

Seeing, Hearing, and Touching: Putting It All Together

Seeing Module

Rapid Vision

Rensink

Visual Encoding

Munzner

Procedural Vision

Rensink

Navigating Visual Space

Munzner



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SIGGRAPH2004



Overview

Visual Encoding

- Perceptual Channels
- Visualization Frameworks
- Spatial Layout
- Color

Navigating Visual Space

- External Representation
- Navigation/Zooming
- Focus+Context
 - Occlusion
 - Highlighting
- Spatial Navigation
 - Zooming
 - Focus+Context

Visual Encoding

represent dataset using perceptual channels

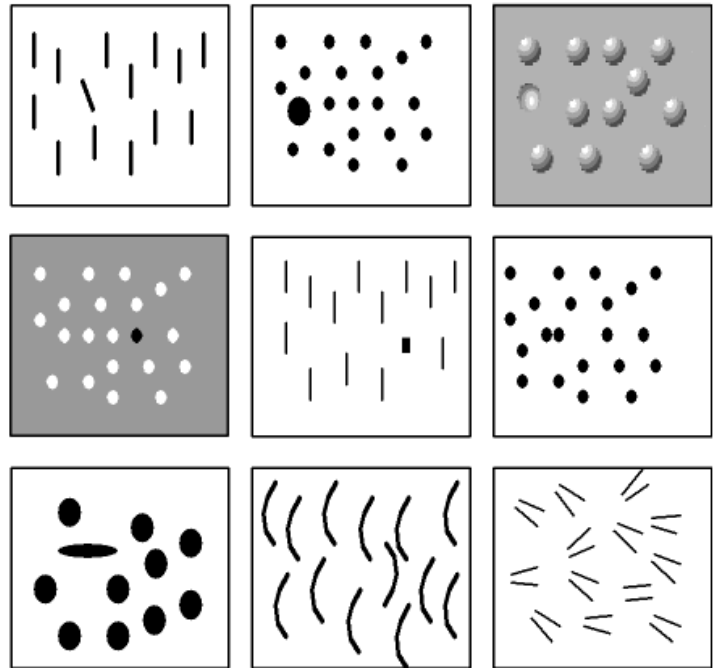
challenges

- rapid processing for only one channel
sometimes two

Preattentive Visual Channels

many preattentive channels of visual modality

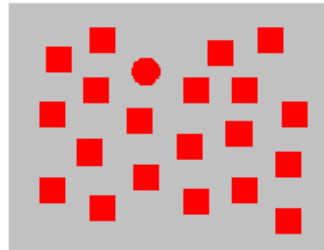
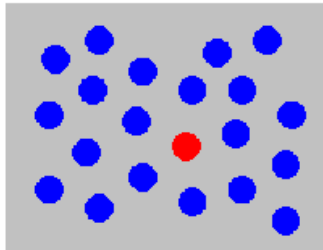
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction
- and more...



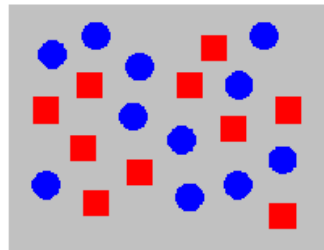
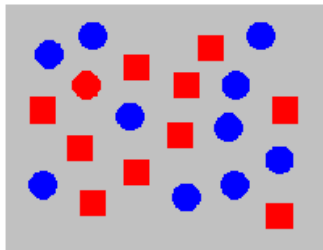
Preattentive Visual Channels

color alone: preattentive

shape alone: preattentive



combined hue and shape: multimodal



- requires attention
- search speed linear with distractor count

Visual Encoding

represent dataset using perceptual channels

challenges

- rapid processing for only one channel
sometimes two
- only some channels separable
others integral

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.]

Visual Encoding

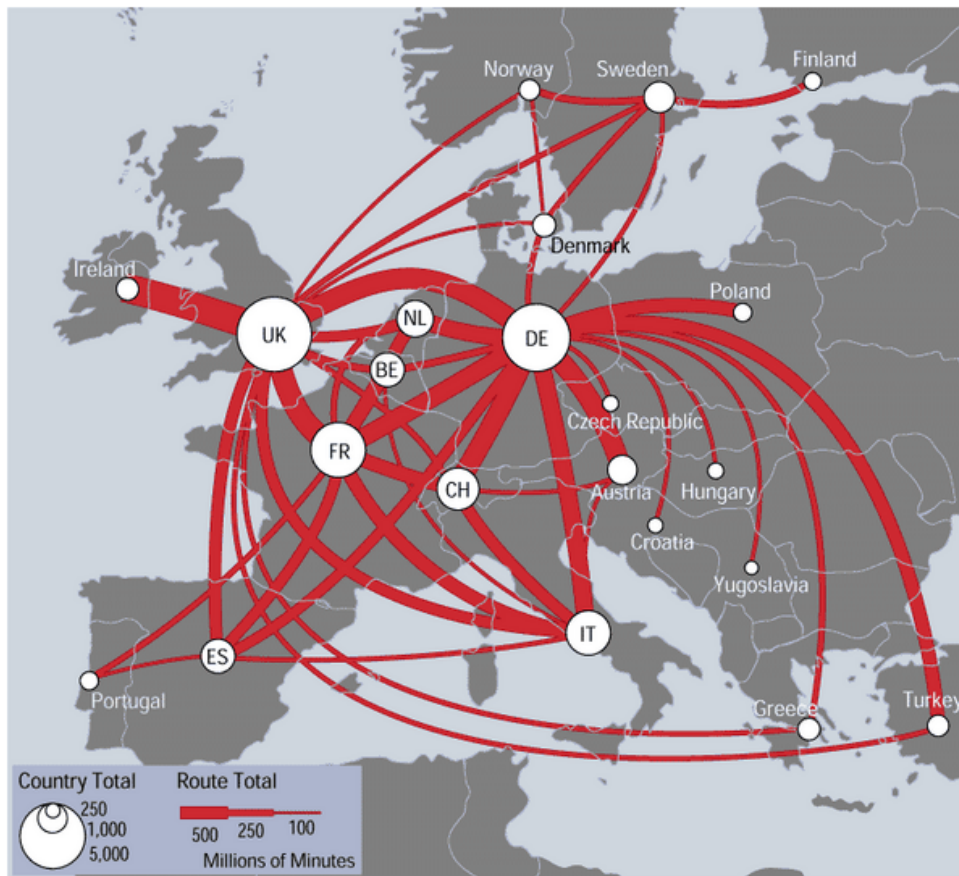
represent dataset using perceptual channels

challenges

- rapid processing for only one channel
sometimes two
- only some channels separable
others integral
- not all channels created equal
variable dynamic range

Channel Dynamic Range

linewidth: limited discriminability, but salient



Visual Encoding

represent dataset using perceptual channels

challenges

- rapid processing for only one channel
sometimes two
- only some channels separable
others integral
- not all channels created equal
variable dynamic range

vast parameter space of choices

- need methodology for guidance

information visualization framework

- how to match data variables to visual channel

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Framework

Data Variables

- 1D, 2D, 3D, 4D, 5D, ..., ND

Geometric Primitives/ Marks

- point, line, area, surface, volume

Perceptual Channels/ Retinal Properties

- size, brightness, color, texture, orientation, shape,...
- parameters control appearance of marks
- channels of information flowing from retina to brain

Data Types

- nominal, ordered, quantitative

[Mackinlay/Card; Bertin; Wilkinson; Stolte et al]

Data Types

categorical (nominal)

- apples, oranges, bananas



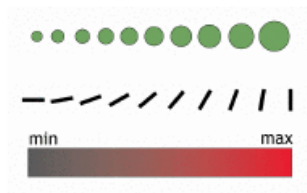
ordered (ordinal)

- small, medium, large
- days: Sun, Mon, Tue, Wed, Thu, Fri, Sat

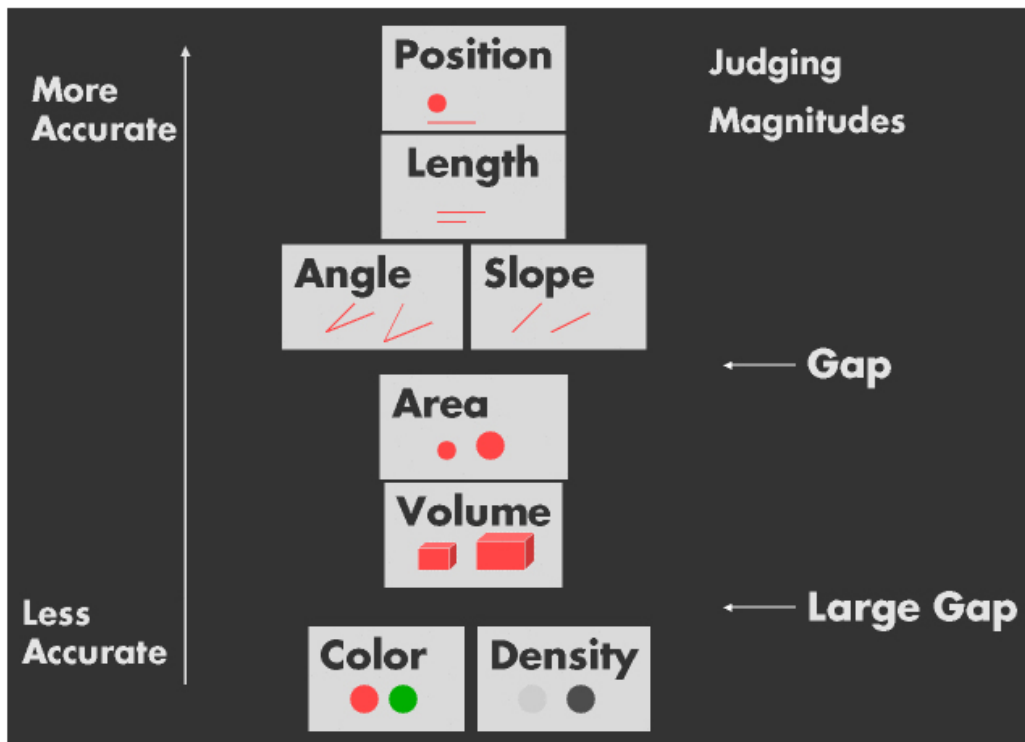


continuous (quantitative)

- 10 inches, 17 inches, 23 inches

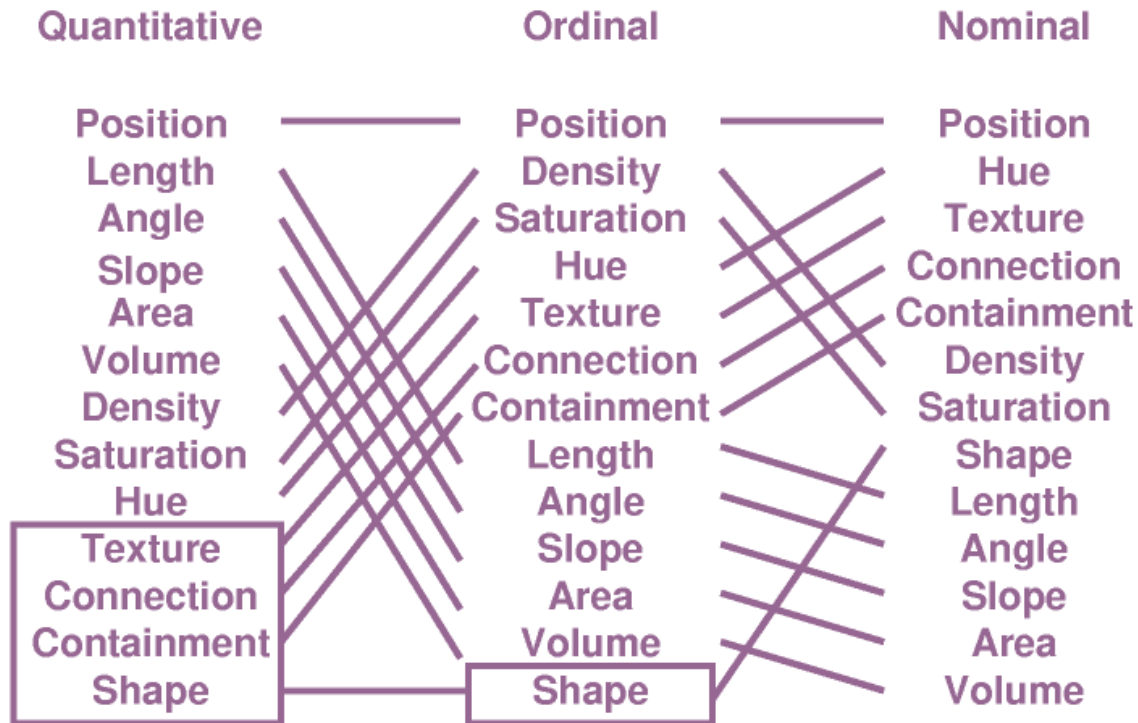


Ranked Perceptual Channels, Quantitative Data



Ranking Varies by Data Type

spatial position best for all types



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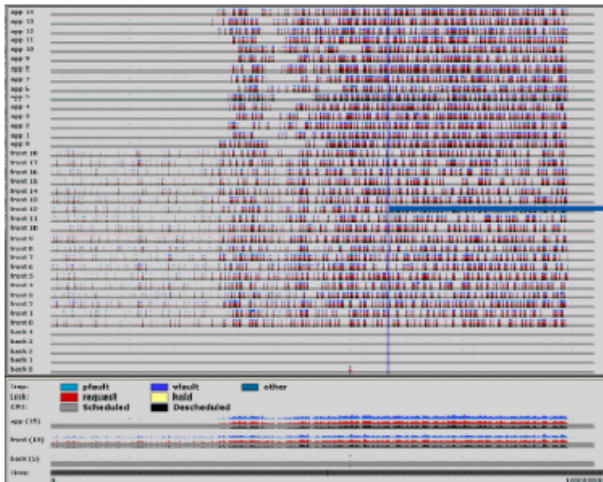
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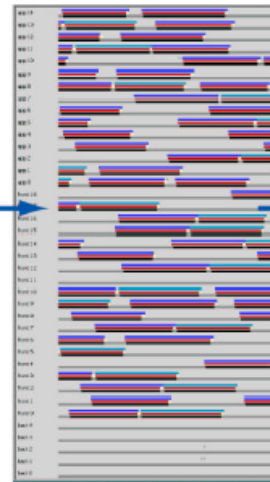
Interactive Ordering: Rivet

performance analysis of parallel system

overview



zoom



reorder



[Bosch, Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study, HPCA6, 2000.
graphics.stanford.edu/papers/rivet_argus]

Space vs. Time: Showing Change



animation: show time using temporal change

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



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

Space vs. Time: Showing Change



animation: show time using temporal change

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



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



Space vs. Time: Showing Change



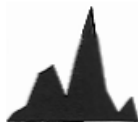
animation: show time using temporal change

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

change blindness from intermediate frames



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

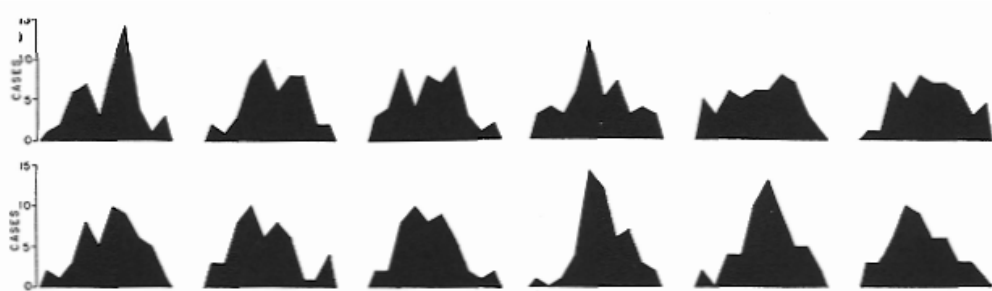


Space vs. Time: Showing Change



small multiples: show time using space

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



Overview

Visual Encoding

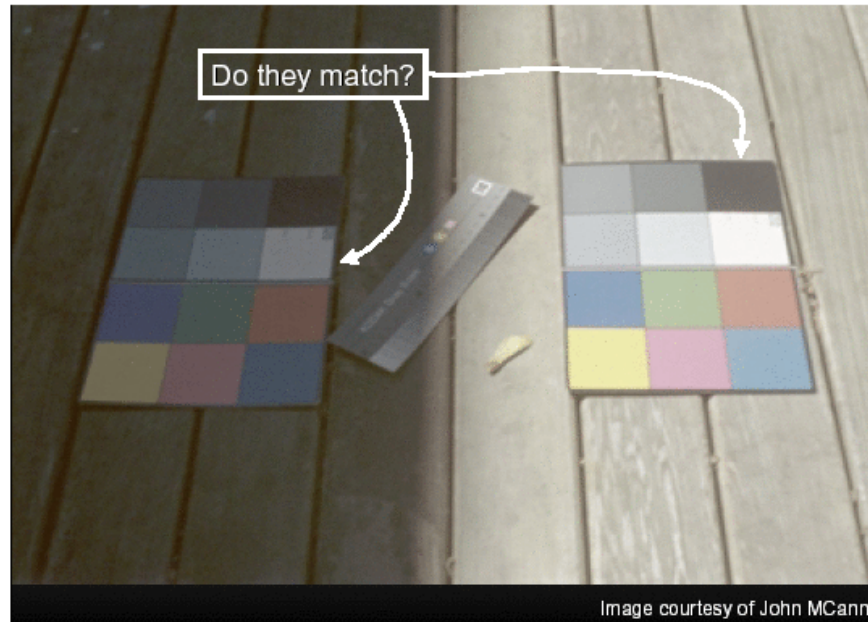
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Color/Brightness Constancy

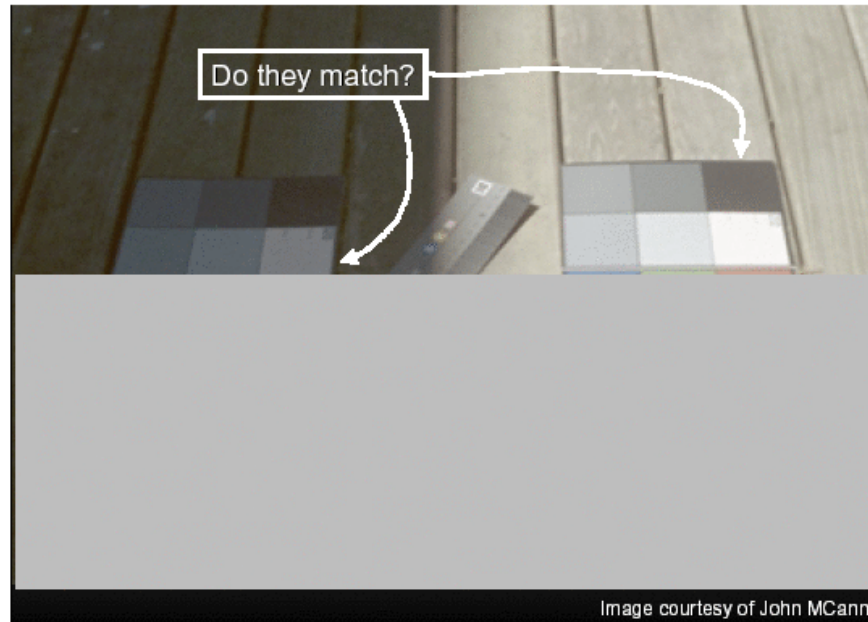
segmentation: relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color/Brightness Constancy

segmentation: relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color/Brightness Constancy

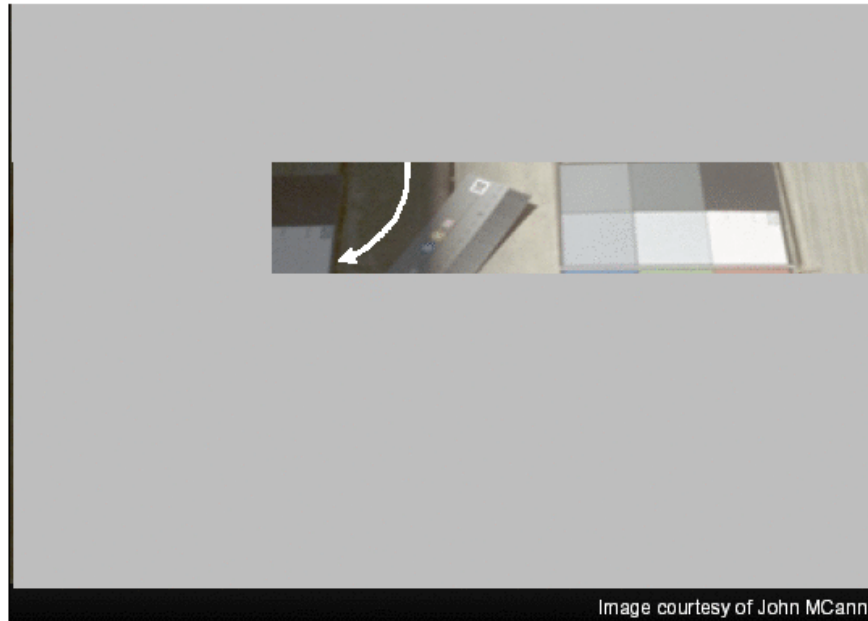
segmentation: relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color/Brightness Constancy

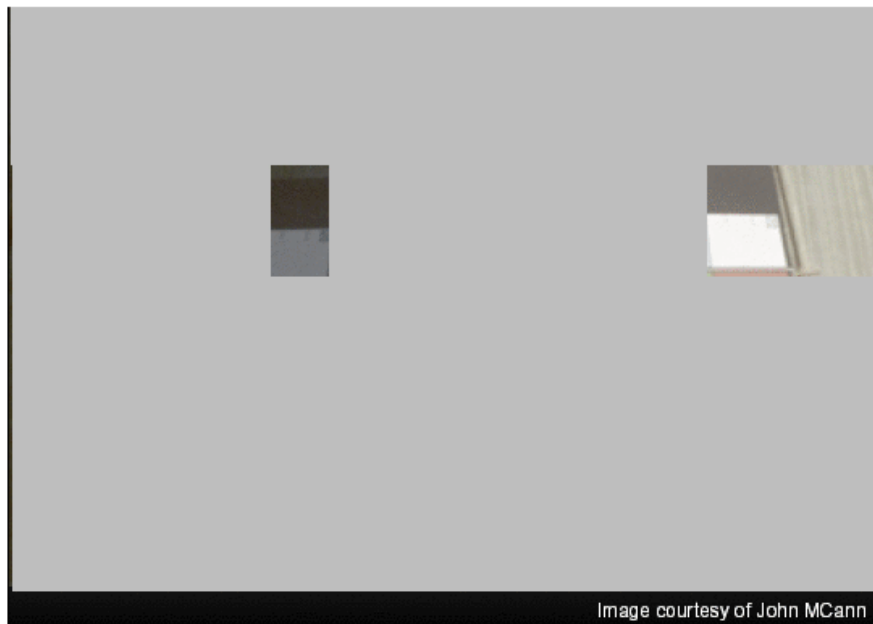
segmentation: relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color/Brightness Constancy

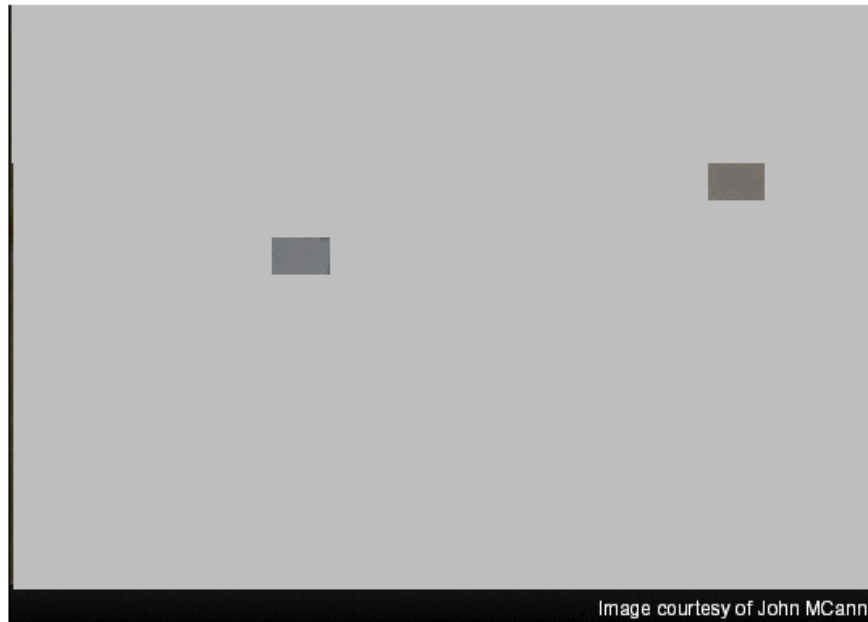
segmentation: relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color/Brightness Constancy

segmentation: relative judgements



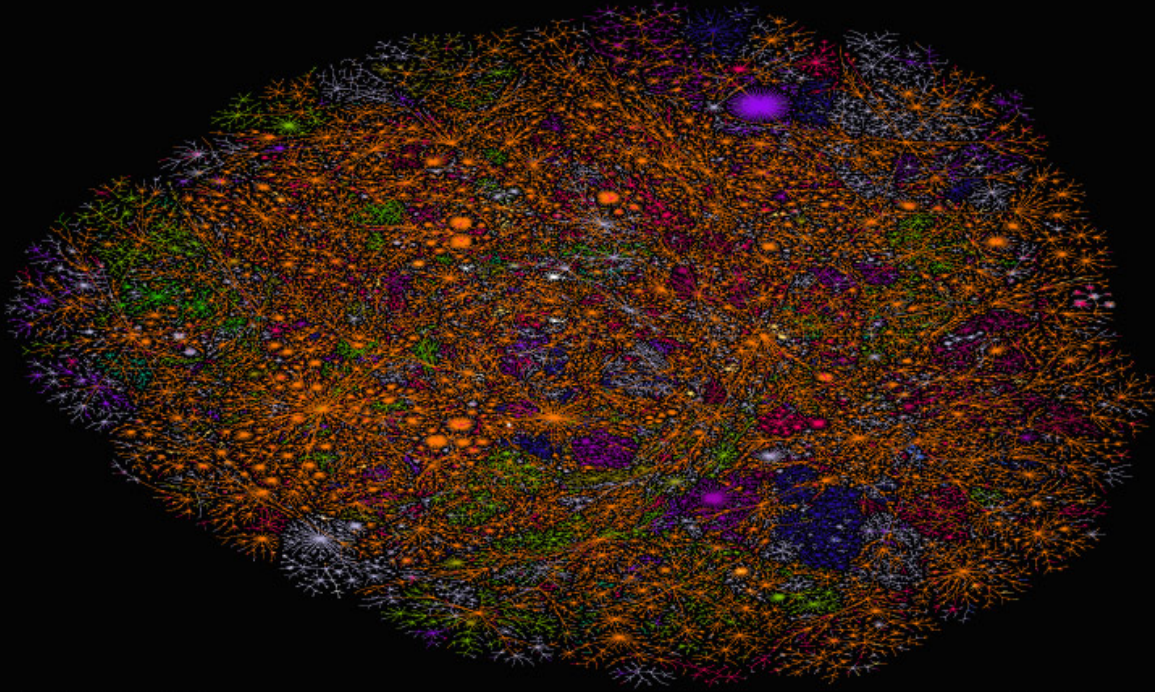
[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Coloring Categorical Data

22 colors, but only ~8 distinguishable



The Internet: 2002



Graph by the Rand and MIT Research Center for Internet and Society Team



The graph of the Internet was created by plotting the shortest path between a selected computer in Germany, New Jersey and the 100,000 nearest nodes in the global network. Images of North America, etc., and other administrative mapping systems. The data were collected in January 1, 2002.

Published by
arXiv:cs/0212222
www.petercollinge.com

Colors show the 100 top level domain classes whose network addresses couldn't be assigned. 100 numbers are included. Some branch of routing topology may show a color which is listed in a few computers or a firewall, obtaining a large network.

Coloring Categorical Data

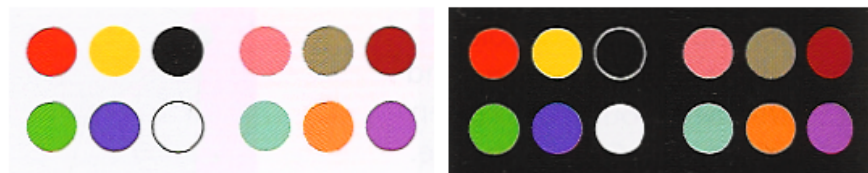
discrete small patches separated in space

limited distinguishability: around 8–14

- channel dynamic range: low

maximally discriminable colors from Ware

- maximal saturation for small areas



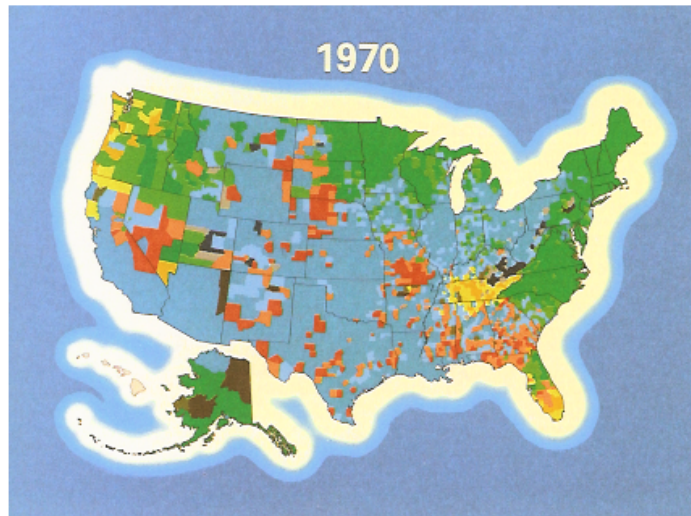
[Colin Ware, Information Visualization: Perception for Design.
Morgan Kaufmann 1999. Figure 4.21]

choose bins explicitly for maximum mileage

Minimal Saturation for Large Areas

avoid saturated color in large areas

- "excessively exuberant"

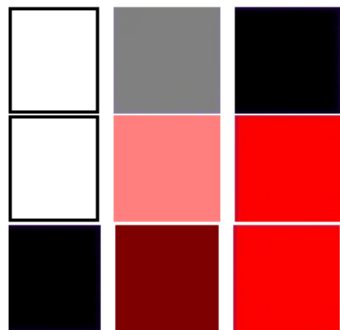


[Edward Tufte, Envisioning Information, p.82]

Coloring Ordered Data

innate visual order

- greyscale/luminance
- saturation
- brightness



visual order

- hue



Coloring Quantitative Data

continuous field

side by side patches highly distinguishable

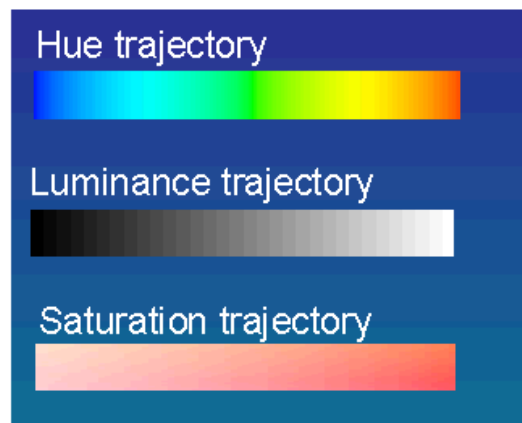
- channel dynamic range: high

mediocre

- hue (rainbow)

good

- greyscale/luminance
- saturation
- brightness

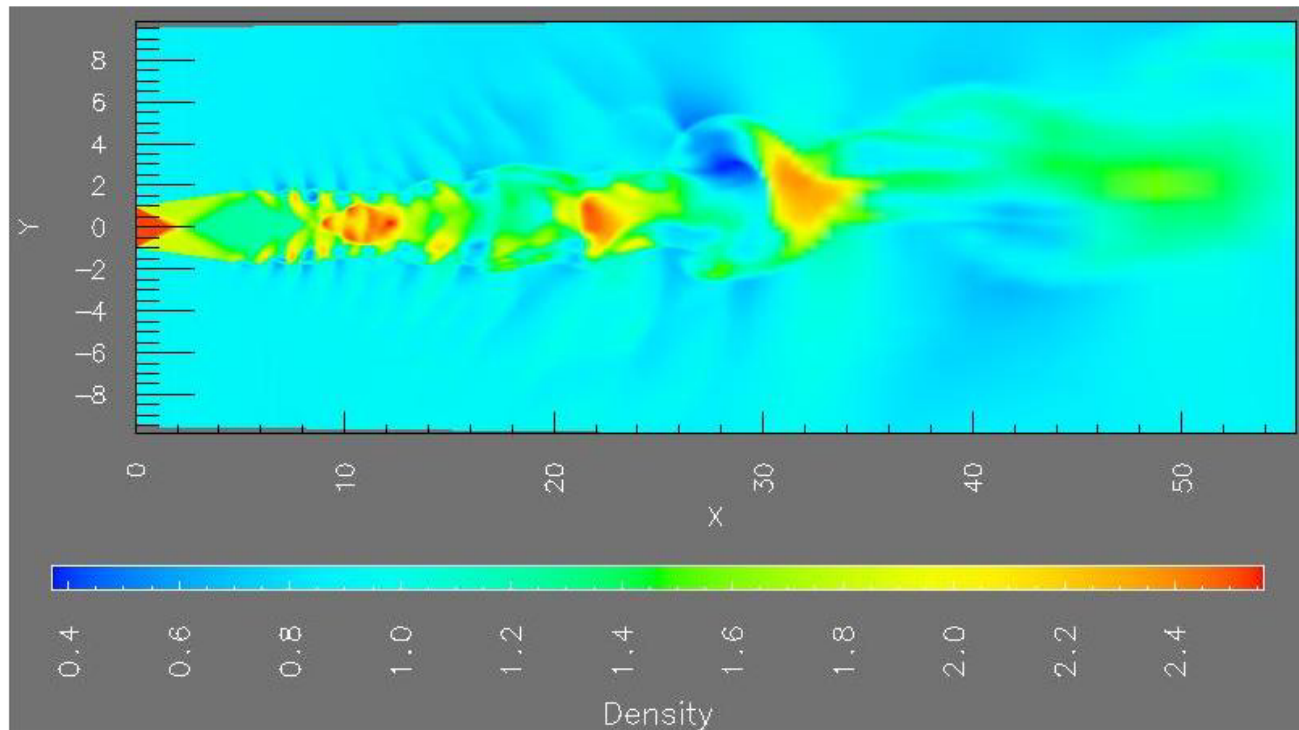


[www.research.ibm.com/visualanalysis/perception.html]

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/lloyd/color/color.HTM>

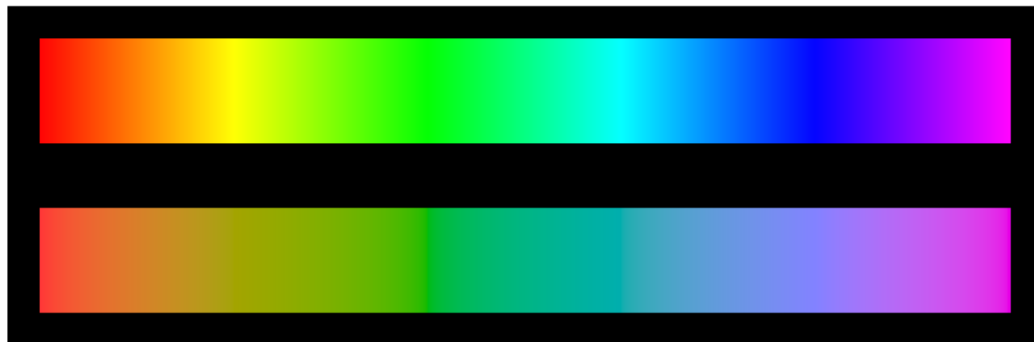
Rainbow Colormap Disadvantages

segmentation artifacts

- popular interpolation perceptually nonlinear!

solution

- create perceptually isolinear map



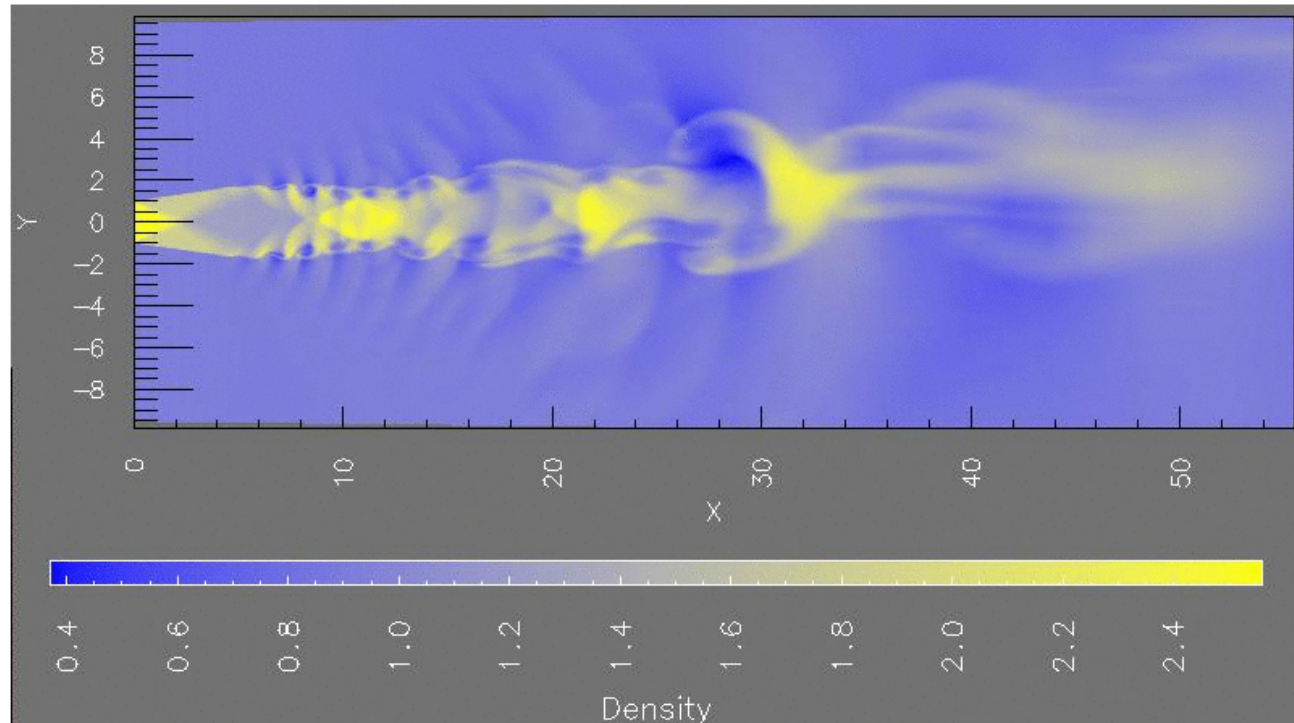
[Kindlmann, Reinhard, and Creem.

Face-based Luminance Matching for Perceptual Colormap Generation. Proc. Vis 02
www.cs.utah.edu/~gk/lumFace]

Non-Rainbow Colormap Advantages

high-frequency continuity

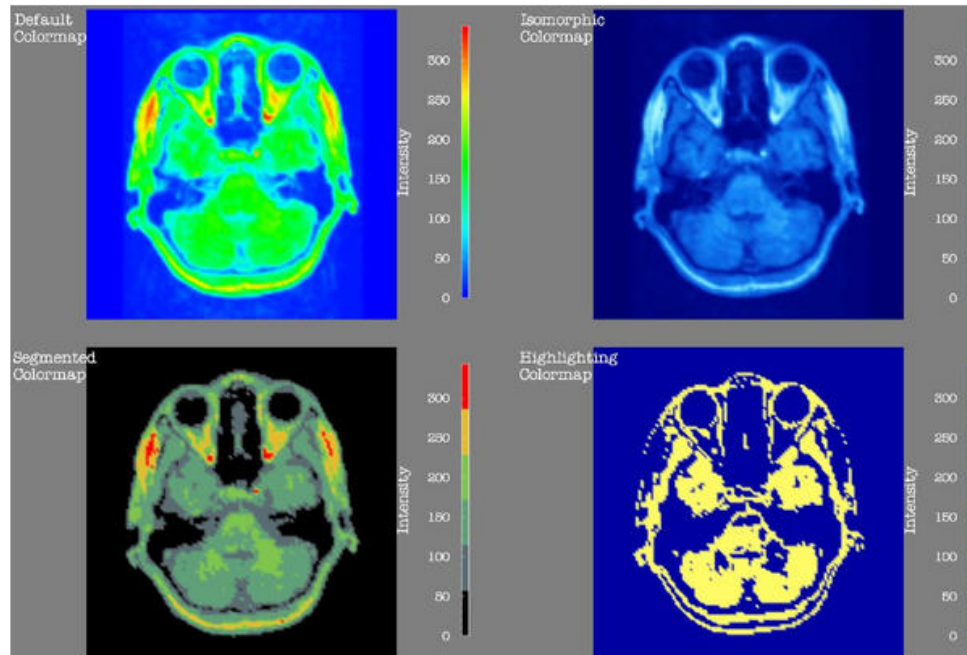
- interpolating between just two hues



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

Segmenting Colormaps

explicit rather than implicit segmentation



[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

deutanope

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

tritanope

- has yellow/blue deficit

<http://www.vischeck.com/vischeck>

- test your images

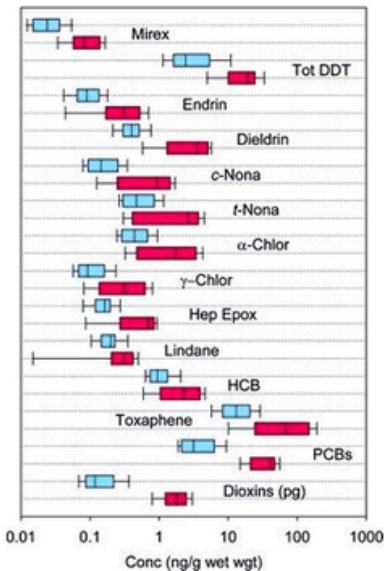
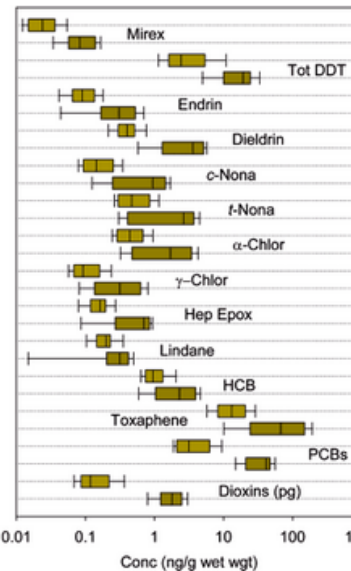
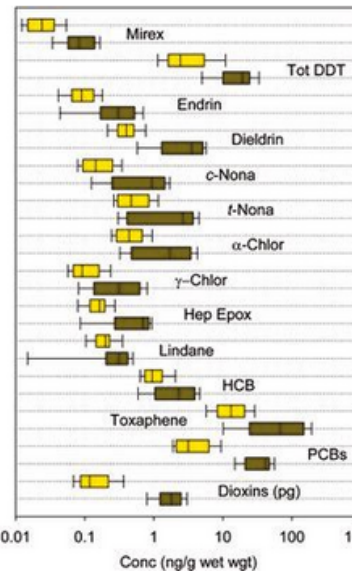
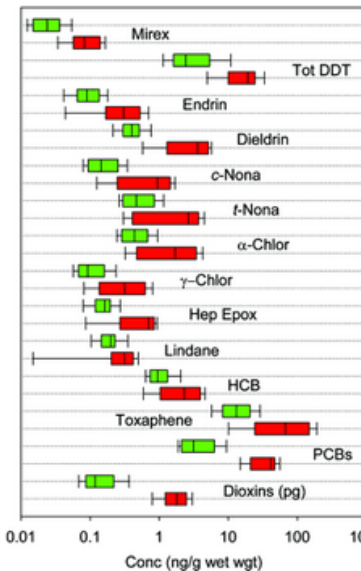
Color Deficiency Examples: vischeck

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 than hue alone

- redundantly encode with saturation, brightness

original

Qty	Limit	Dest	Status	Ex Qty
+ 20,000	29.96			10,000
+ 80,000	MKT			13,000
+ 20,000	MKT		Cxl:Trd	15,000
- 200,000	30		Cor:Yes	86,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port		17,000
+ 20,000	29.96	Joe G.	Cxl:Trd	20,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port	Cxl:Brk	
+ 20,000	29.96	Joe G.		13,000
+ 80,000	29.96	DOT		10,000
- 200,000	MKT			200,000
+ 20,000	MKT	Joe G.		25,000

protanope

Qty	Limit	Dest	Status	Ex Qty
+ 20,000	29.96			10,000
+ 80,000	MKT			13,000
+ 20,000	MKT		Cxl:Trd	15,000
- 200,000	30		Cor:Yes	86,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port		17,000
+ 20,000	29.96	Joe G.	Cxl:Trd	20,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port	Cxl:Brk	
+ 20,000	29.96	Joe G.		13,000
+ 80,000	29.96	DOT		10,000
- 200,000	MKT			200,000
+ 20,000	MKT	Joe G.		25,000

deuteranope

Qty	Limit	Dest	Status	Ex Qty
+ 20,000	29.96			10,000
+ 80,000	MKT			13,000
+ 20,000	MKT		Cxl:Trd	15,000
- 200,000	30		Cor:Yes	86,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port		17,000
+ 20,000	29.96	Joe G.	Cxl:Trd	20,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port	Cxl:Brk	
+ 20,000	29.96	Joe G.		13,000
+ 80,000	29.96	DOT		10,000
- 200,000	MKT			200,000
+ 20,000	MKT	Joe G.		25,000

tritanope

Qty	Limit	Dest	Status	Ex Qty
+ 20,000	29.96			10,000
+ 80,000	MKT			13,000
+ 20,000	MKT		Cxl:Trd	15,000
- 200,000	30		Cor:Yes	86,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port		17,000
+ 20,000	29.96	Joe G.	Cxl:Trd	20,000
+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port	Cxl:Brk	
+ 20,000	29.96	Joe G.		13,000
+ 80,000	29.96	DOT		10,000
- 200,000	MKT			200,000
+ 20,000	MKT	Joe G.		25,000

[Courtesy of Brad Paley]

More Reading: Perceptual Channels

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 5: Visual Attention and Information That Pops Out

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 6: Static and Moving Patterns

The Psychophysics of Sensory Function, S. S. Stevens, Sensory Communication, MIT Press, 1961, pp 1–33.

<http://www.cs.ubc.ca/~tmm/courses/cpsc533c-03-spr/readings/ss.pdf>

Perception in Visualization. Christopher G. Healey

<http://www.csc.ncsu.edu/faculty/healey/PP/index.html>

More Reading: Frameworks

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

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>

The Structure of the Information Visualization Design Space. Stuart Card and Jock Mackinlay, Proc. InfoVis 97
<http://citeseer.nj.nec.com/card96structure.html>

The Grammar of Graphics, Leland Wilkinson, Springer 1999

Semiology of Graphics: Diagrams, Networks, Maps. Jaques Bertin. University of Wisconsin Press, Madison (WI), 1983. W. J. Berg (Translator).

More Reading: Spatial Layout

The Visual Design and Control of Trellis Display

R. A. Becker, W. S. Cleveland, and M. J. Shyu

Journal of Computational and Statistical Graphics, 5:123–155. (1996).

<http://cm.bell-labs.com/stat/doc/trellis.jcgs.col.ps>

Envisioning Information. Edward Tufte. Graphics Press, 1990.

Chapter 4: Small Multiples, Chapter 6: Narratives of Space and Time

The Elements of Graphing Data, William S. Cleveland, Hobart Press 1994.

The Table Lens: Merging Graphical and Symbolic Representations in an Interactive Focus + Context Visualization for Tabular Information

Ramana Rao and Stuart K. Card, SIGCHI '94, pp. 318–322.

<http://citeseer.ist.psu.edu/545353.html>

Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study. Robert Bosch, Chris Stolte, Gordon Stoll, Mendel Rosenblum, and Pat Hanrahan. In Proc. Sixth IEEE International Symposium on High-Performance Computer Architecture, Jan 2000. http://graphics.stanford.edu/papers/rivet_argus/

More Reading: Color

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 3: Lightness, Brightness, Contrast, and Constancy

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 4: Color

Envisioning Information. Edward Tufte. Graphics Press, 1990. Chapter
5: Color and Information

How Not to Lie with Visualization, Bernice E. Rogowitz and Lloyd A. Treinish, Computers In
Physics 10(3) May/June 1996, pp 268–273.
<http://www.research.ibm.com/dx/proceedings/pravda/truevis.htm>

A Field Guide To Digital Color, Maureen Stone, AK Peters 2003