```

[8+5 = 13]

External Representation: multiplication

paper | mental buffer

```
   57
 x 48
 ----
  1
  456
 228
 ----
   36
```

[8+5 = 13]

External Representation: multiplication

paper | mental buffer

```
   57
 x 48
 ----
  1
  456
 228
 ----
   36
```

[4+2+1=7]

External Representation: multiplication

paper | mental buffer

```
  57
x 48
----

 456
258
----
 736
```

[4+2+1=7]

External Representation: multiplication

paper mental buffer

```
   57
 x 48
 ----
  456
 258
 ----
 2736
```

Information Visualization

interactive visual representation of abstract data

- help human perform some task more effectively

bridging many fields

- graphics: interacting in realtime
- cognitive psych: finding appropriate representation
- HCI: using 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

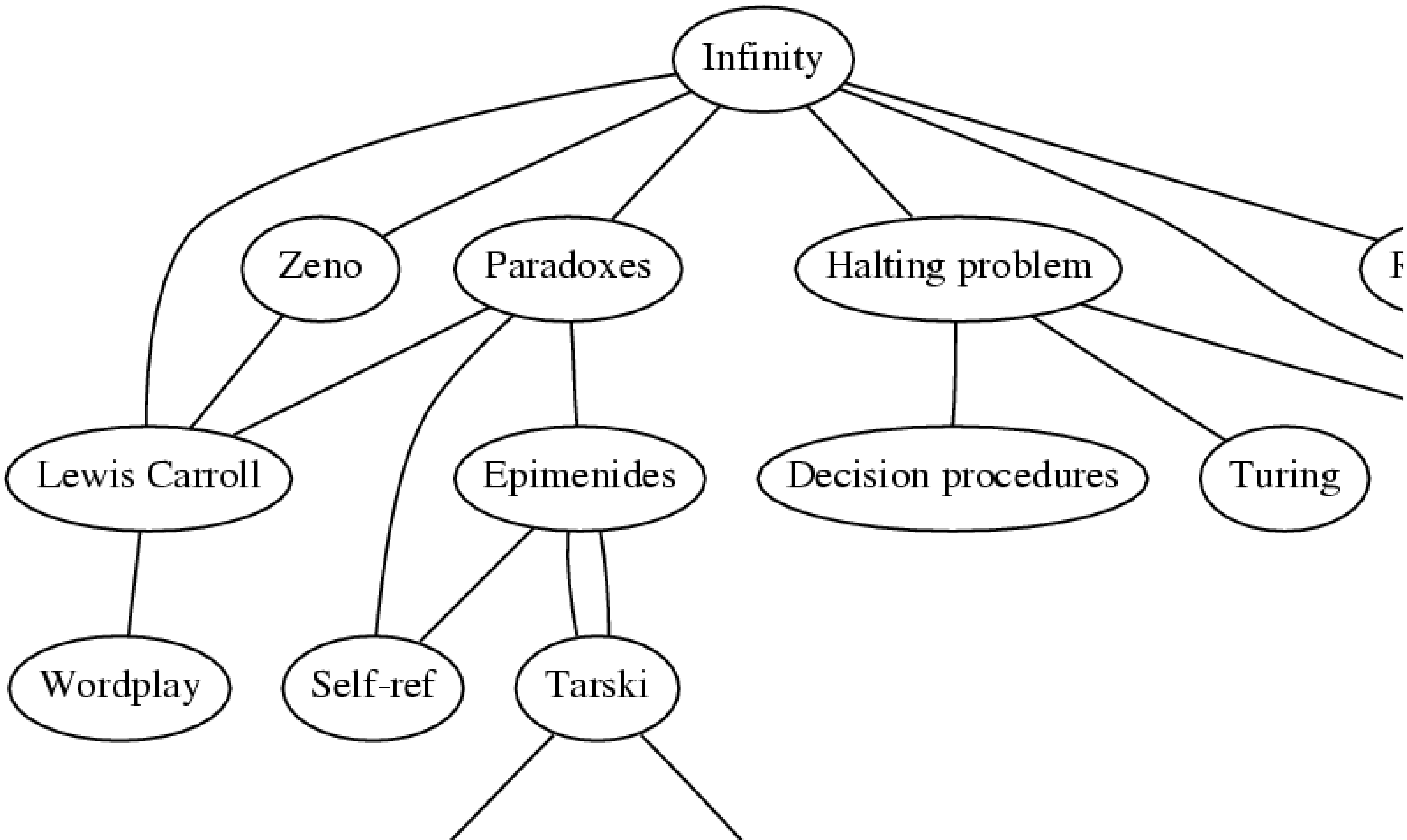
[Godel, Escher, Bach. Hofstadter 1979]

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
[...]

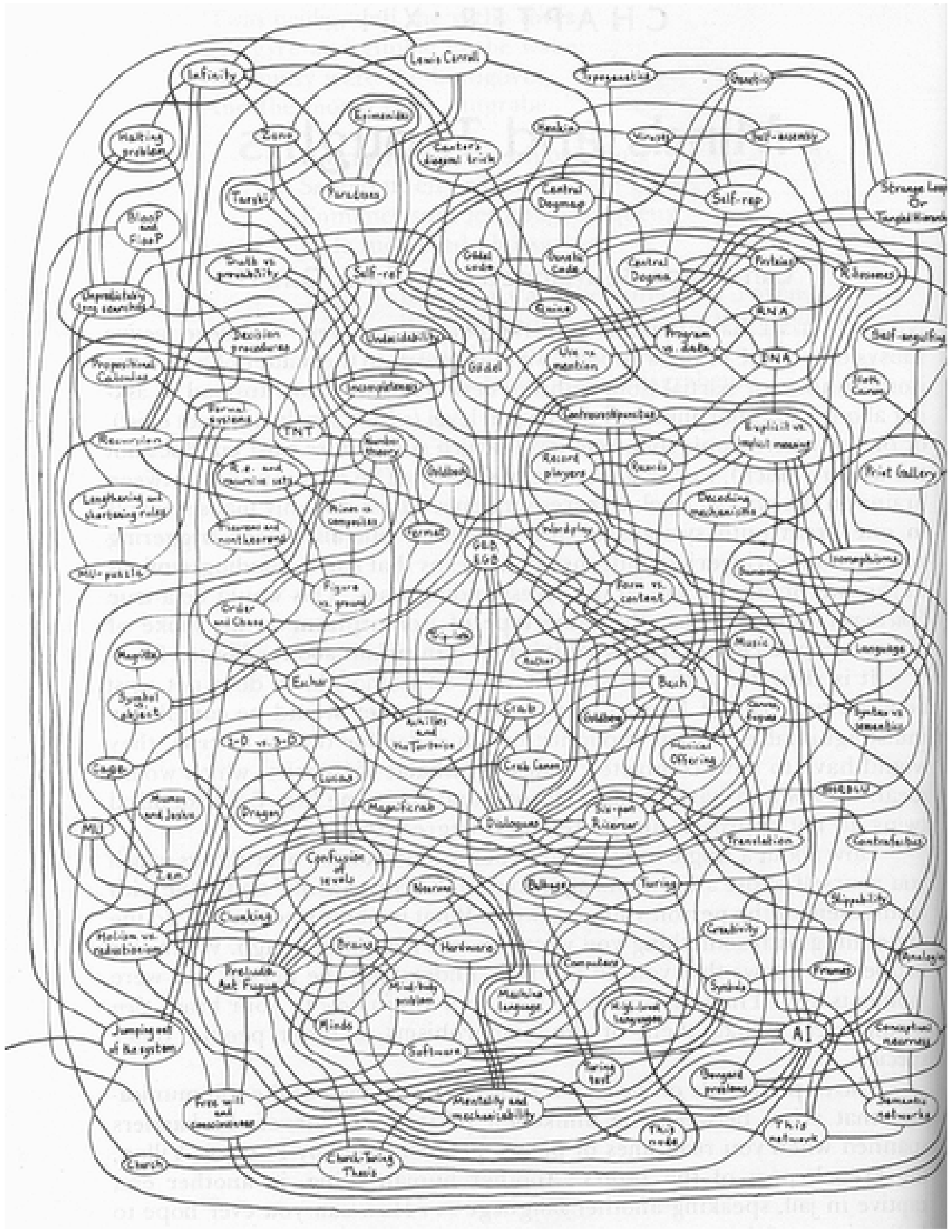
External Representation: Topic Graphs

offload cognition to visual systems
minimal attention to read answer



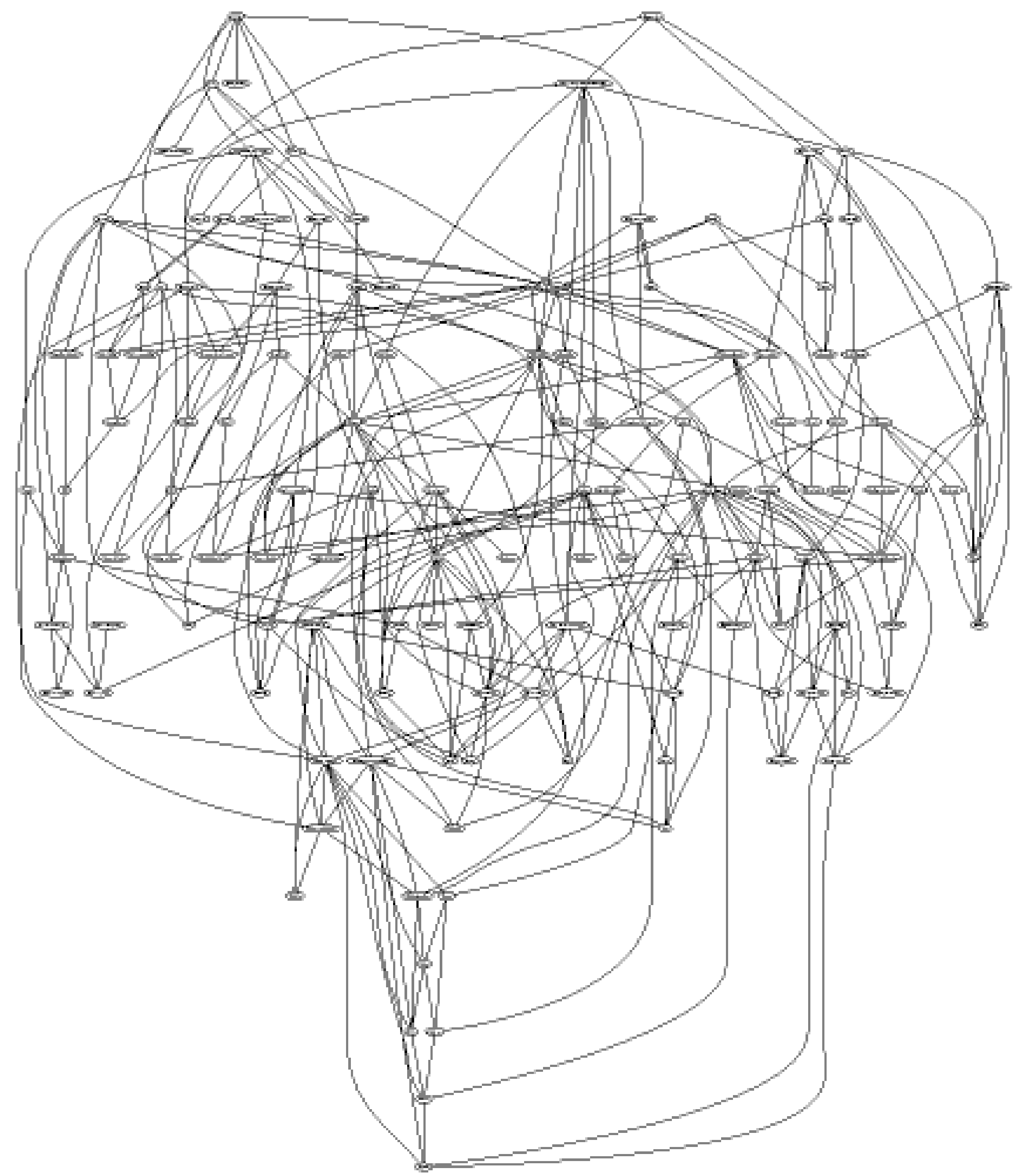
External Rep: Automatic Layout

manual: hours, days



[Godel, Escher, Bach. Hofstader 79]

automatic: seconds



dot, [Gansner et al 93]

InfoVis vs. SciVis

is spatialization given (scivis) or chosen (infovis)

- my definition

names are unfortunate historical accidents

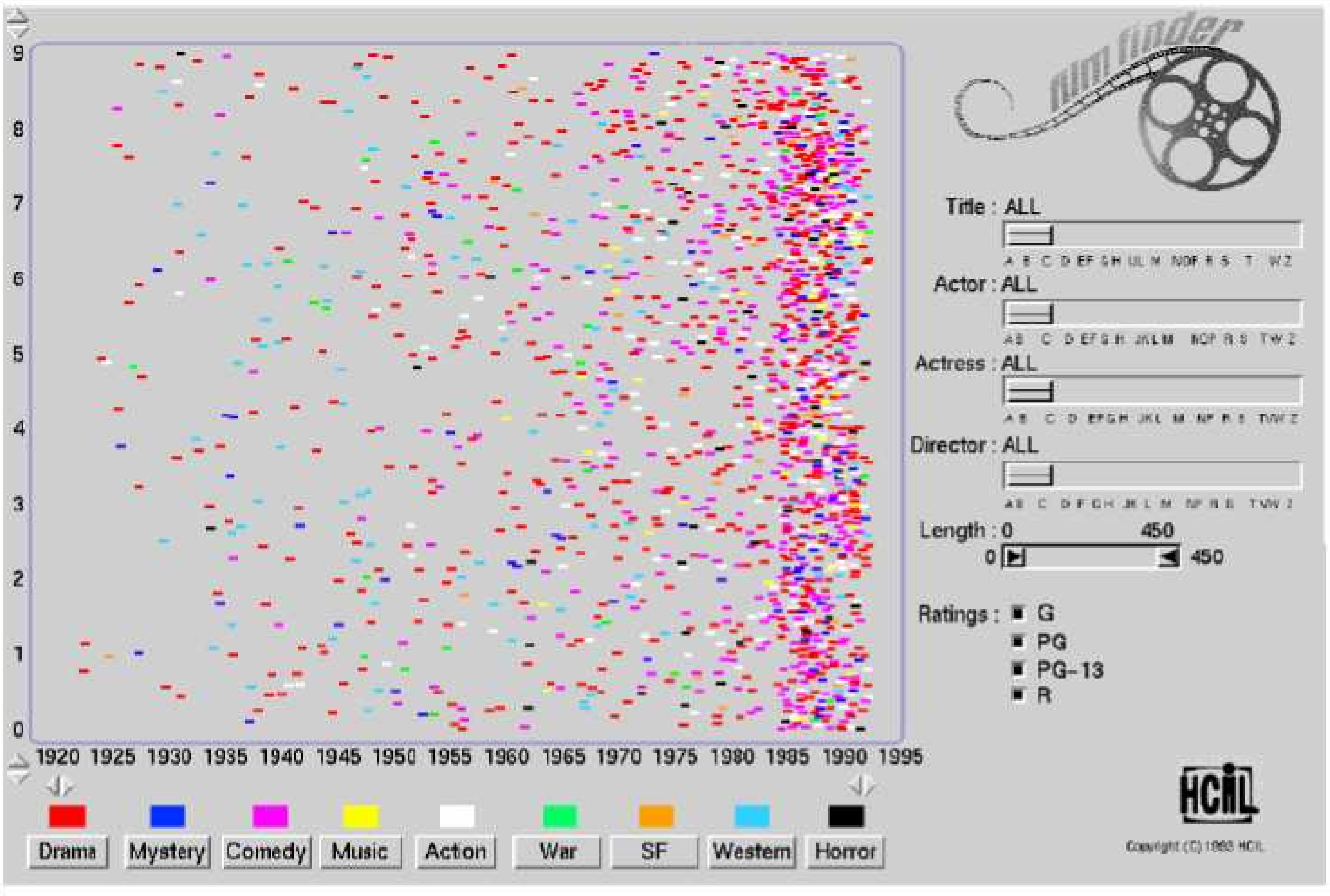
- not scivis iff data generated by scientists
- infovis not unscientific
- scivis not uninformative
- but – too late to change

infovis: how to represent

- choosing, doing, evaluating
- huge space of possibilities: random walk ineffective
- need design guidelines

Overviews: mantra

overview

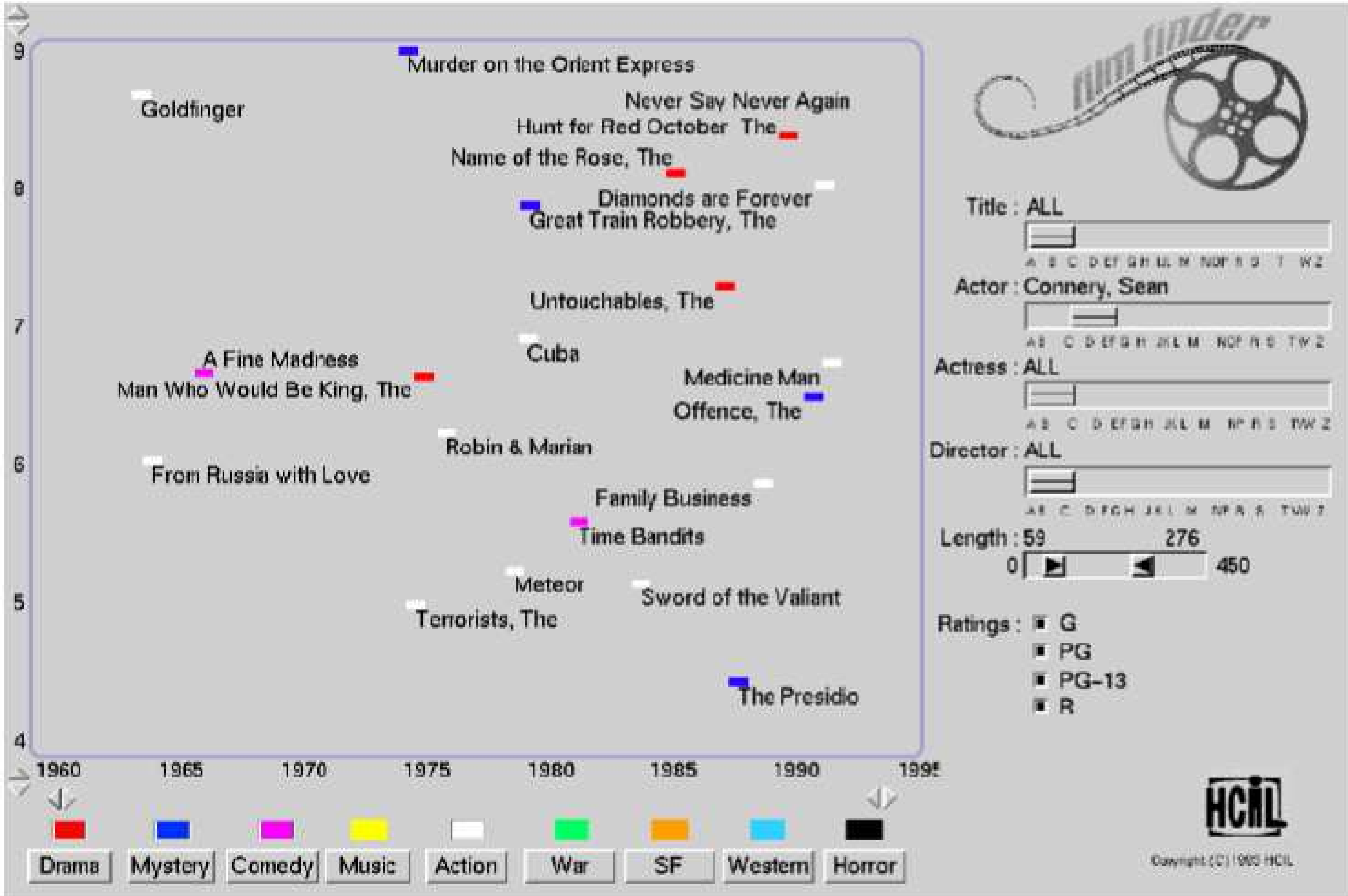


Ahlberg & Shneiderman, Color plate 1. The FilmFinder.

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94, citeseer.ist.psu.edu/ahlberg94visual.html]

Overviews: mantra

overview, zoom and filter

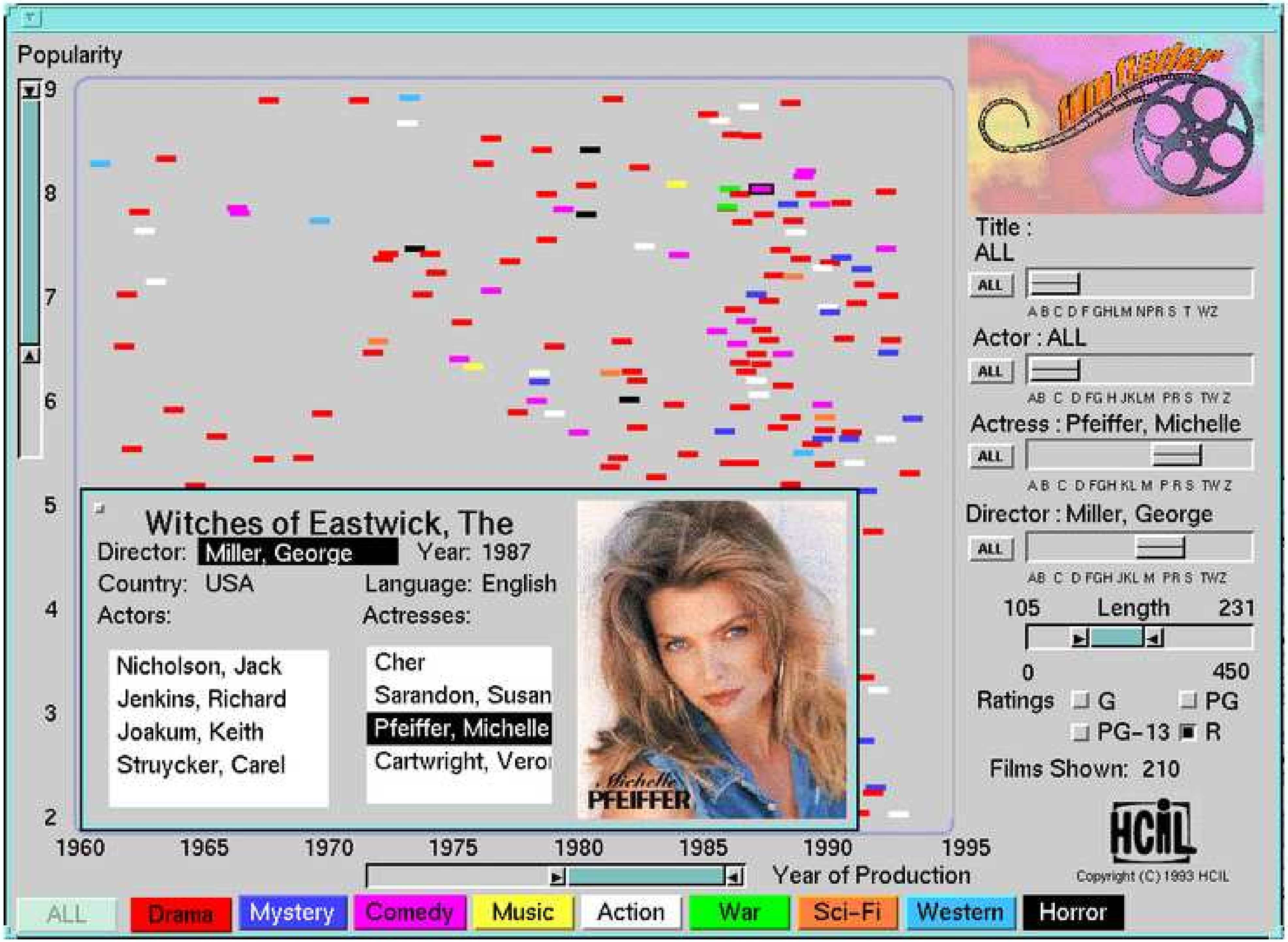


Ahlberg & Shneiderman, Color plate 2. Categories have been selected, the displayed is zoomed

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94, citeseer.ist.psu.edu/ahlberg94visual.html]

Overviews: mantra

overview, zoom and filter, details-on-demand



[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94, citeseer.ist.psu.edu/ahlberg94visual.html]

Overviews: Shneiderman mantra

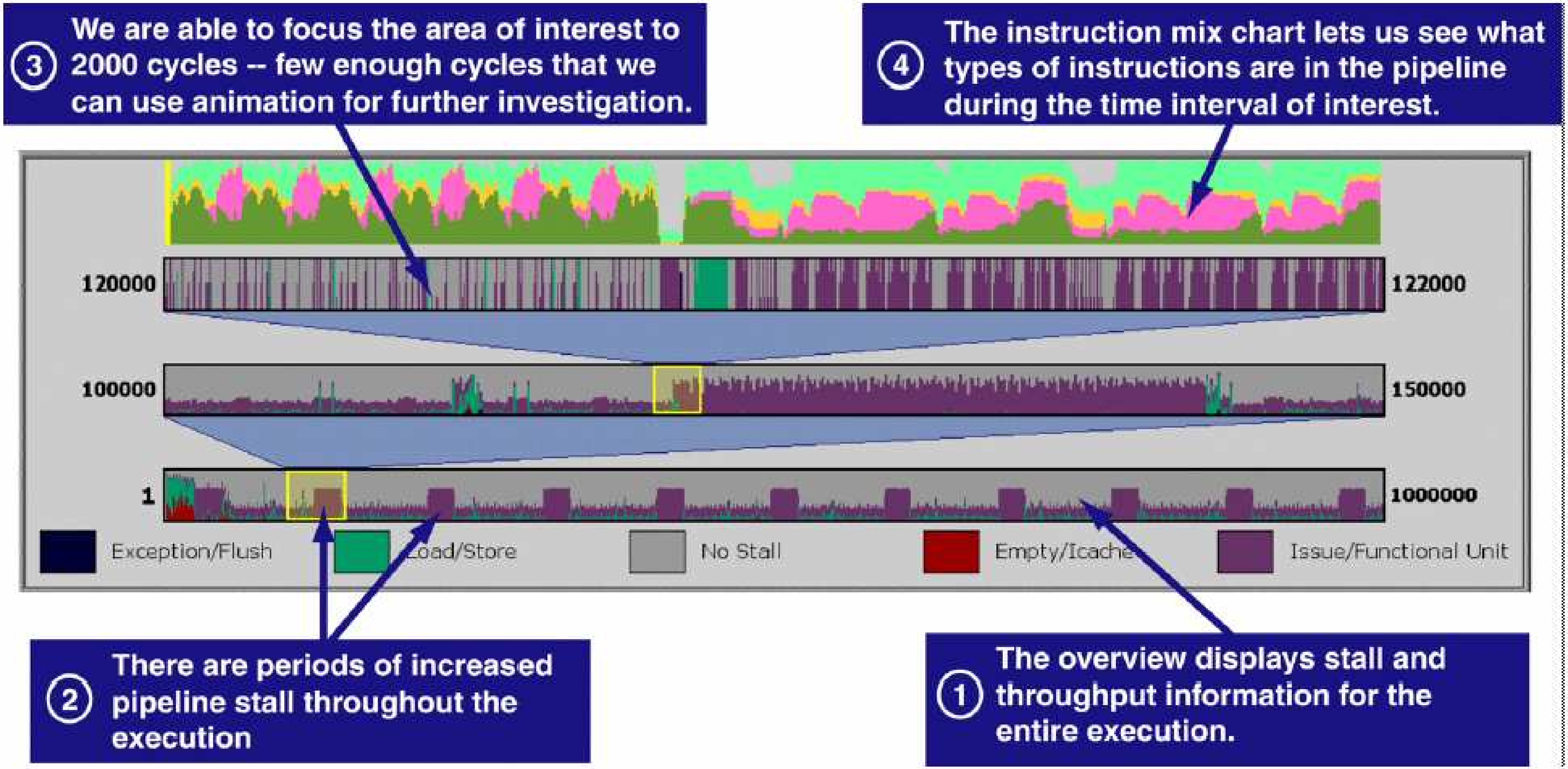
overview first,
then zoom and filter,
details-on-demand

The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations.
Ben Shneiderman, Proc. 1996 IEEE Visual Languages, also Maryland HCIL TR 96-13
ftp://ftp.cs.umd.edu/pub/hcil/Reports-Abstracts-Bibliography/96-13html/96-13.html

Overviews: Rivet

performance tuning

- levels of detail



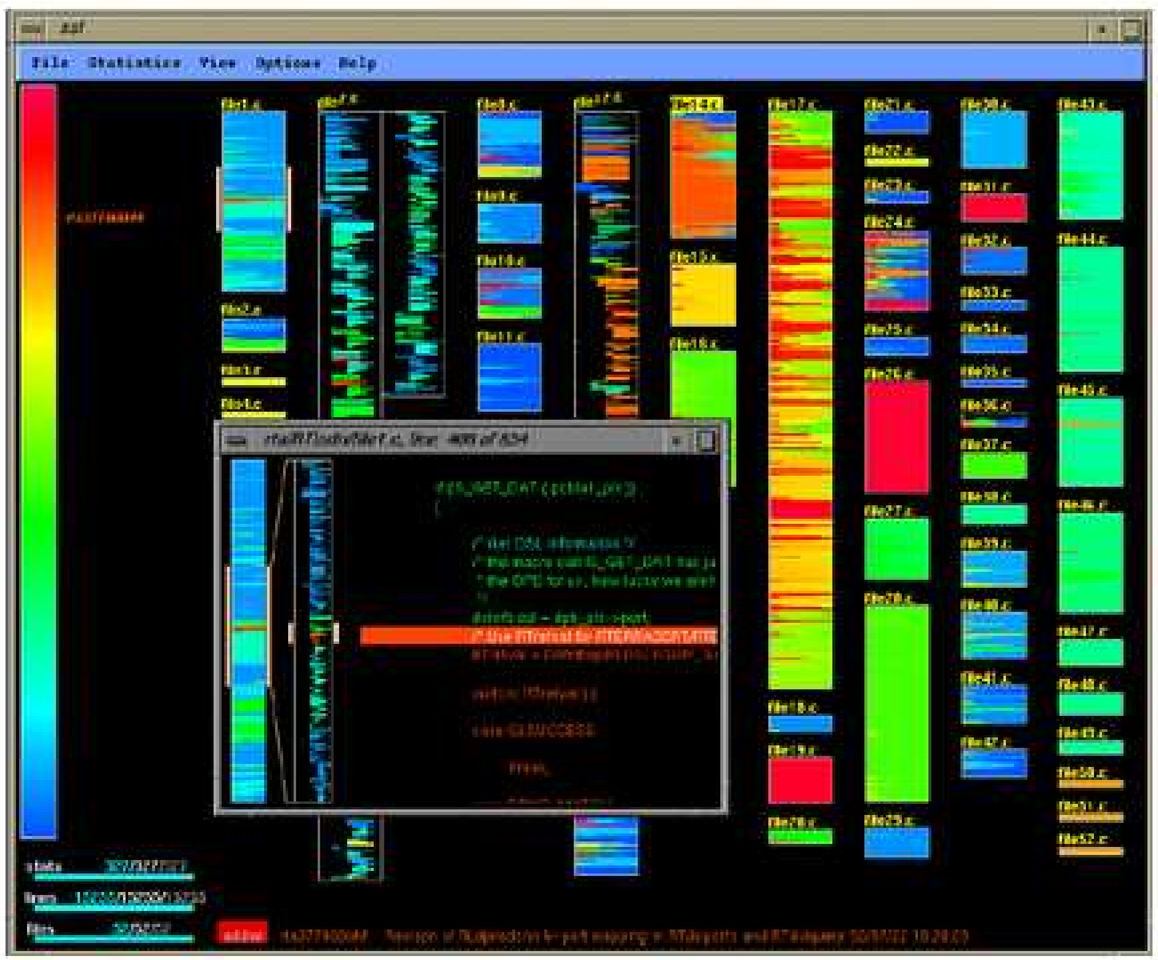
[Stolte et al, Visualizing Application Behavior on Superscalar Processors, InfoVis 99, graphics.stanford.edu/papers/rivet_pipeline]

Overviews: SeeSoft

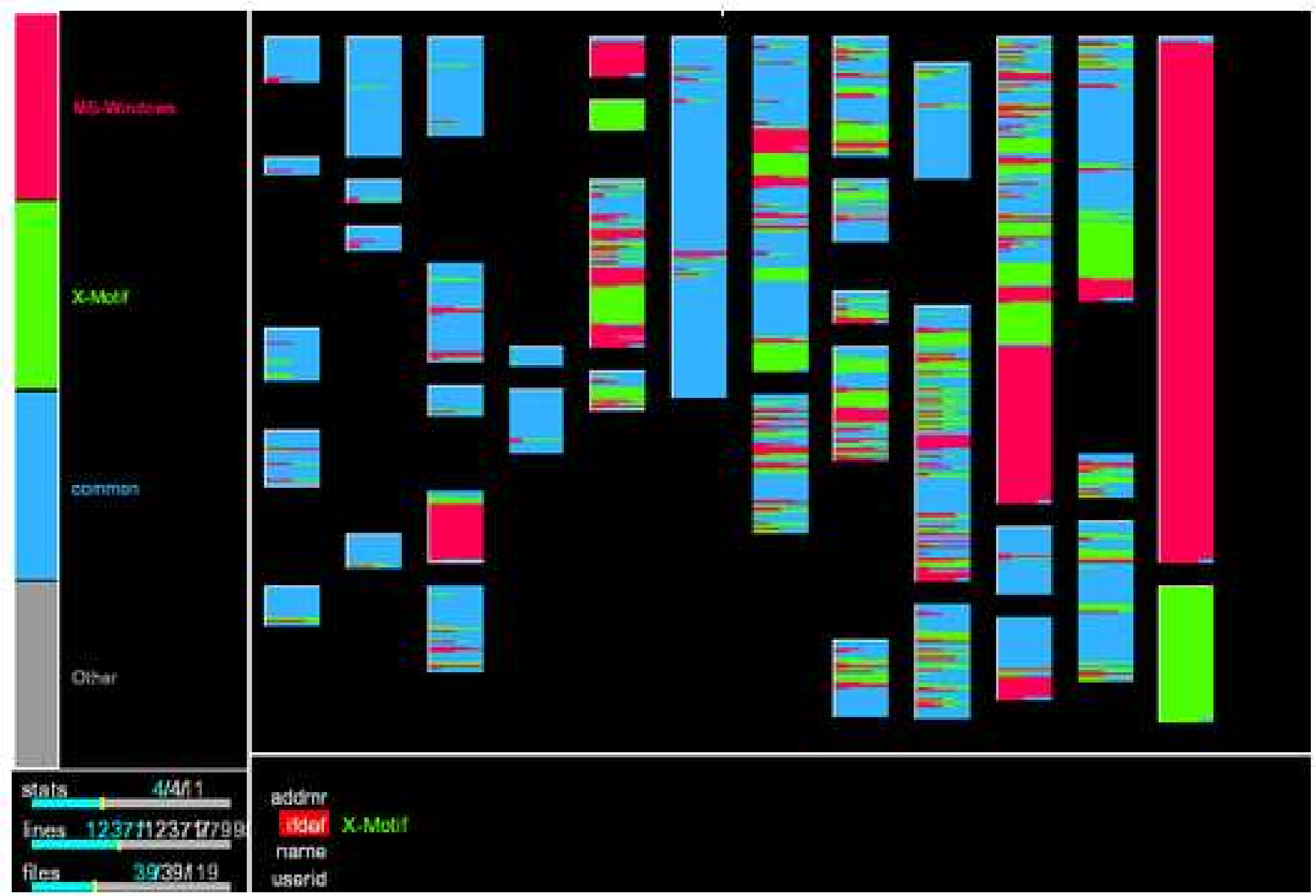
software maintenance

- colored lines of code -> lines one pixel high

code age



platform dependencies

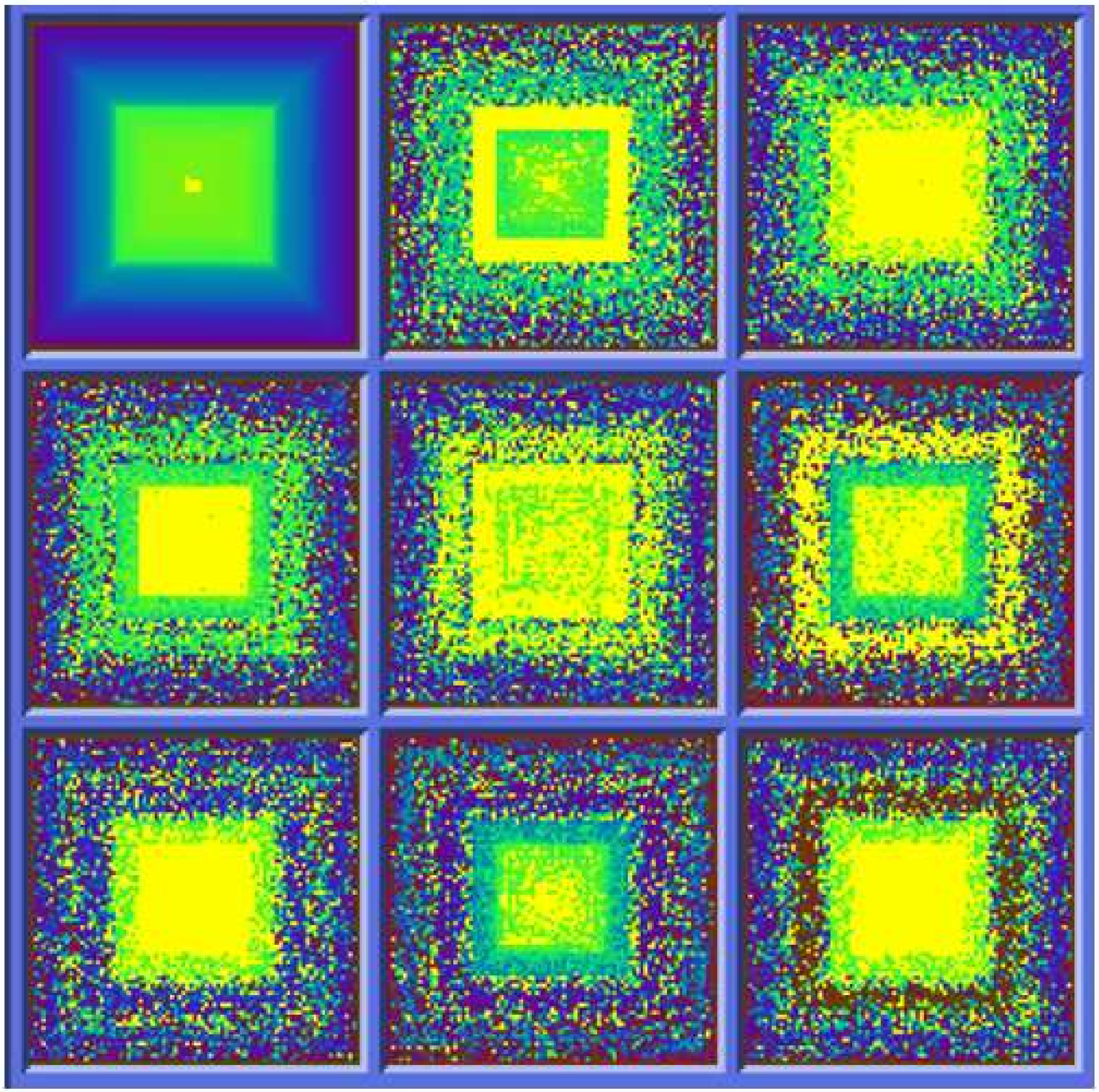


[Ball and Eick, Software Visualization in the Large, Computer 29:4, 1996
citeseer.nj.nec.com/ball96software.html]

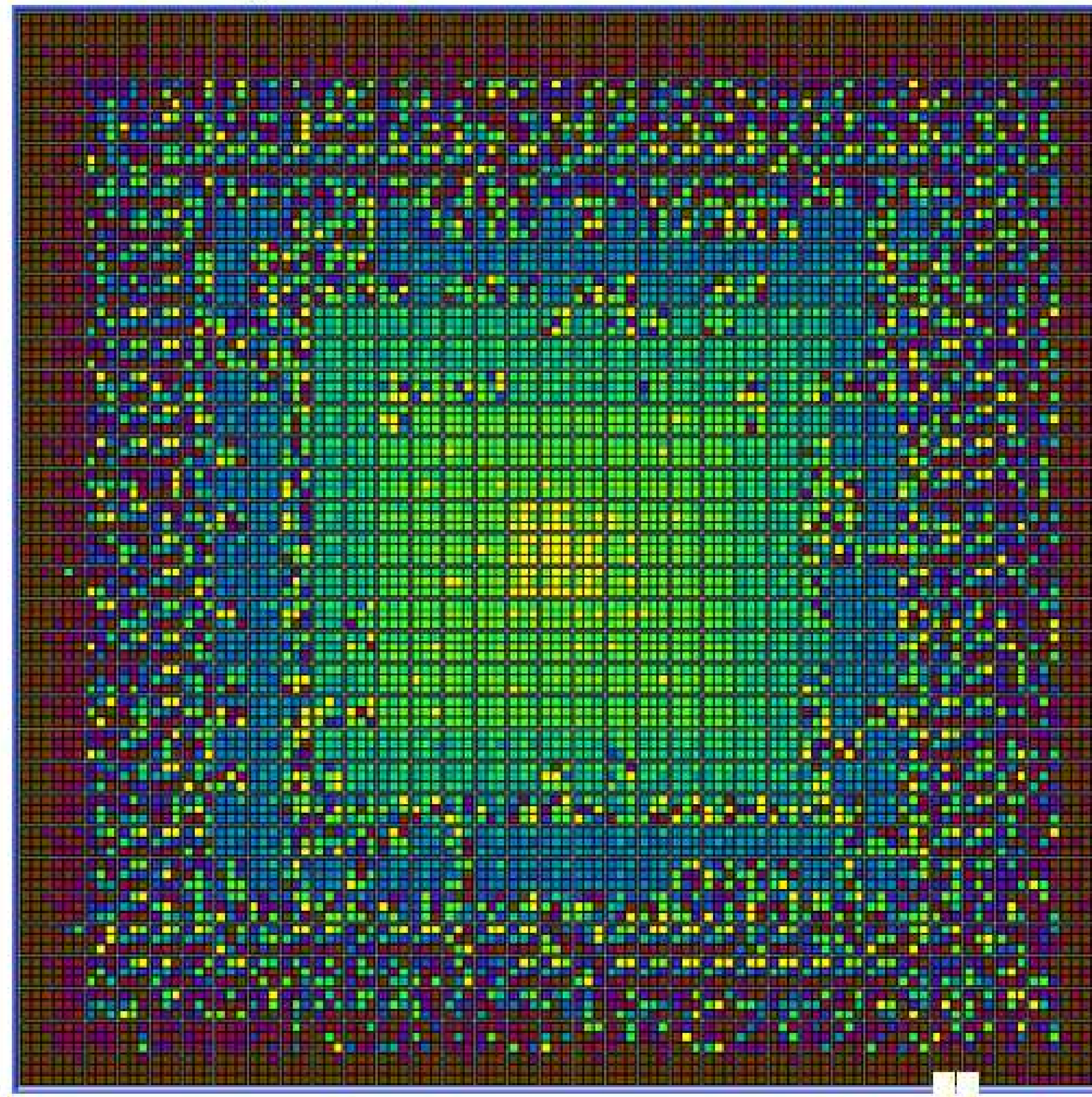
Overviews: VisDB

database queries

separate attributes



grouped attributes



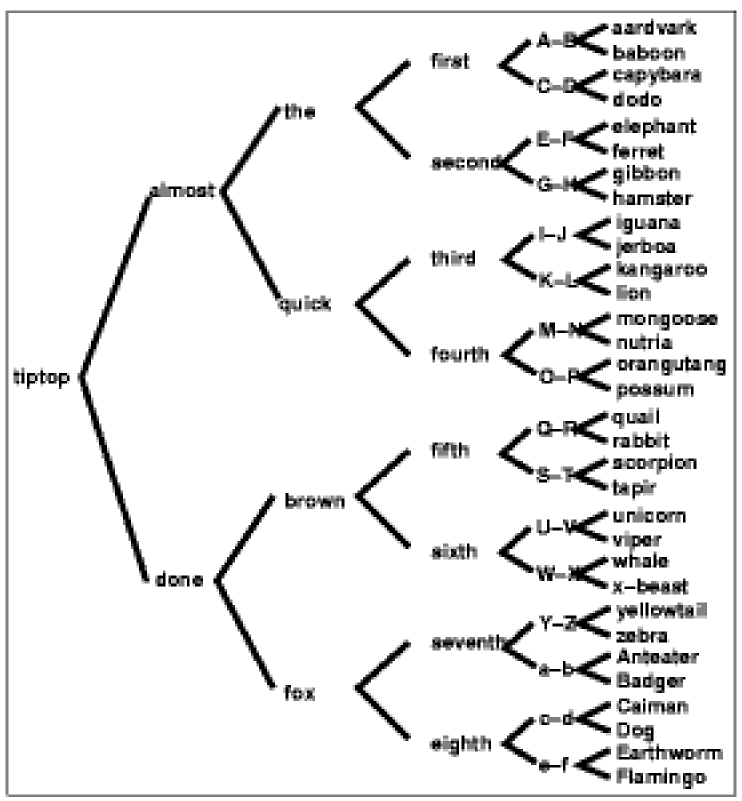
[Keim and Kriegel, VisDB: Database Exploration using Multidimensional Visualization, IEEE CG&A, 1994 www.dbs.informatik.uni-muenchen.de/dbs/projekt/papers/visdb.ps]

Overview+Detail

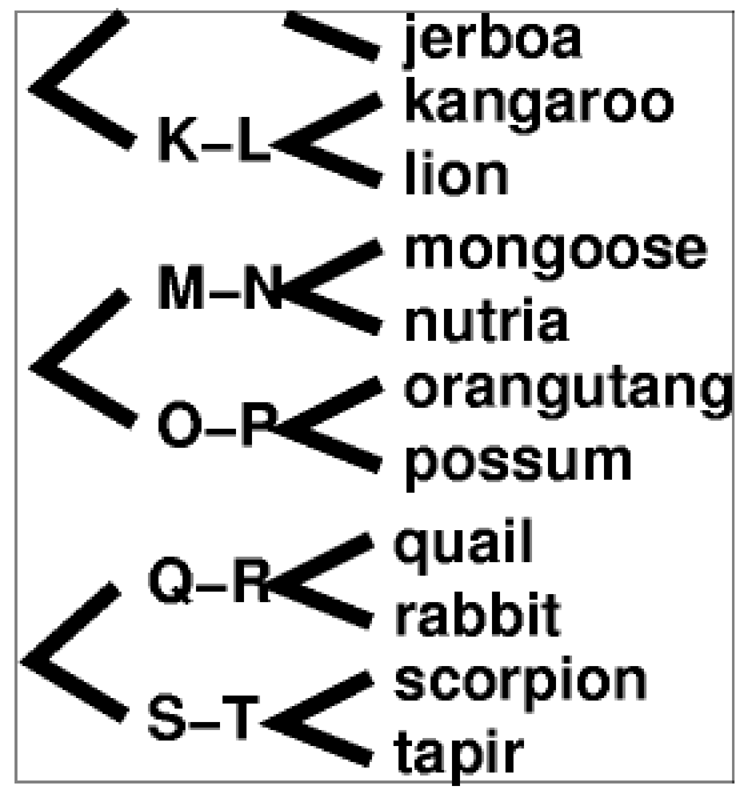
problem

- avoid user disorientation when inspecting detail
- hard for big datasets

bad: one window, must remember position



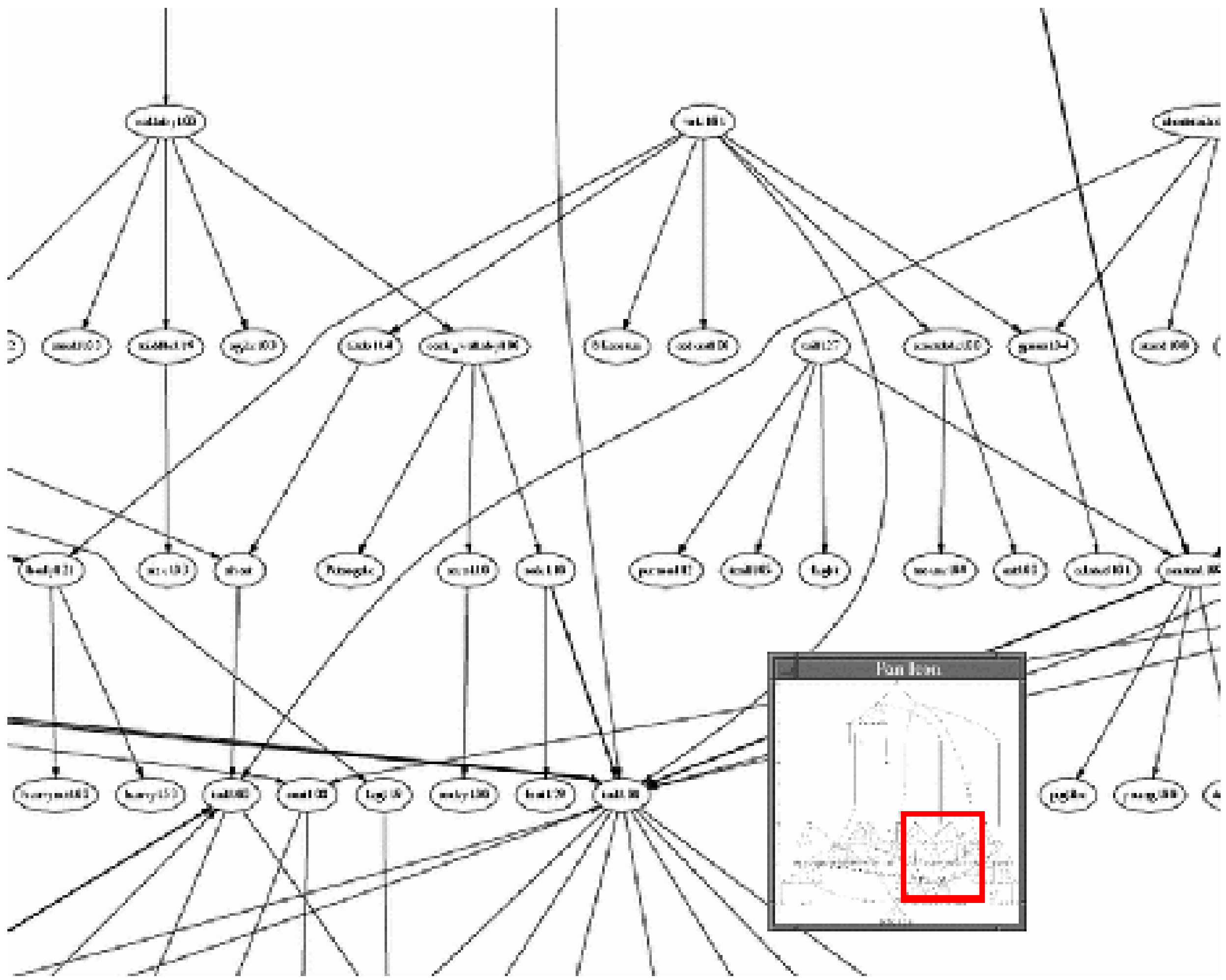
global overview



local detail

Overview+Detail

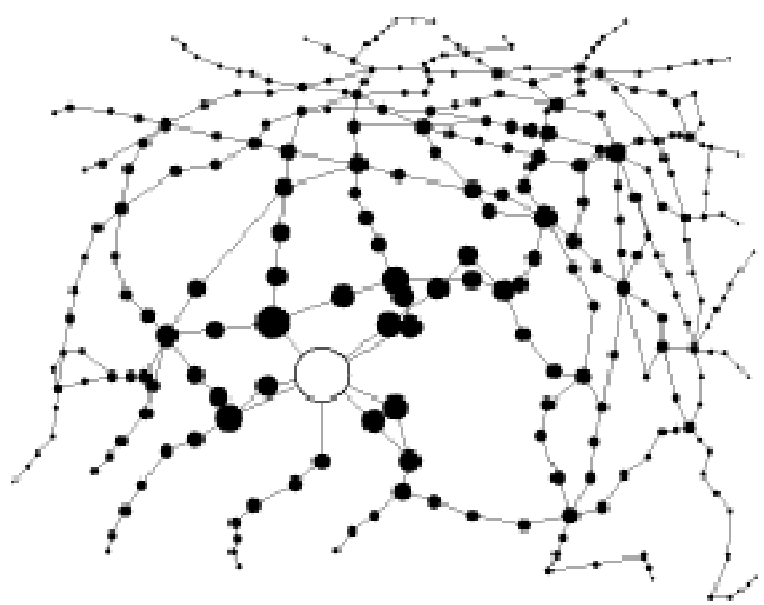
better: add linked overview window(s)
problem: still cognitive load to correlate

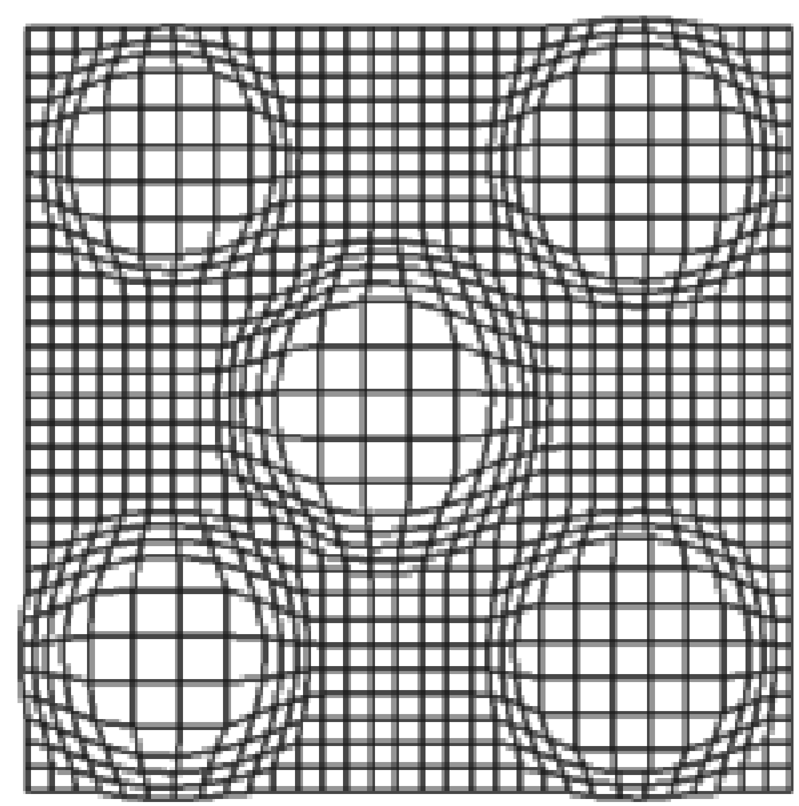


Focus+Context

merge overview, detail into single window

- fisheye views [Furnas 86], [Sarkar et al 94]
- nonlinear magnification [Keahey 96]



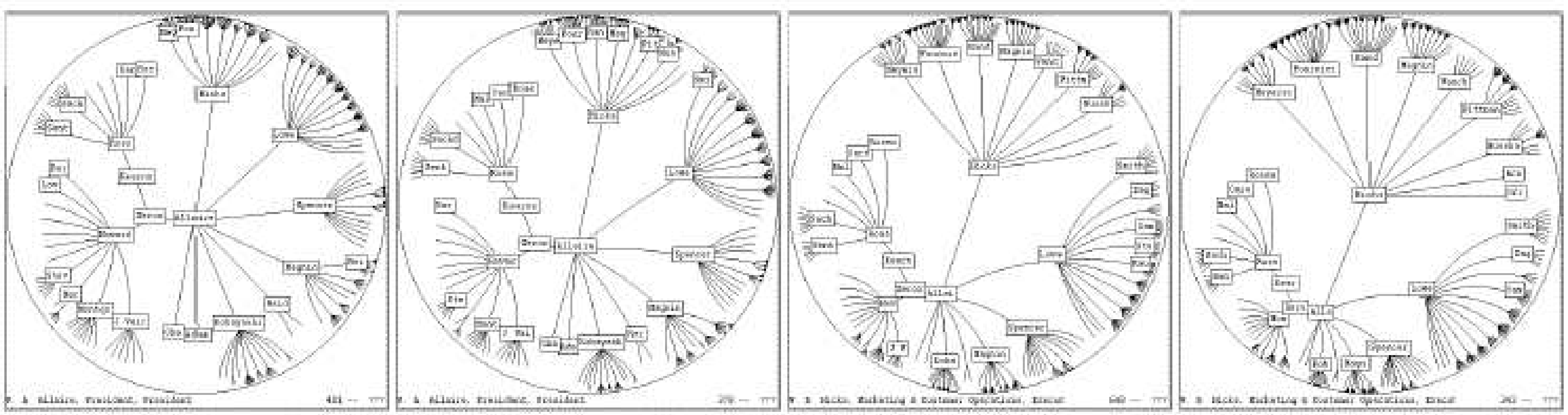


[Manojit Sarkar and Marc H. Brown. Graphical Fisheye Views, CACM 37(12):73-84, Dec 1994]
[Alan Keahey. www.cs.indiana.edu/~tkeahey/research/nlm/nlm.html]

Focus+Context: Hyperbolic Trees

fisheye effect from 2D hyperbolic geometry

- [demo: www.lexisnexis.com/startree]

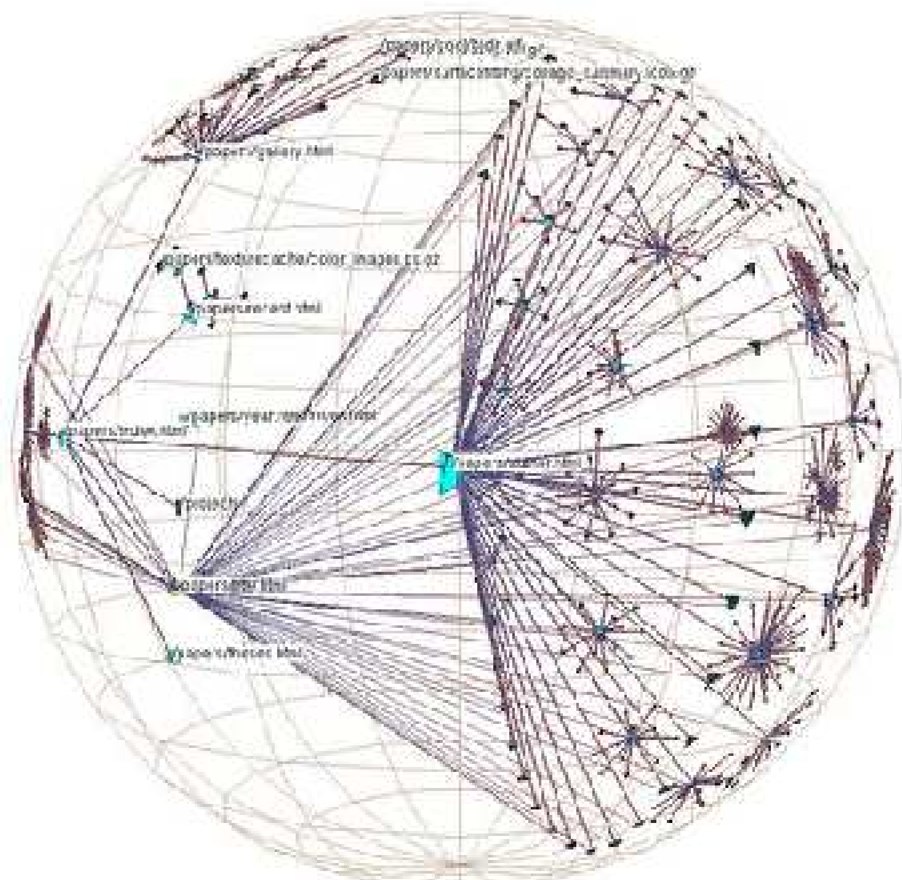


[The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies. John Lamping and Ramana Rao, Proc SIGCHI '95.]

Focus+Context: H3

fisheye effect from 3D hyperbolic geometry

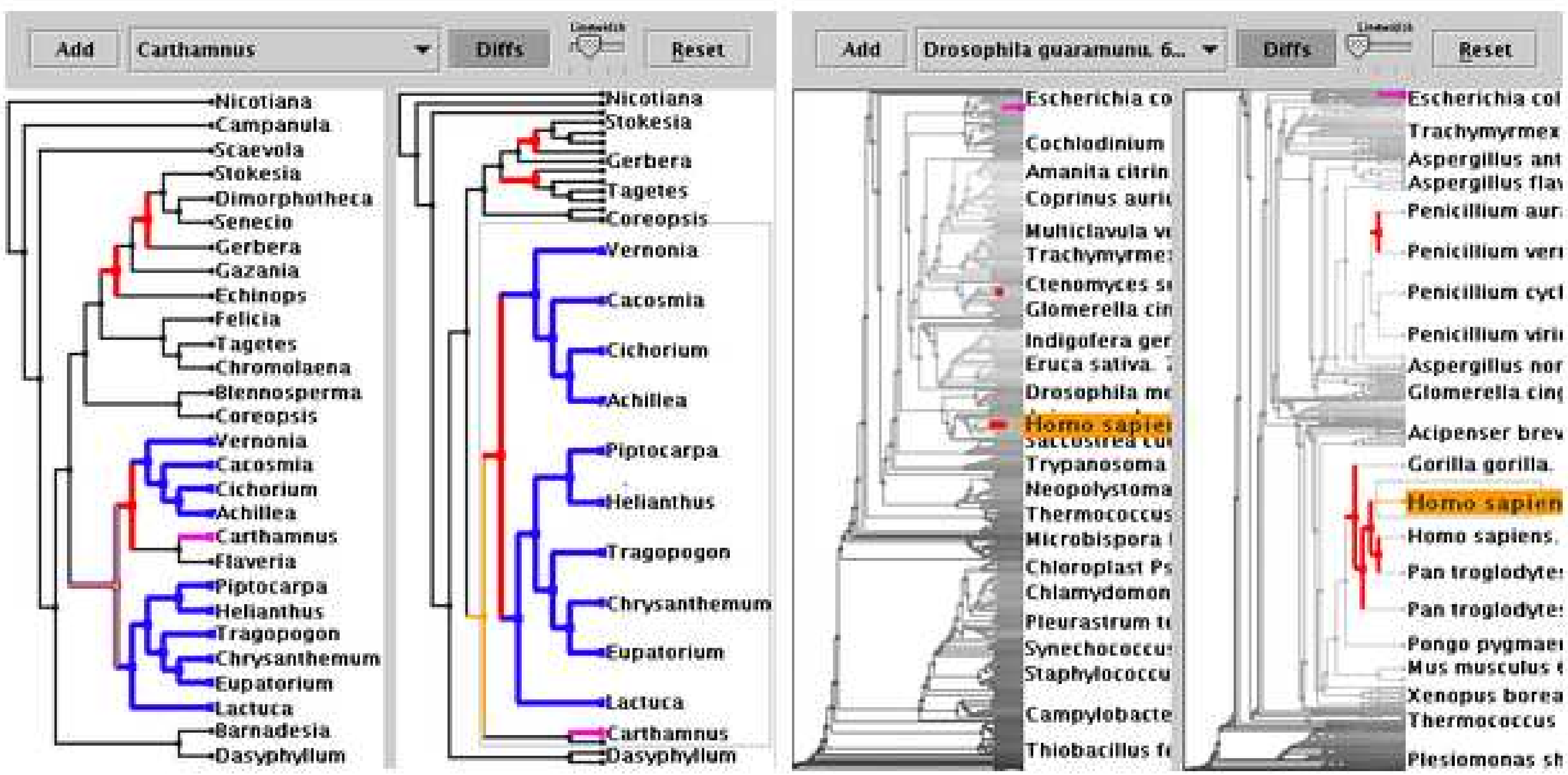
- [demo: graphics.stanford.edu/~munzner/h3]



[Tamara Munzner. H3: Laying Out Large Directed Graphs in 3D Hyperbolic Space. Proc. InfoVis 1997. graphics.stanford.edu/papers/h3]

Focus+Context: TreeJuxtaposer

stretch and squish "rubber sheet"
guaranteed visibility
- keeping highlighted marks visible at all times
- [demo: olduvai.sf.net/tj]

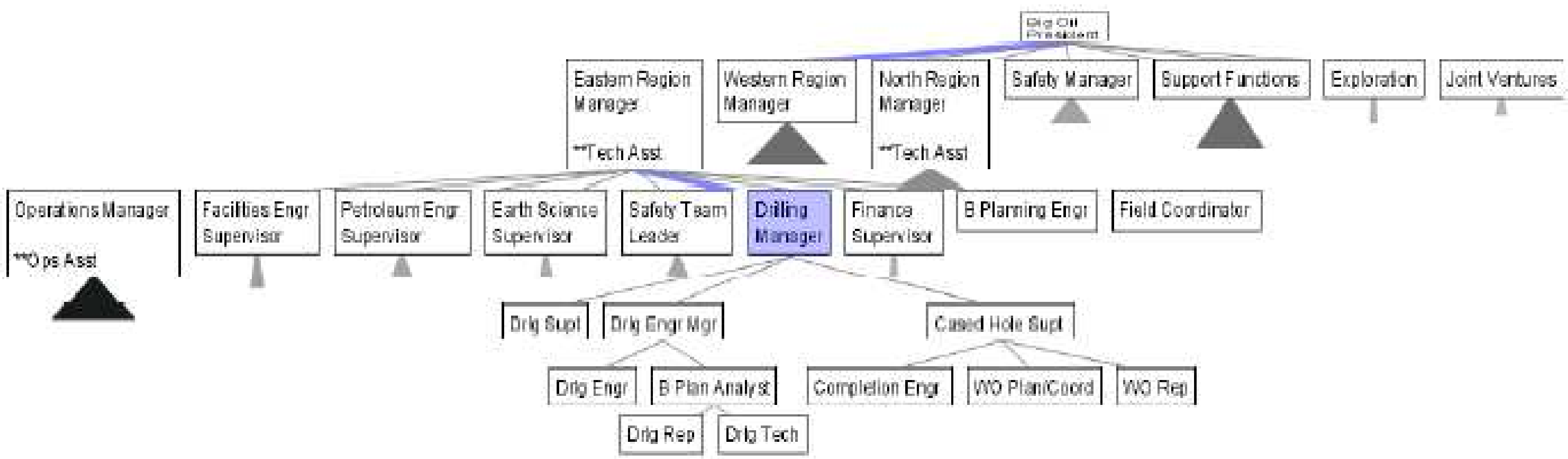


[TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Munzner et al. SIGGRAPH 2003. www.cs.ubc.ca/~tmm/papers/tj]

Focus+Context: SpaceTree

interactively expand/contract

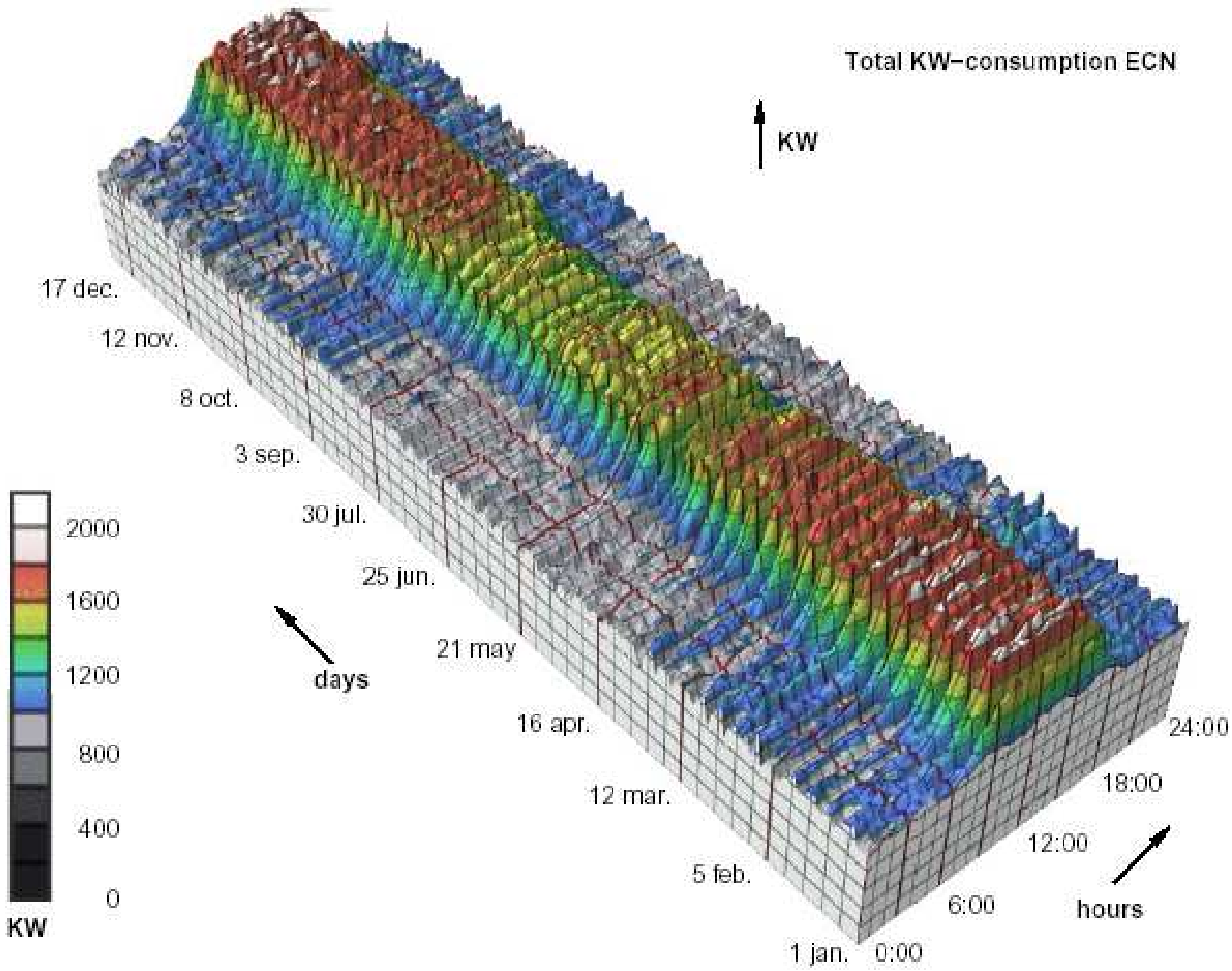
- not stretching space
- [demo: www.cs.umd.edu/hcil/spacetree]



[SpaceTree. Catherine Plaisant, Jesse Grosjean and Ben B. Bederson. Proc. InfoVis 2002 ftp://ftp.cs.umd.edu/pub/hcil/Reports-Abstracts-Bibliography/2002-05html/2002-05.pdf]

3D Extrusion: Obvious but Nonoptimal

- perspective interferes with comparison
- daily, weekly patterns hard to see

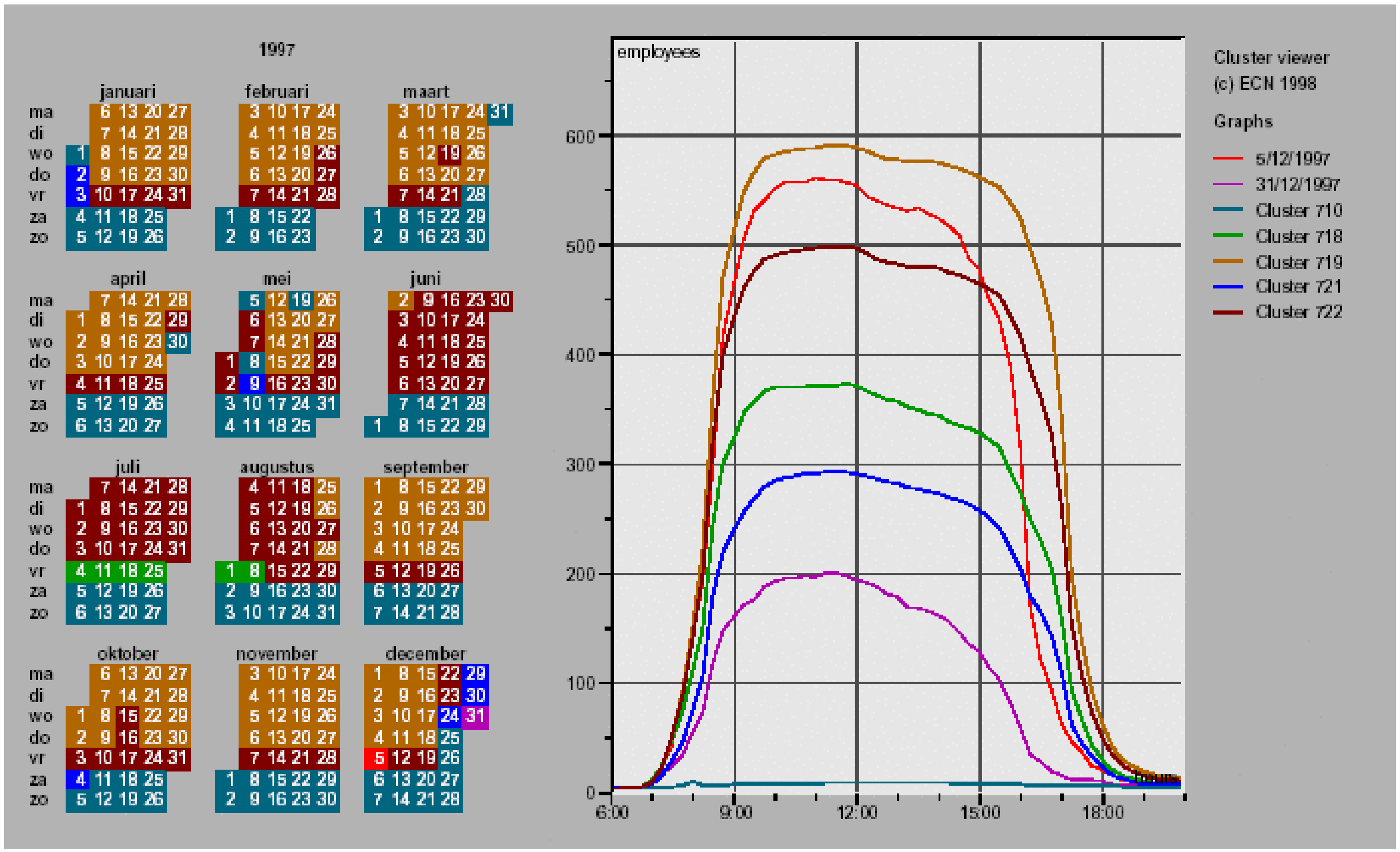


[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99, citeseer.nj.nec.com/vanwijk99cluster.html]

Link Clusters and Calendar

2D linked clusters-calendars shows patterns

- office hours, weekend/holidays, summer/fridays
- school break, post-holiday, santa claus

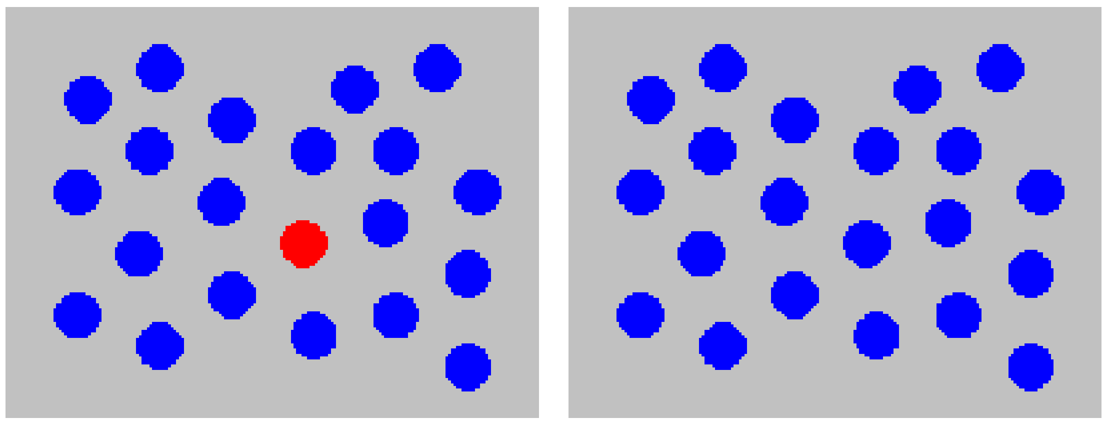


[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99, Figure 4, citeseer.nj.nec.com/vanwijk99cluster.html]

Preattentive Visual Channels: Popout

color (hue) alone: preattentive

- visual attentional system not invoked
- parallel search: speed independent of distractor count

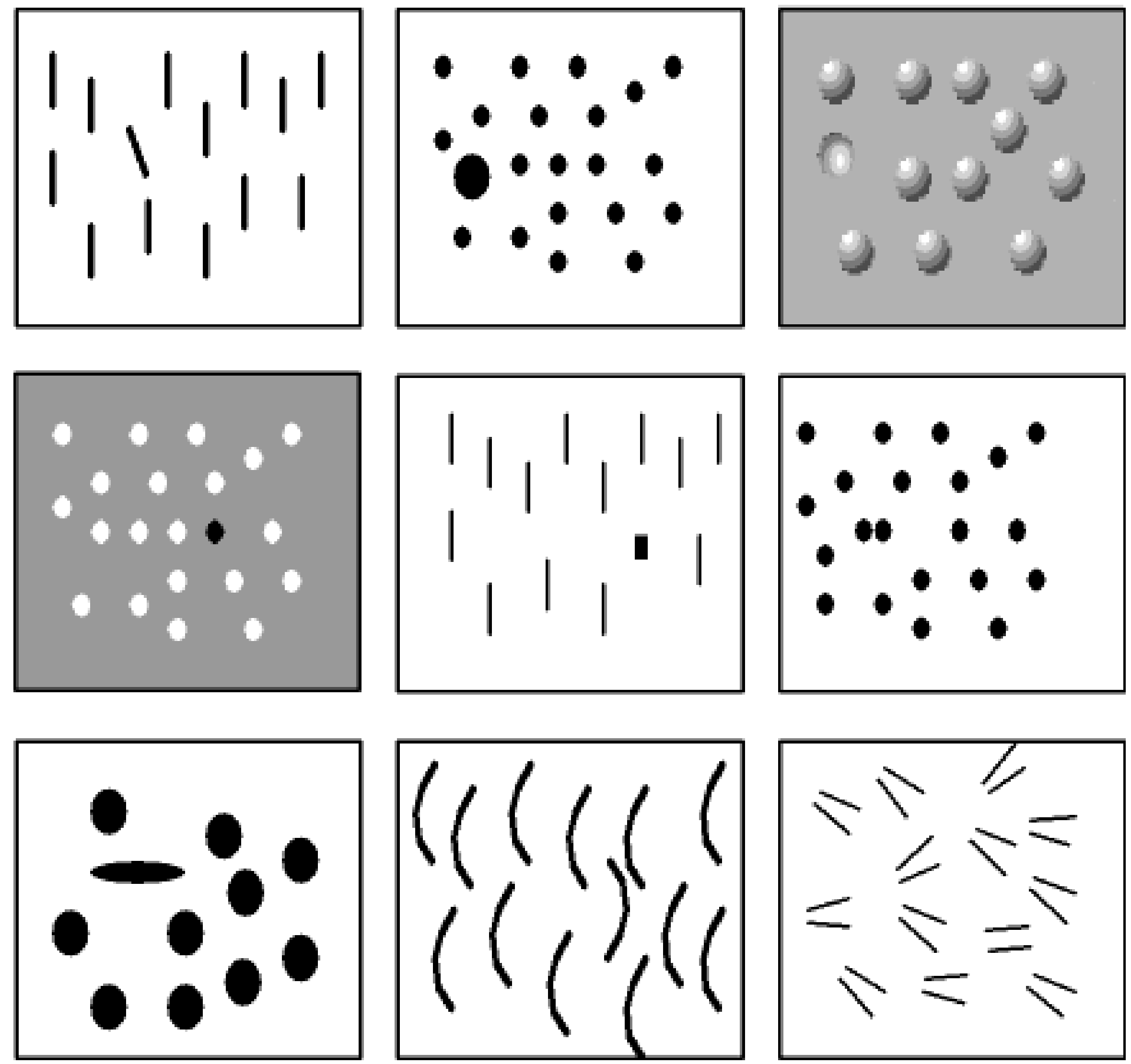


[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]

Preattentive Visual Channels: Popout

many preattentive channels of visual modality

- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction
- [and many more...]

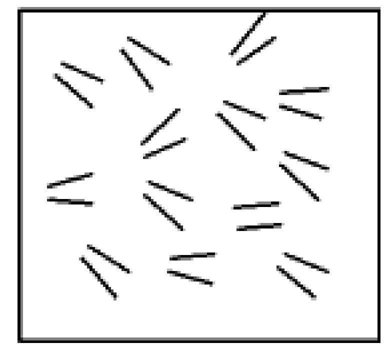


[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]

Non-preattentive: parallelism

many preattentive channels of visual modality

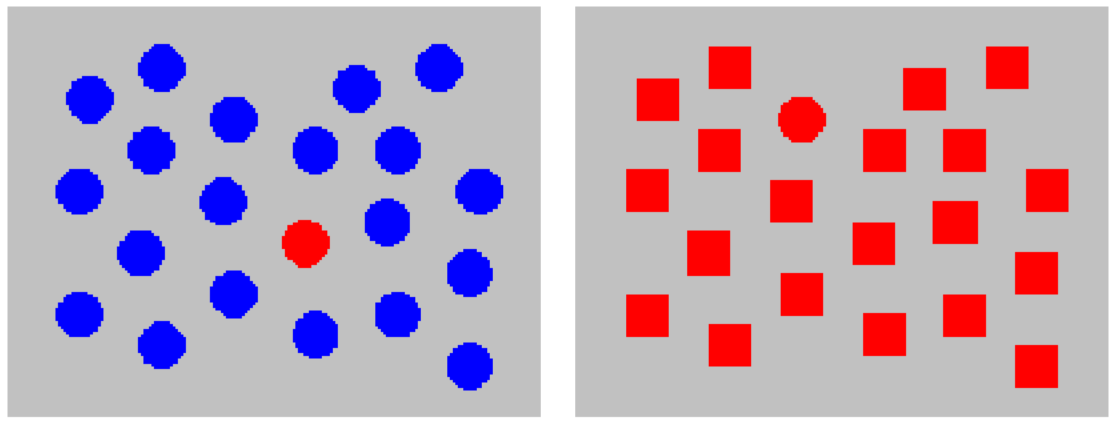
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction
- [and many more...]



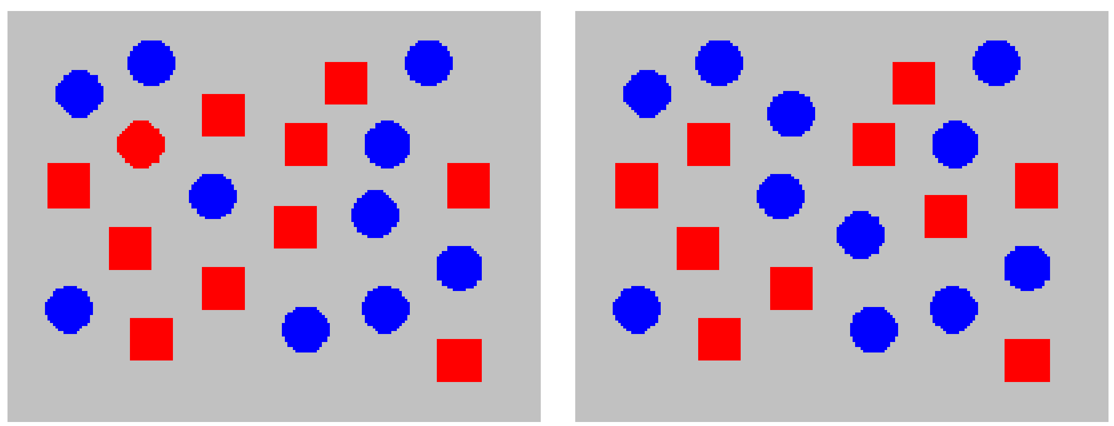
[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]

Preattentive Visual Channels

color alone: preattentive
shape alone: preattentive



combined hue and shape: not preattentive



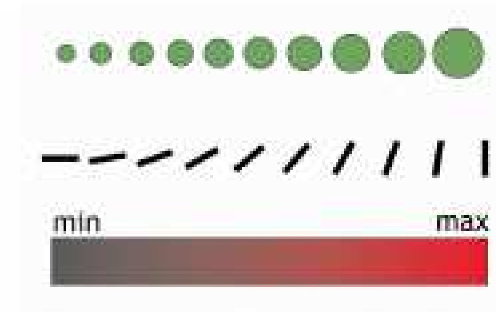
- requires attention
- sequential search: speed linear with distractor count

[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP]

Data Types

continuous (quantitative)

- 10 inches, 17 inches, 23 inches

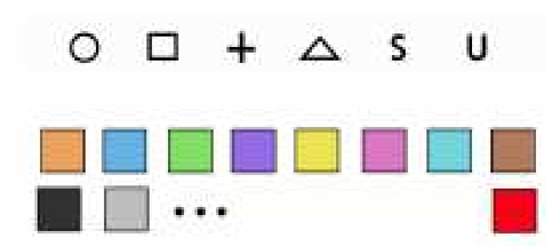


ordered (ordinal)

- small, medium, large

categorical (nominal)

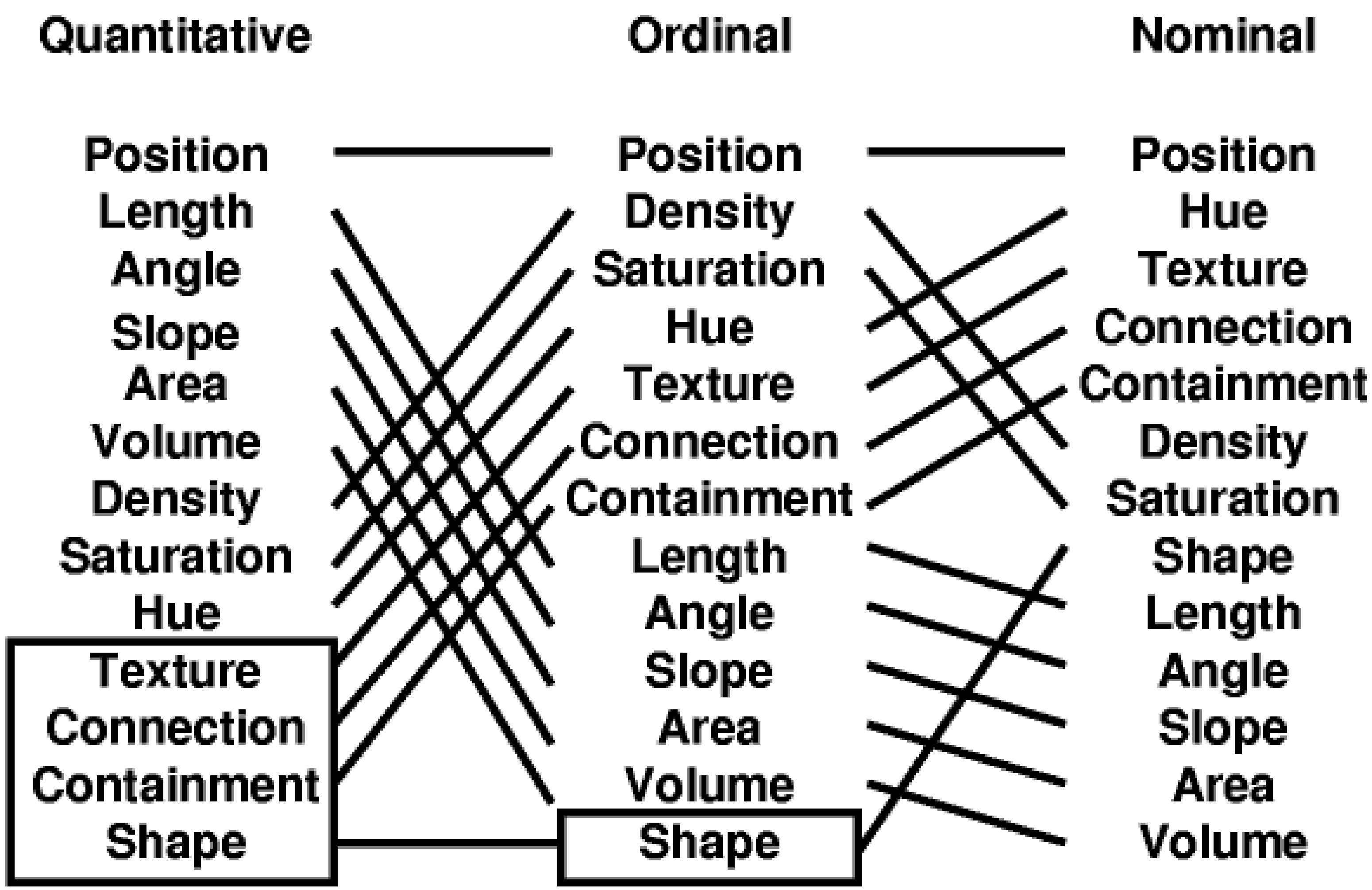
- apples, oranges, bananas



Data Type Affects Channel Ranking

spatial position best for all types

- accuracy at judging magnitudes, from best to worst



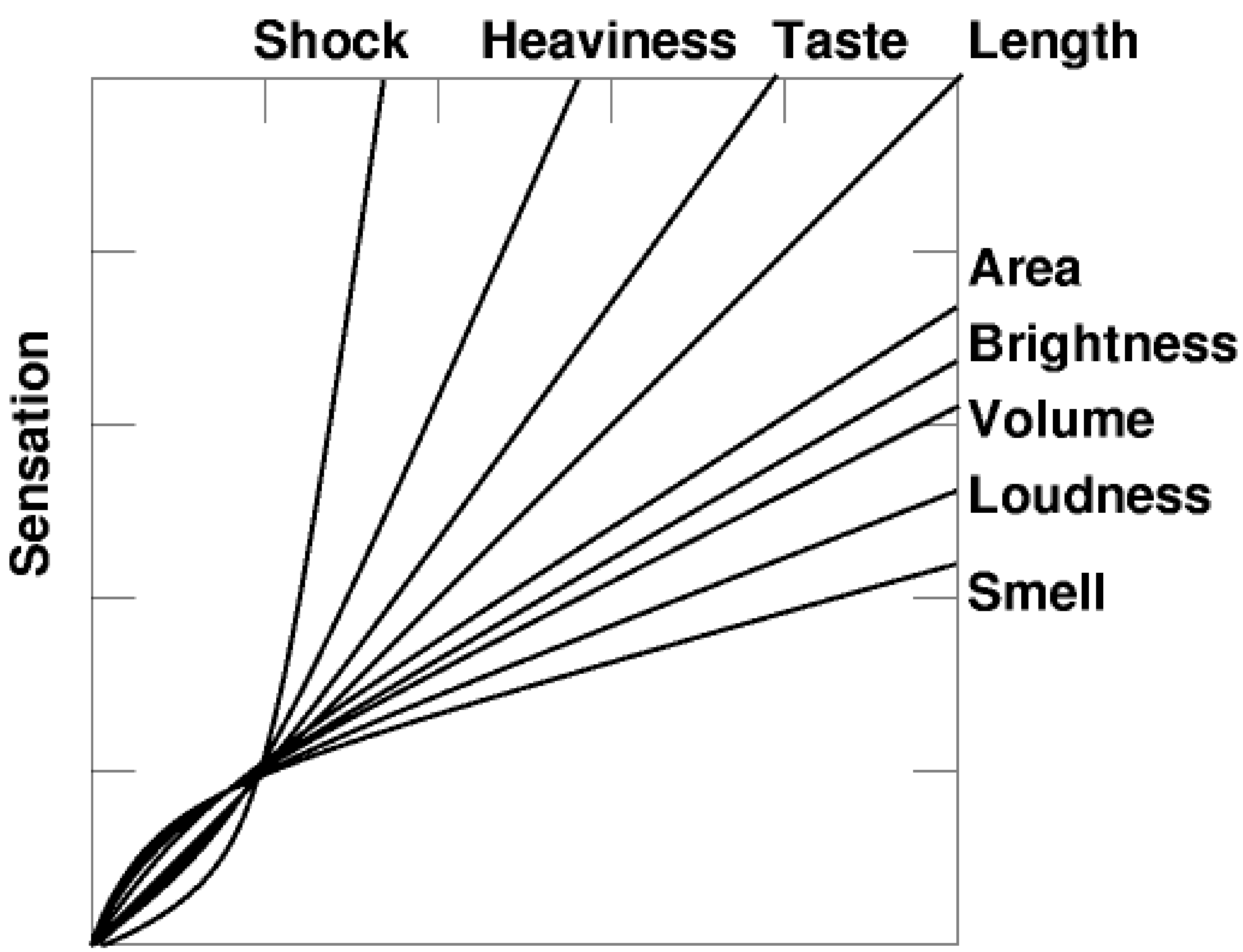
[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

[Card, Mackinlay, and Shneiderman. Readings in Information Visualization: Using Vision to Think. Morgan Kaufmann 1999. Chapter 1]

Nonlinear Perception of Magnitudes

sensory channels not equally discriminable

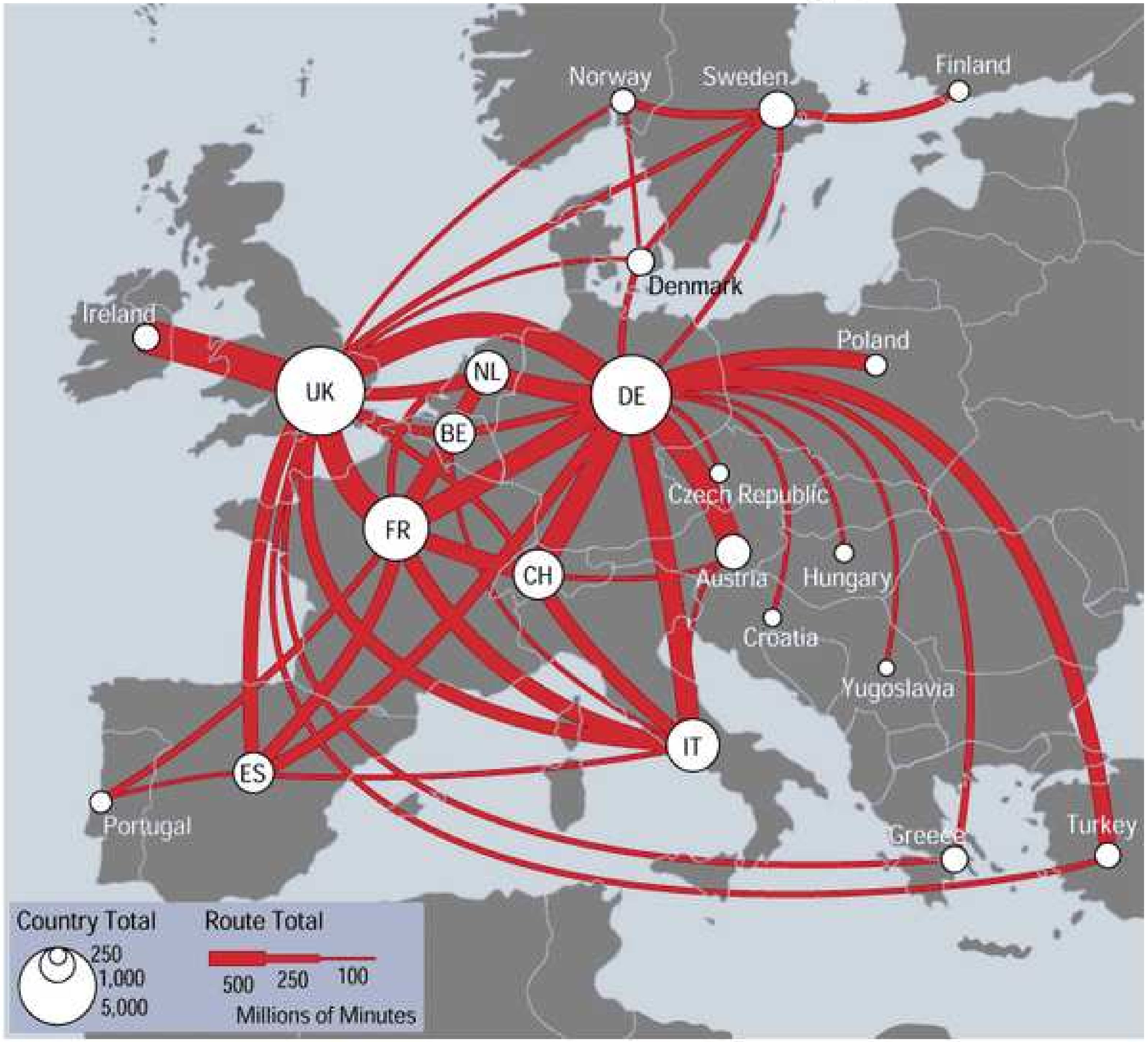
Stevens' Power Law: $I = S^p$



[Stevens, On the Theory of Scales of Measurement, Science 103:2684, 1946]

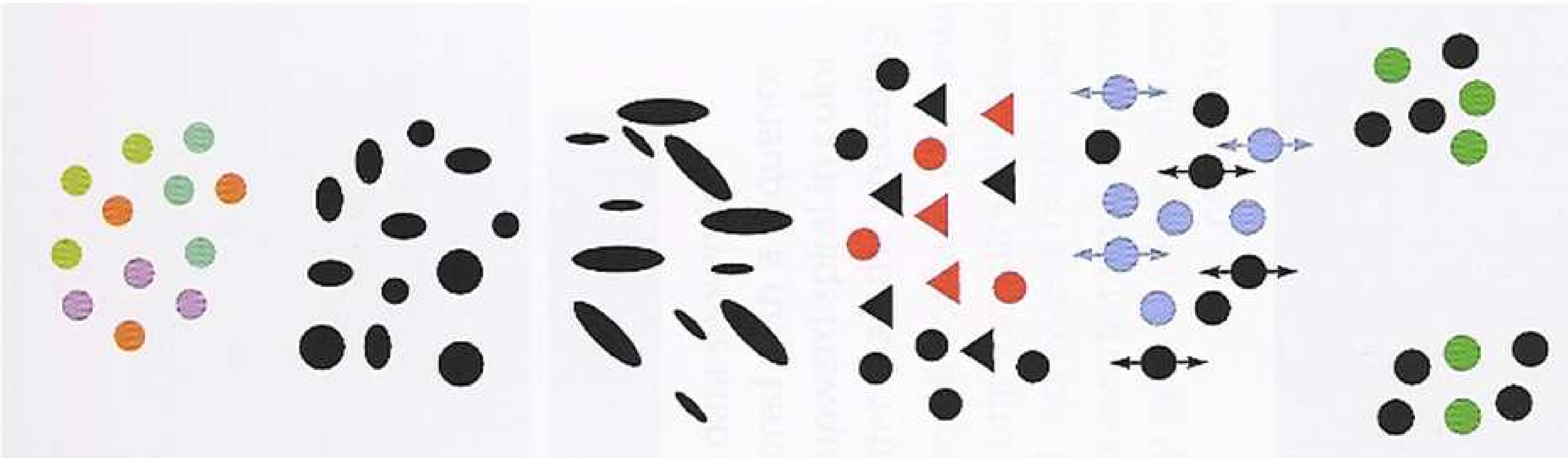
Channel Dynamic Range

linewidth: limited discriminability, but useful



[mappa.mundi.net/maps/maps_014/telegeography.html]

Integral vs. Separable Channels

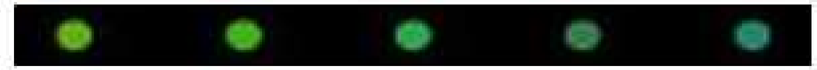


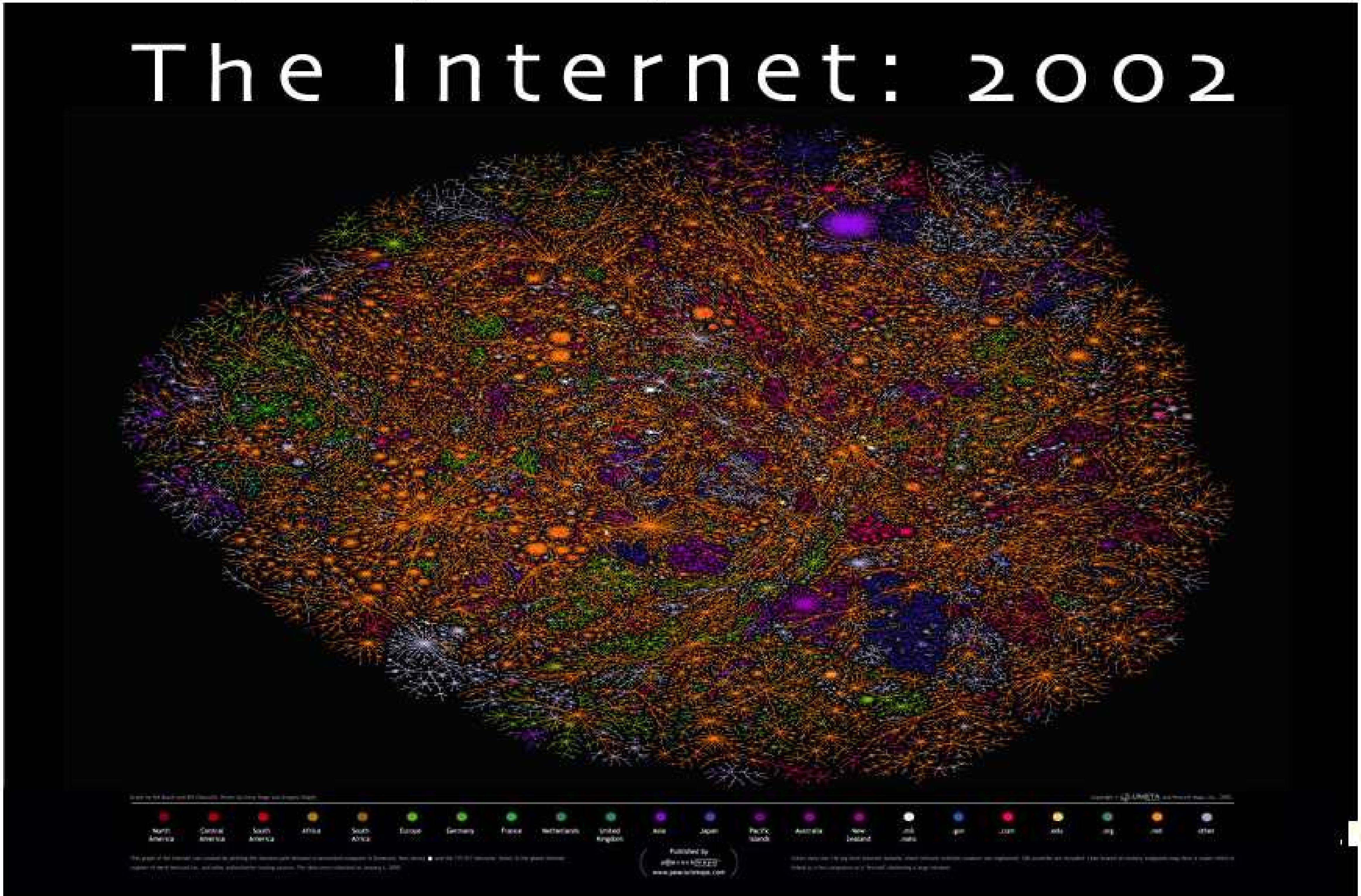
red-green yellow-blue	x-size y-size	size orientation	color shape	color motion	color location

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

Coloring Categorical Data

22 colors, but only ~8 distinguishable





Coloring Categorical Data

discrete small patches separated in space

limited distinguishability: around 8-14

- channel dynamic range: low
- choose bins explicitly for maximum milage

maximally discriminable colors from Ware

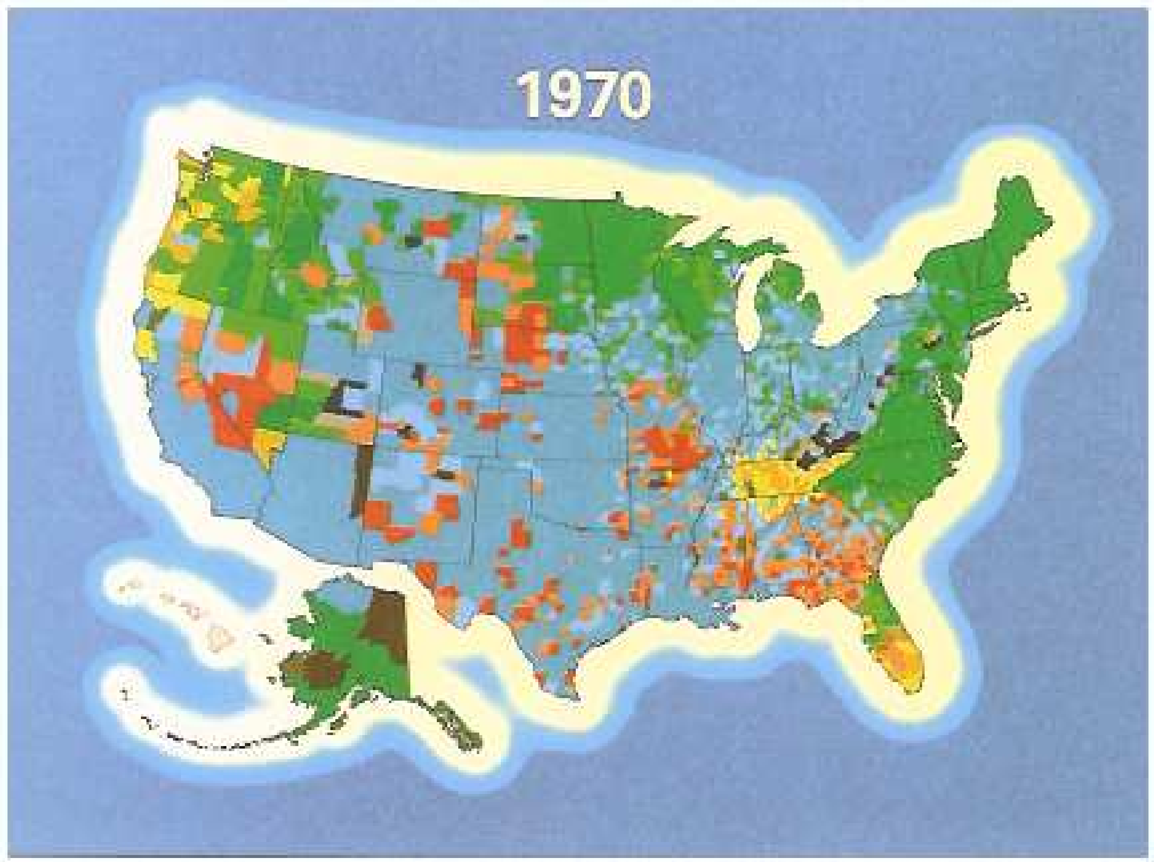
- maximal saturation for small areas

[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.21]

Minimal Saturation for Large Areas

avoid saturated color in large areas

- "excessively exuberant"

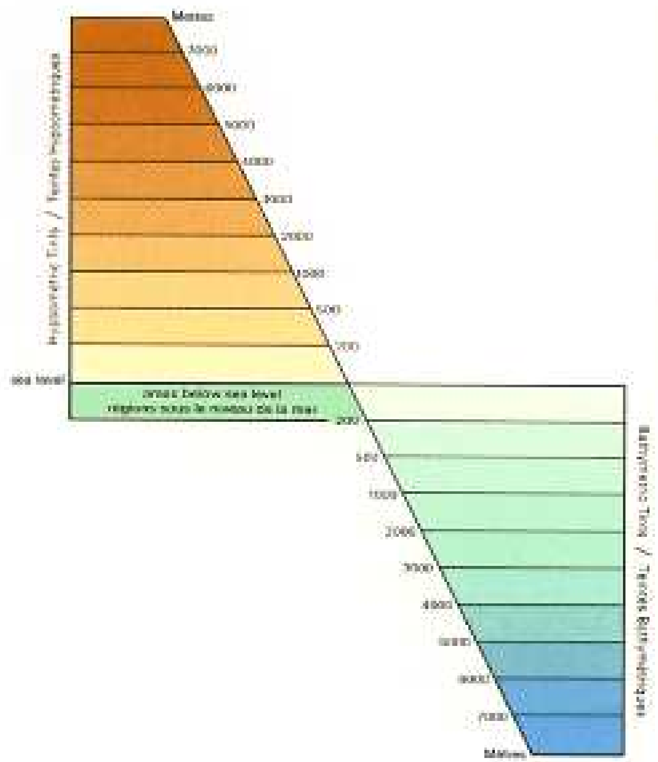


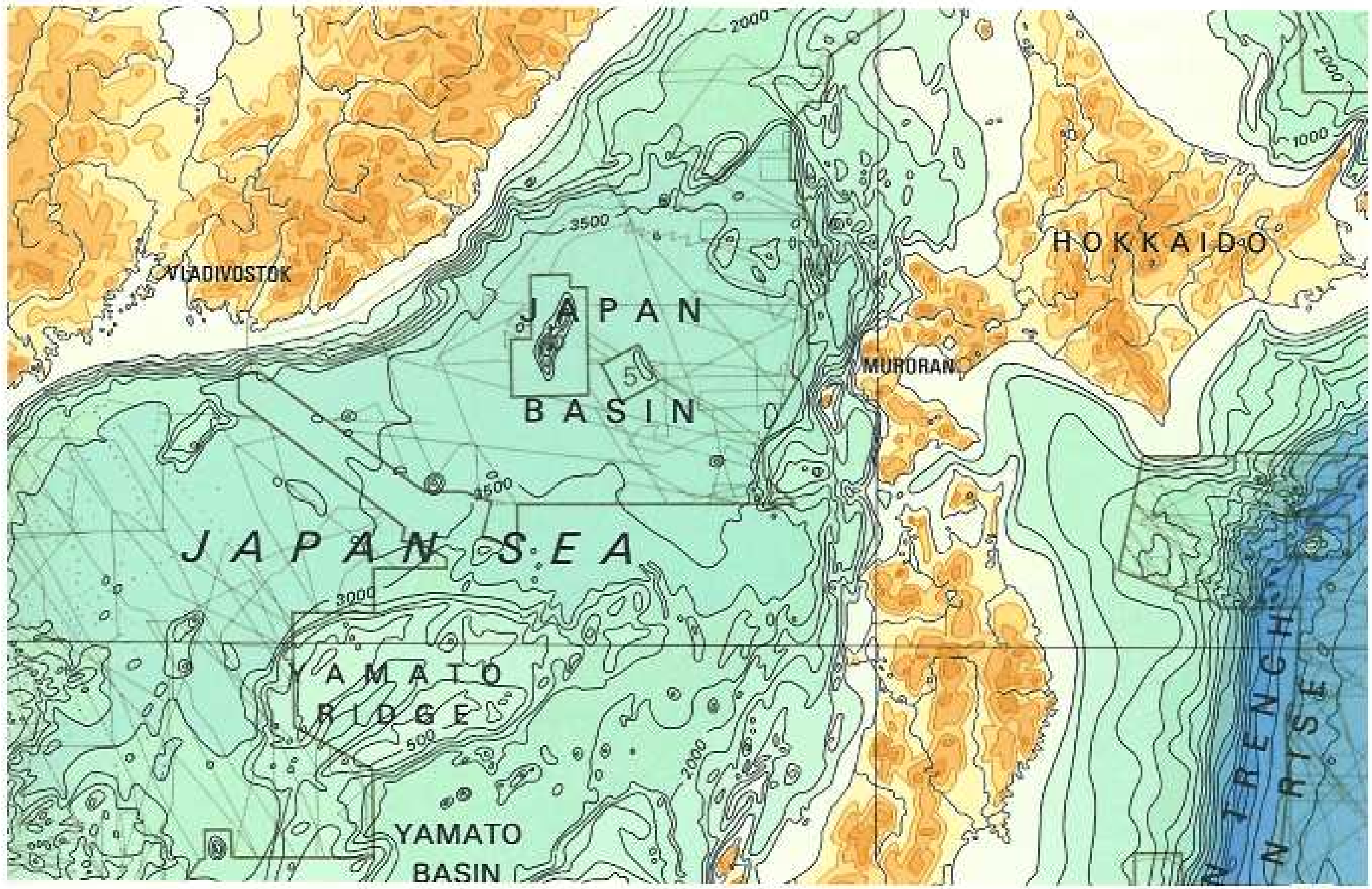
[Edward Tufte, Envisioning Information, p.82]

Minimal Saturation for Large Areas

large continuous areas in pastel

- diverging colormap (bathymetric/hypsometric)



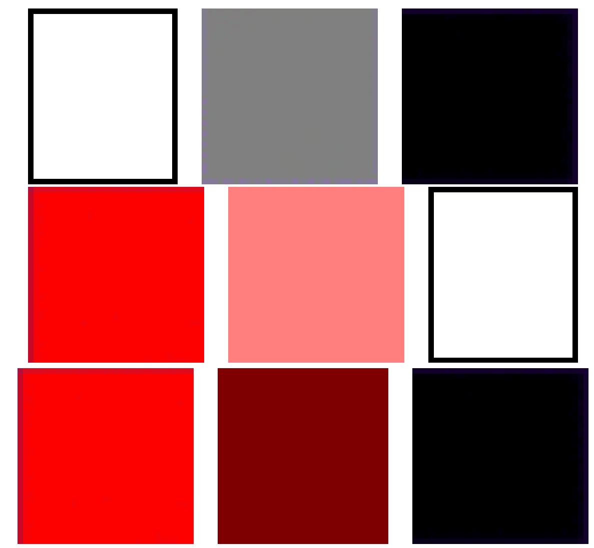


[Tufte, Envisioning Information, p. 91]

Coloring Ordered Data

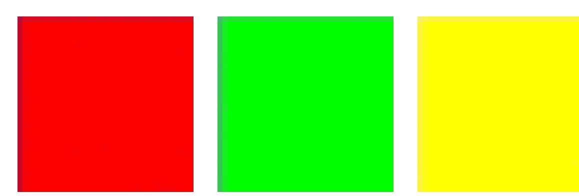
innate visual order

- greyscale/luminance
- saturation
- brightness



debatable visual order

- hue



Coloring Quantitative Data

continuous field

side by side patches highly distinguishable

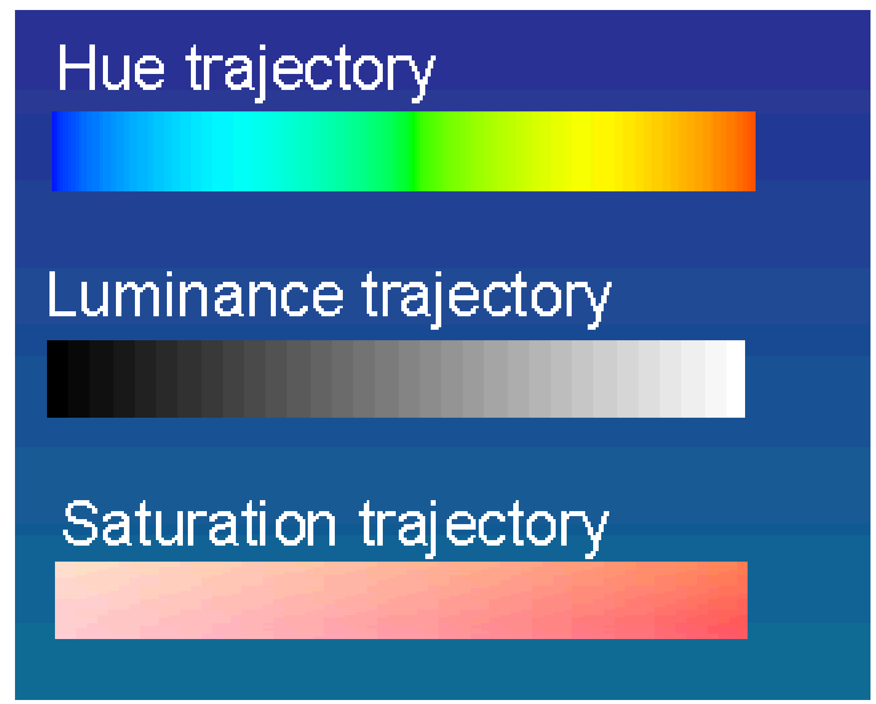
- channel dynamic range: high

mediocre

- hue (rainbow)

good

- greyscale/luminance
- saturation
- brightness

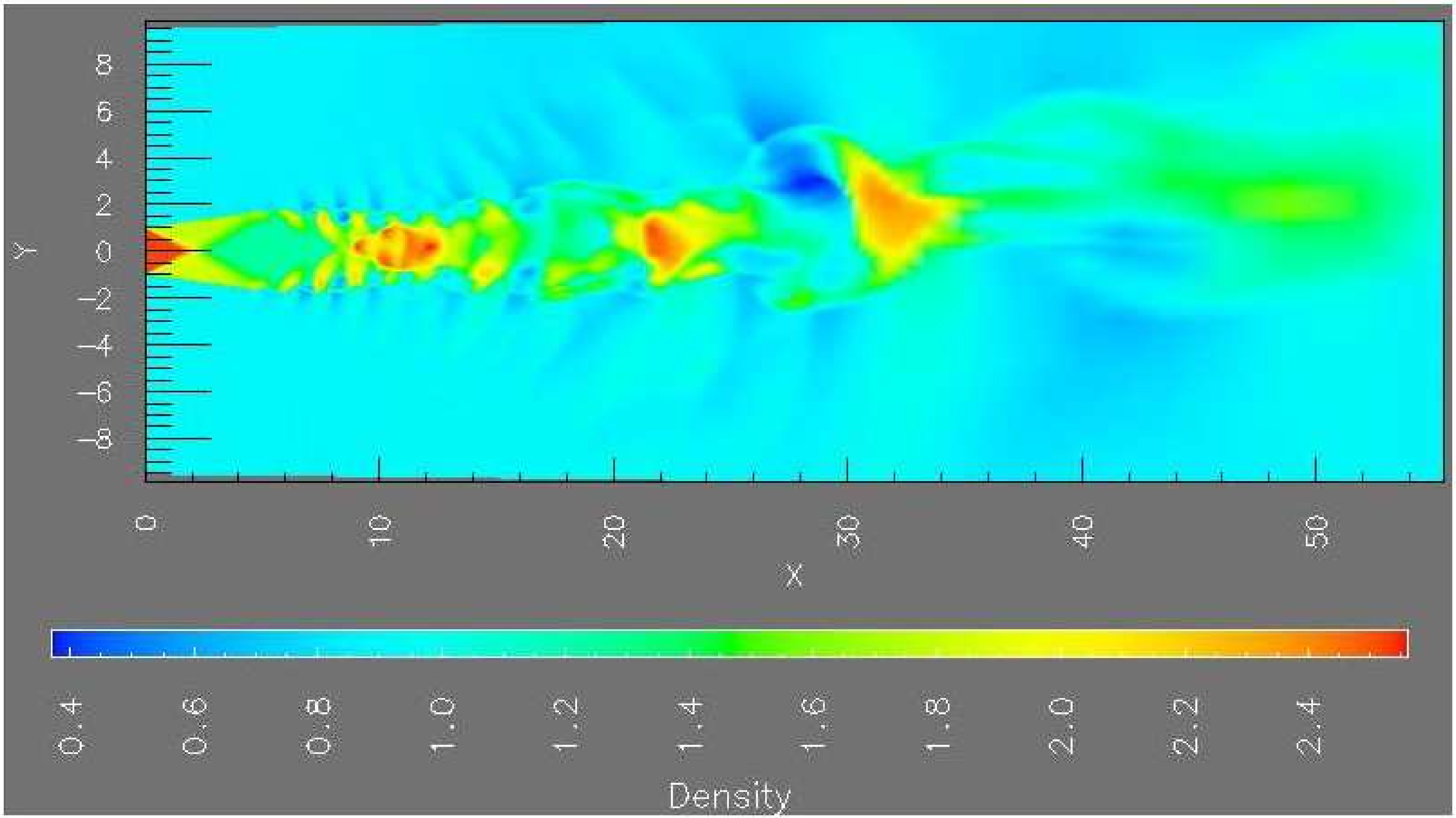


[www.research.ibm.com/visualanalysis/perception.html]

Rainbow Colormap Advantages

low–frequency segmentation

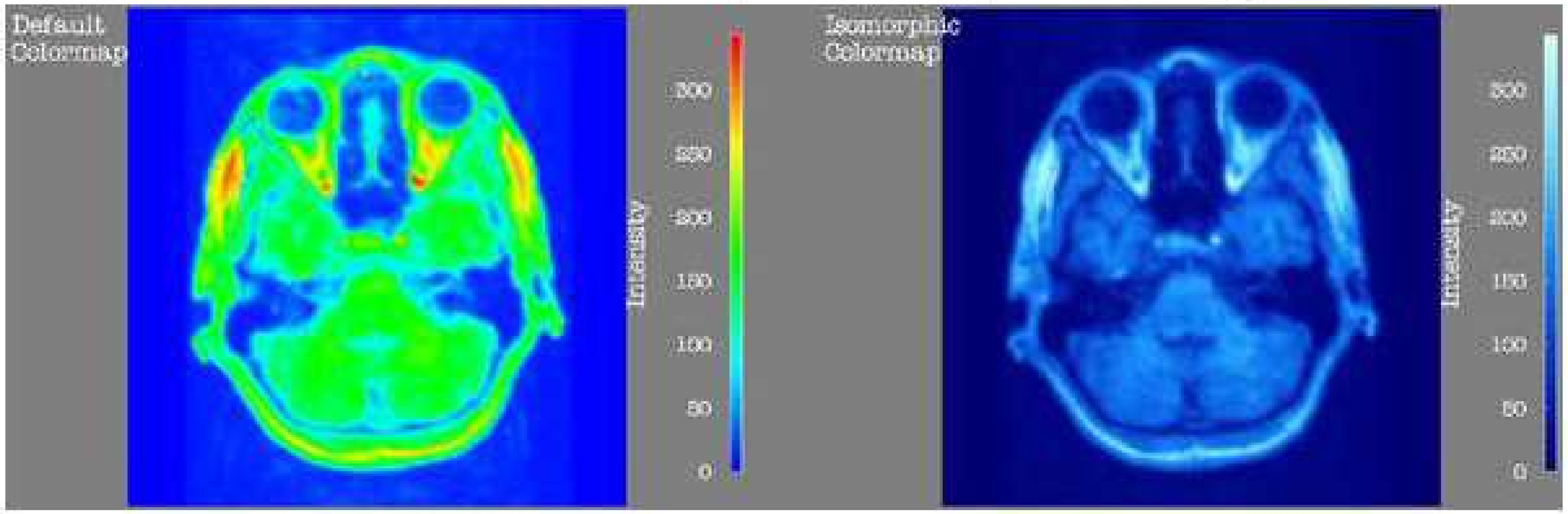
- "the red part", "the orange part", "the green part"



[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color?
http://www.research.ibm.com/people/l/lloydt/color/color.HTM

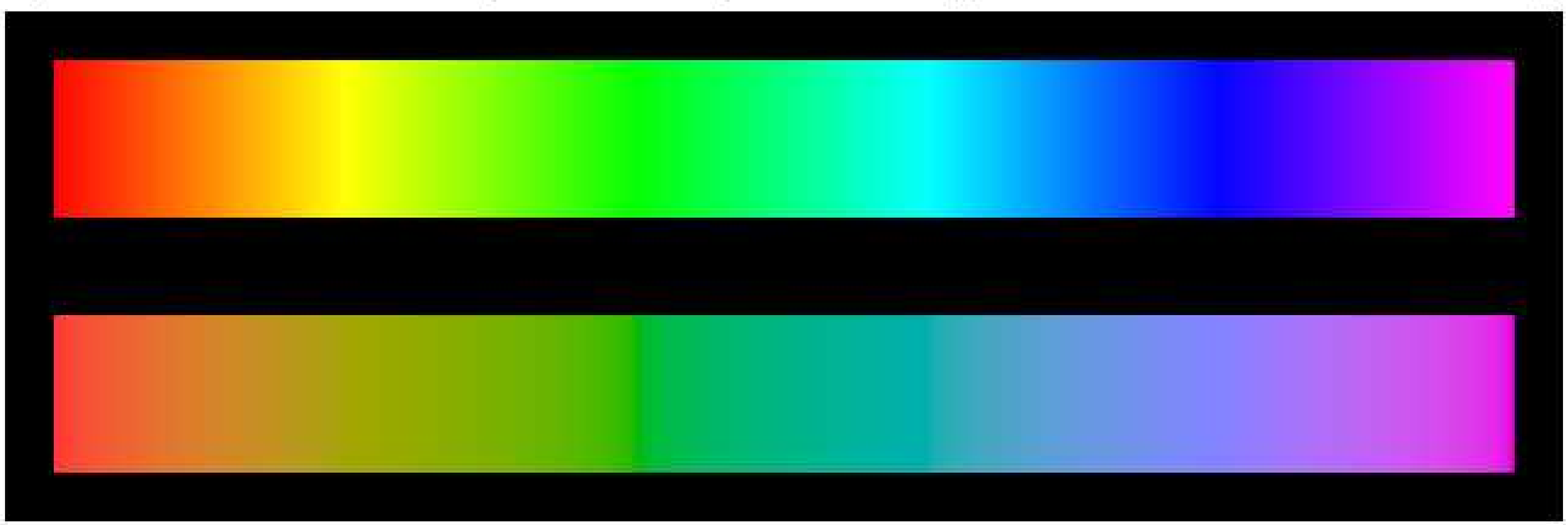
Rainbow Colormap Disadvantages

segmentation artifacts: perceptually nonlinear!



[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm

(partial) solution: perceptually isolinear map

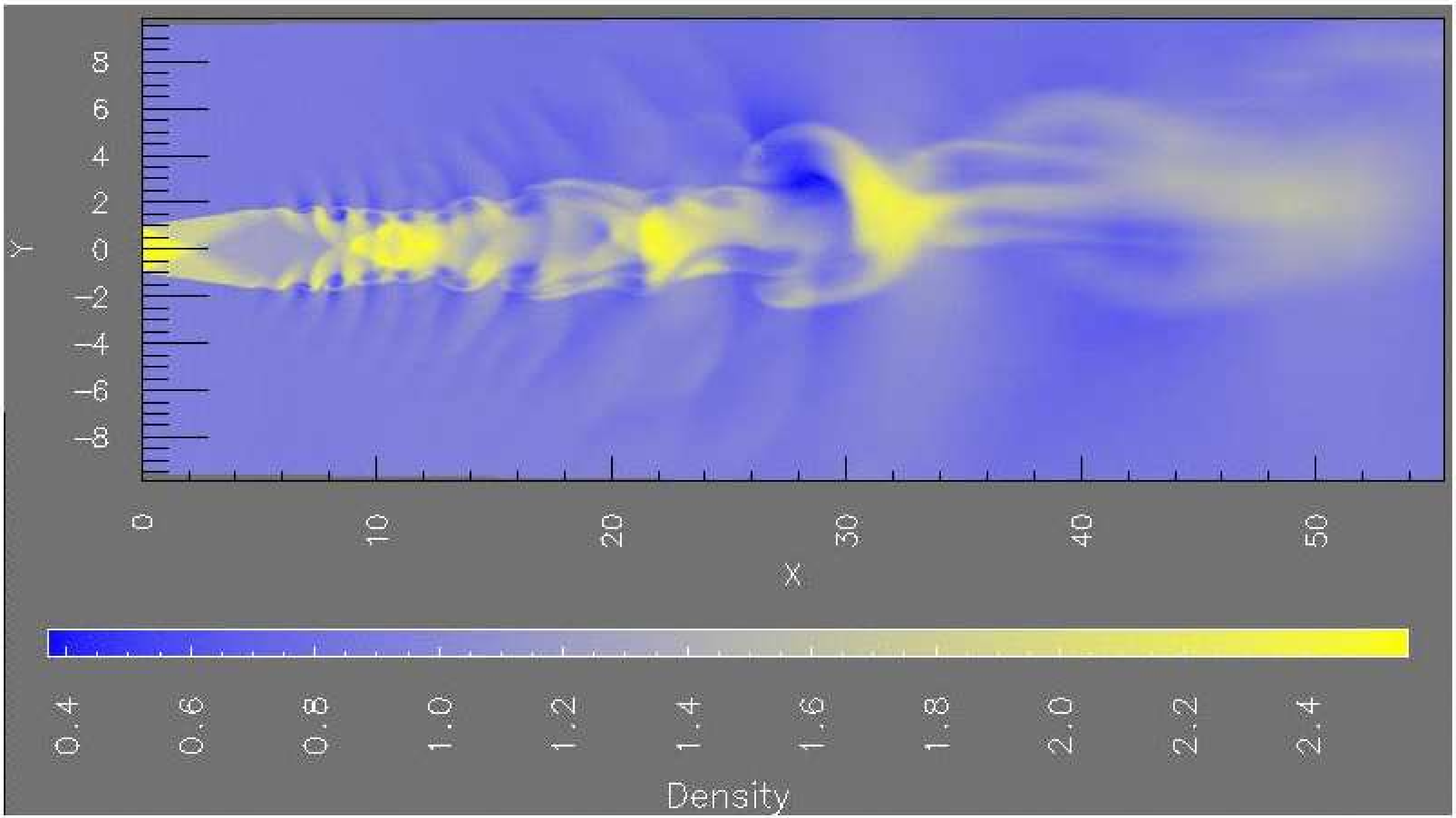


[Kindlmann, Reinhard, and Creem.
Face-based Luminance Matching for Perceptual Colormap Generation. Proc. Vis 02
www.cs.utah.edu/~gk/lumFace]

Non-Rainbow Colormap Advantages

high-frequency continuity

- interpolating between just two hues



[Rogowitz and Treinish, How NOT to Lie with Visualization,
www.research.ibm.com/dx/proceedings/pravda/truevis.htm

Color Deficiency

very low channel dynamic range for some!

protanope
deuteranope

- has red/green deficit
- 10% of males!

tritanope

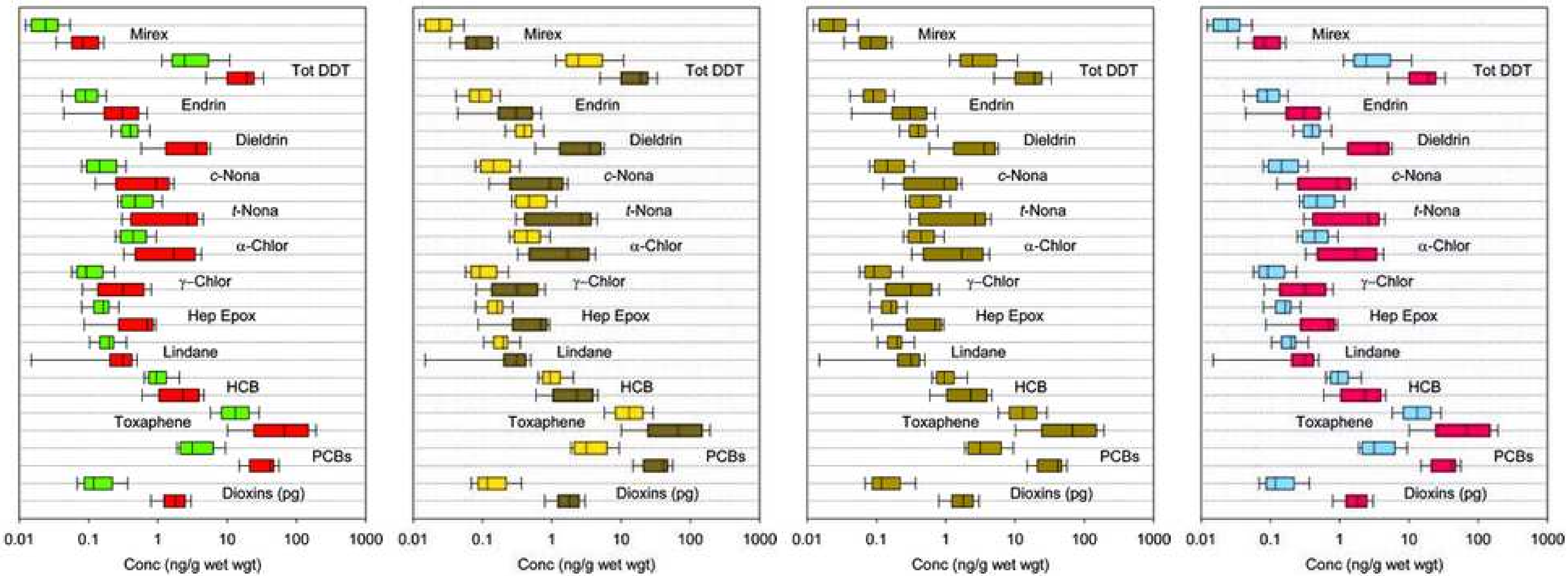
- has yellow/blue deficit

http://www.vischeck.com/vischeck

- test your images

Color Deficiency Examples: vischeck

original protanope deuteranope tritanope



[www.cs.ubc.ca/~tmm/courses/cpsc533c-04-spr/a1/dmitry/533a1.html, citing Global Assessment of Organic Contaminants in Farmed Salmon, Ronald A. Hites, Jeffery A. Foran, David O. Carpenter, M. Coreen Hamilton, Barbara A. Knuth, and Steven J. Schwager, Science 2004 303: 226-229.]

Designing Around Deficiencies

red/green could have domain meaning

then distinguish by more then hue alone

- redundantly encode with saturation, brightness

original · protanope · deuteranope · tritanope

[Courtesy of Brad Paley]

Space vs. Time: Showing Change

literal <--> abstract

time for time — space for time

animation: show time using temporal change

- good: show process

[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]

Space vs. Time: Showing Change

literal — abstract

<-->

time for time — space for time

animation: show time using temporal change

- good: show process
- good: compare by flipping between two things

[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
[www.astroshow.com/ccdpho/pluto.gif]

Space vs. Time: Showing Change

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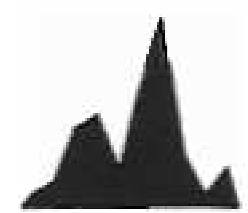
- good: show process
- good: compare by flipping between two things
- bad: compare between many things



[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

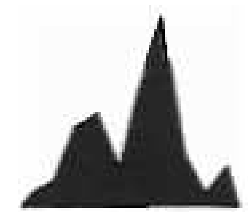
literal ←------------------------------------→ abstract

time for time   space for time

animation: show time using temporal change

- good: show process
- good: compare by flipping between two things
- bad: compare between many things
  interference from intermediate frames



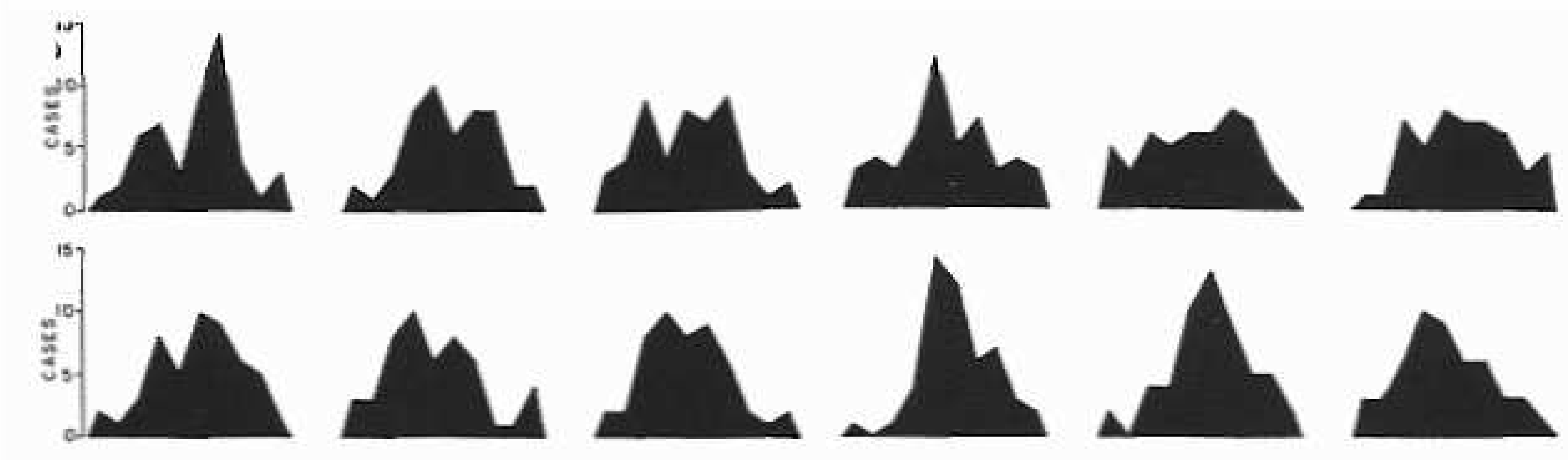
[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
[www.astroshow.com/ccdpho/pluto.gif]
[Edward Tufte. The Visual Display of Quantitative Information, p 172]

Space vs. Time: Showing Change

literal <--> abstract

time for time — space for time

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



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

More Information

http://www.cs.ubc.ca/~tmm
- talks, papers, projects: lots of pictures!

UBC Term 1 grad course
- CPSC 533C Visualization

current project domains
- bioinformatics, data mining, sustainability

past project domains
- topology, networking, computational linguistics, ...