

Color

Lecture 7 CPSC 533C, Fall 2004

4 October 2004

Tamara Munzner

Readings

Ware, Chapter 3: Lightness, Brightness, Contrast, and Constancy

Ware, Chapter 4: Color

Tufte, 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>

Color use guidelines for data representation. C. Brewer, 1999.

<http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/ASApaper.html>

More

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

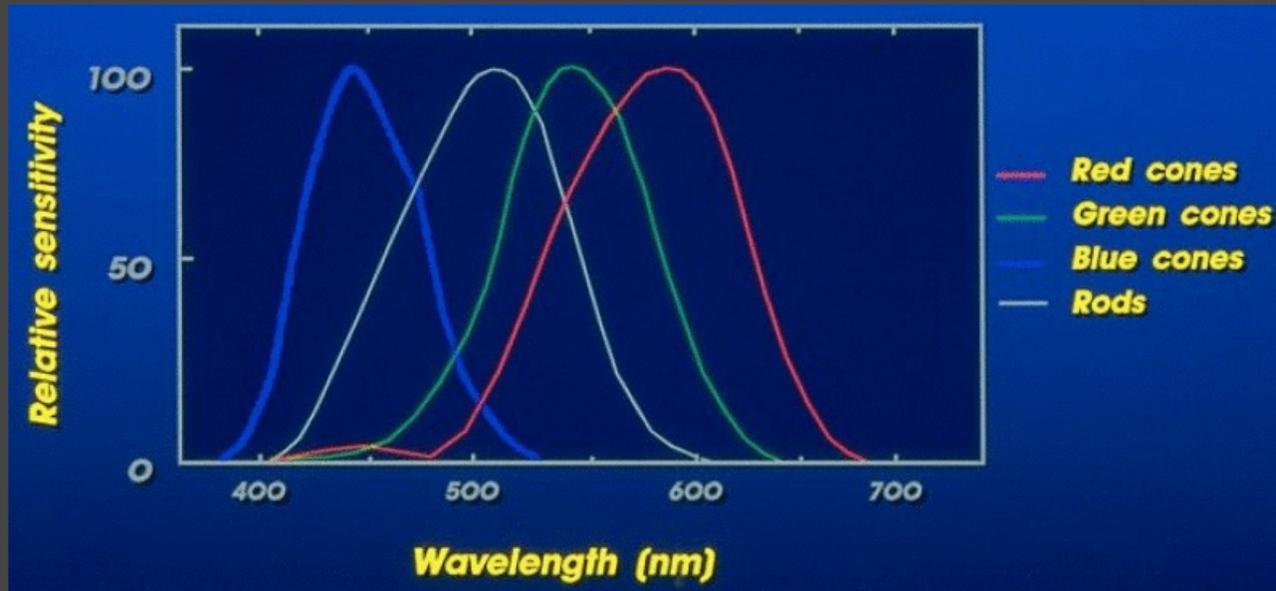
Face-based Luminance Matching for Perceptual Colormap Generation. Gordon Kindlmann, Erik Reinhard, Sarah Creem. IEEE Visualization 2002.

<http://www.cs.utah.edu/~gk/papers/vis02>

Trichromacy

cone response is a function of wavelength
for a given spectrum

- multiple by response curve
- integrate to get response

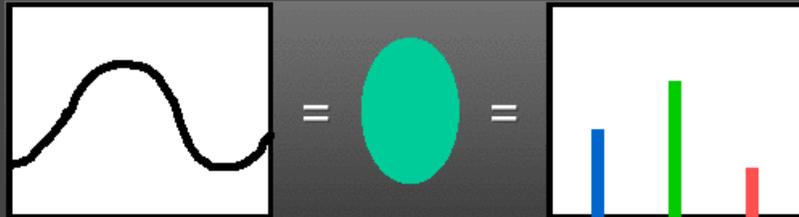


[Stone, SIGGRAPH 2001 course notes,
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf

Metamerism

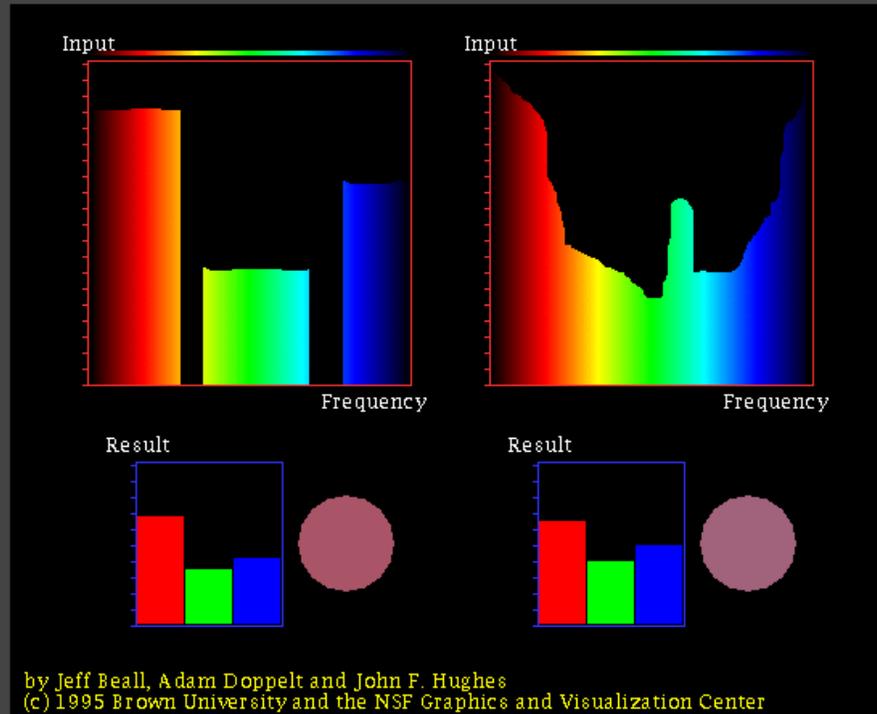
brain sees only cone response

different spectra appear the same



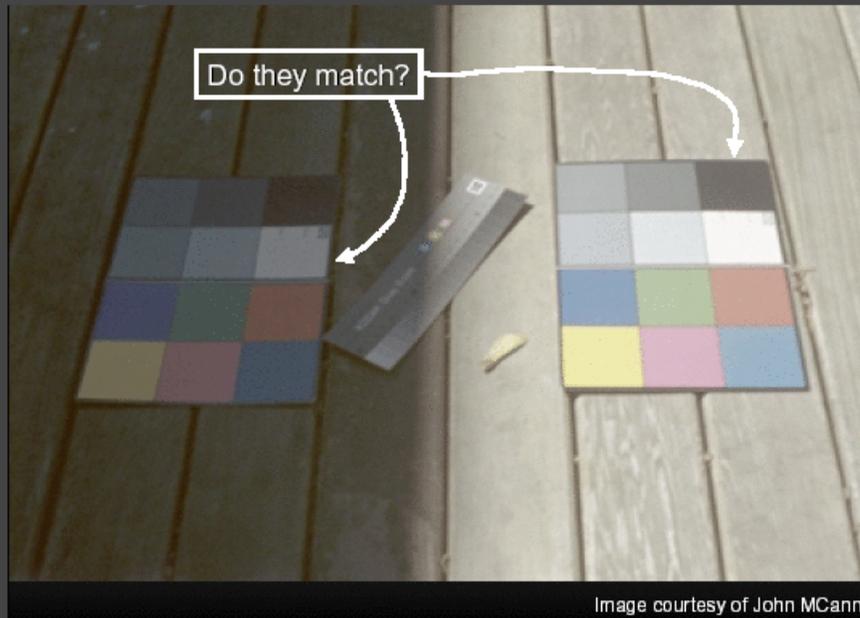
[Stone, SIGGRAPH 2001 course notes,
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf

Metamerism Demo



Color/Brightness Constancy

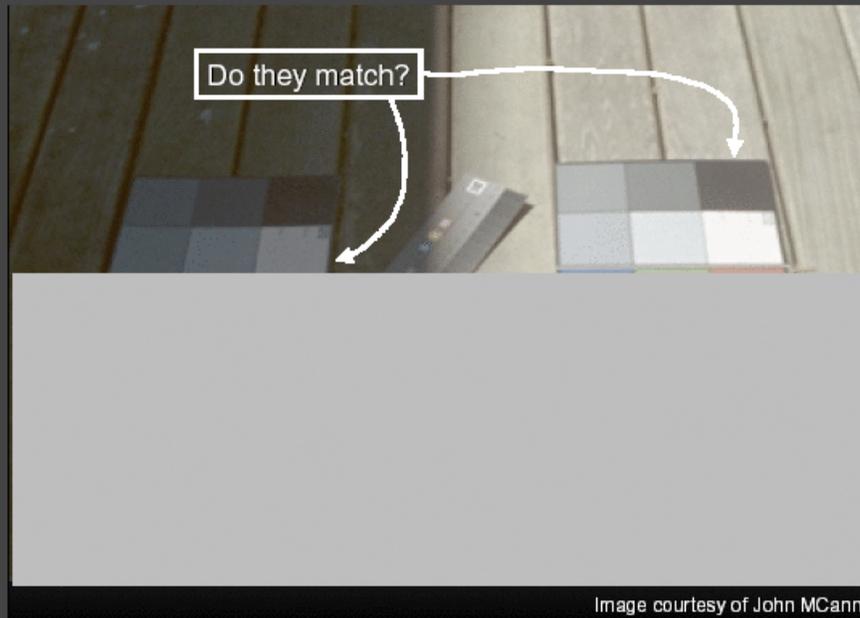
segmentation: relative judgements



[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

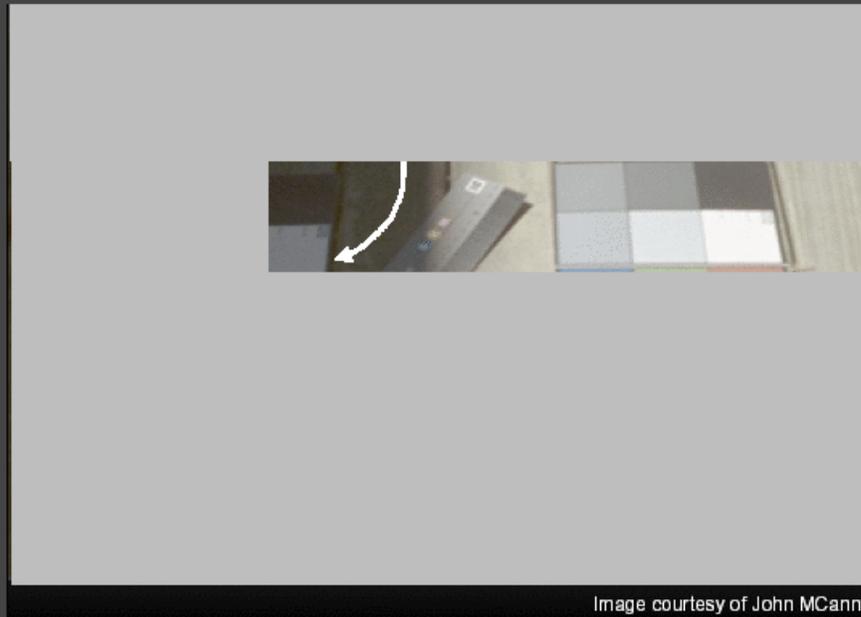
segmentation: relative judgements



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

Color/Brightness Constancy

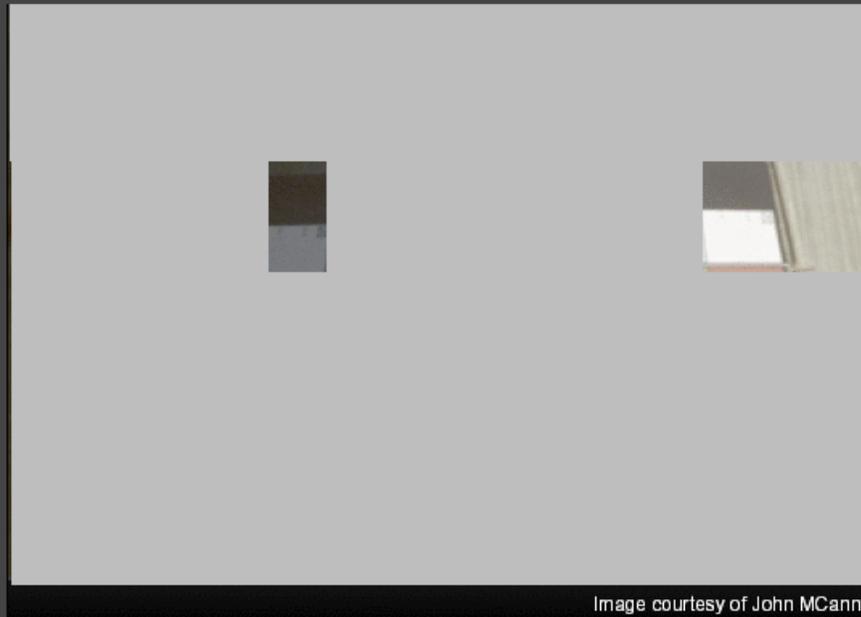
segmentation: relative judgements



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

Color/Brightness Constancy

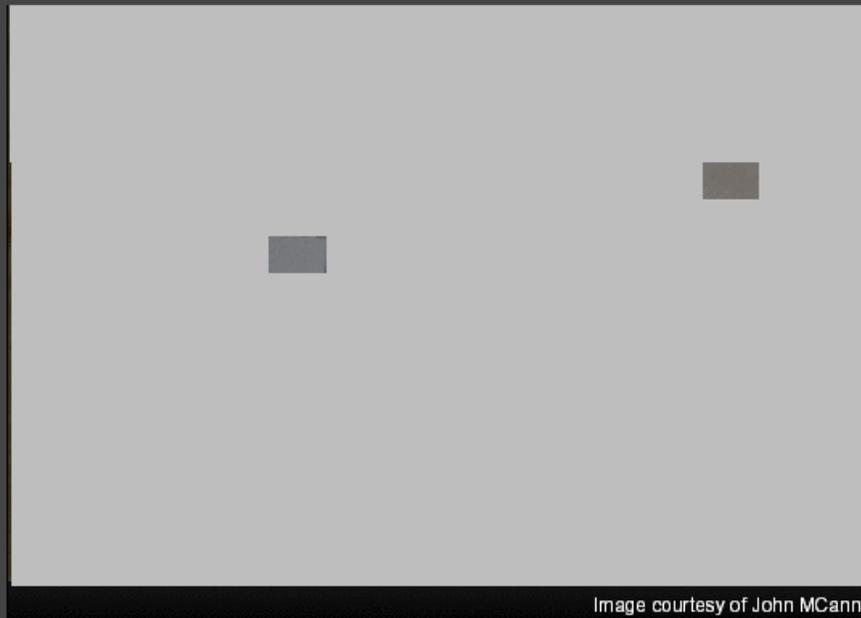
segmentation: relative judgements



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

Color/Brightness Constancy

segmentation: relative judgements



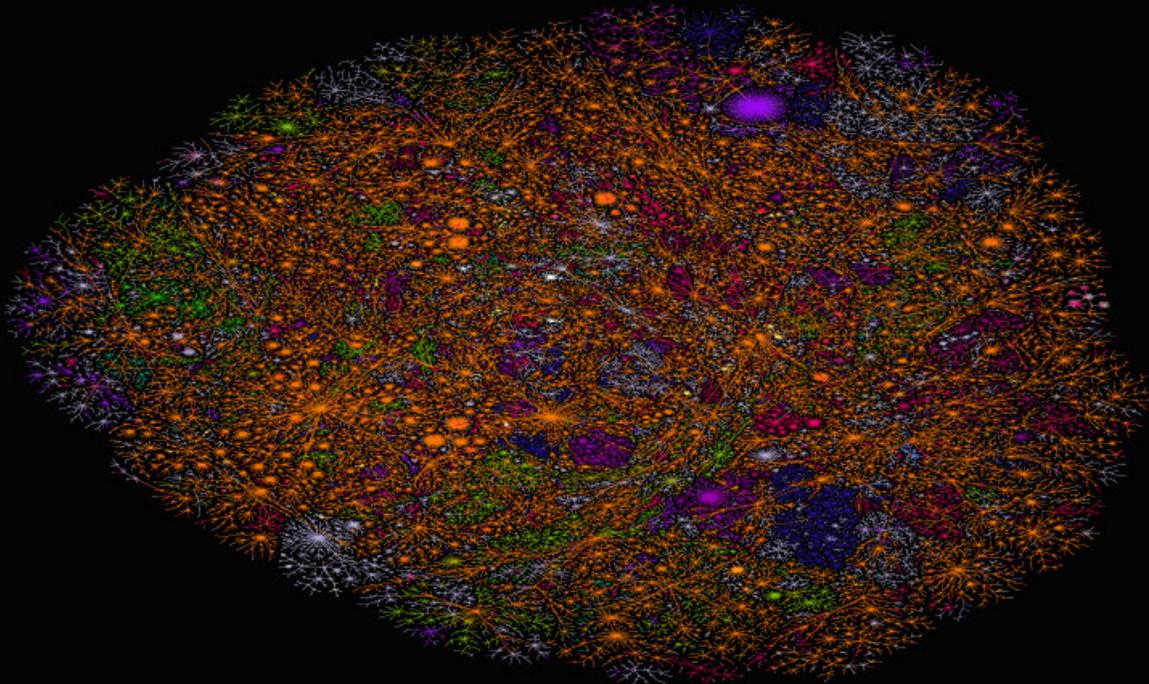
[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Coloring Categorical Data

22 colors, but only ~8 distinguishable



The Internet: 2002



Graph by Ian Buck and Bill Denslow. Nodes by Steve Beyer and Gregory Riegler.

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The graph of the Internet was created by joining the domain and IP addresses a centralized computer in Germany, then, during 2002, by 127,000 routers, based on the global network map of the Internet by and other administrative mapping systems. The data were collected in January 2002.

Published by
QUMETA
www.qumeta.com

Colors from the 22 top-level Internet domains, whose national websites exist, are assigned. 20 countries are included. Like branch of country, websites may show a color which is related to their registration or domain, following a single standard.

Coloring Categorical Data

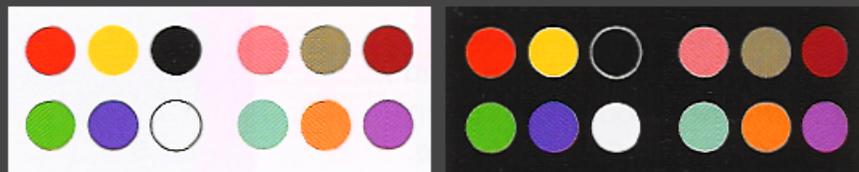
discrete small patches separated in space

limited distinguishability: around 8–14

- channel dynamic range: low

maximally discriminable colors from Ware

- maximal saturation for small areas



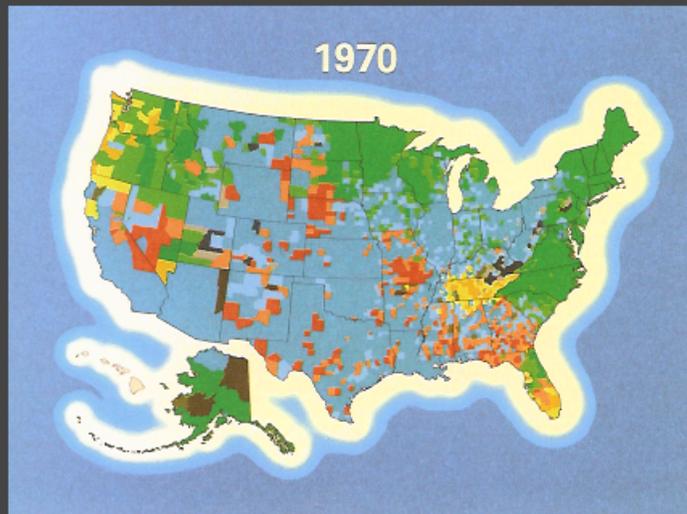
[Colin Ware, Information Visualization: Perception for Design.
Morgan Kaufmann 1999. Figure 4.21]

choose bins explicitly for maximum mileage

Minimal Saturation for Large Areas

avoid saturated color in large areas

- "excessively exuberant"

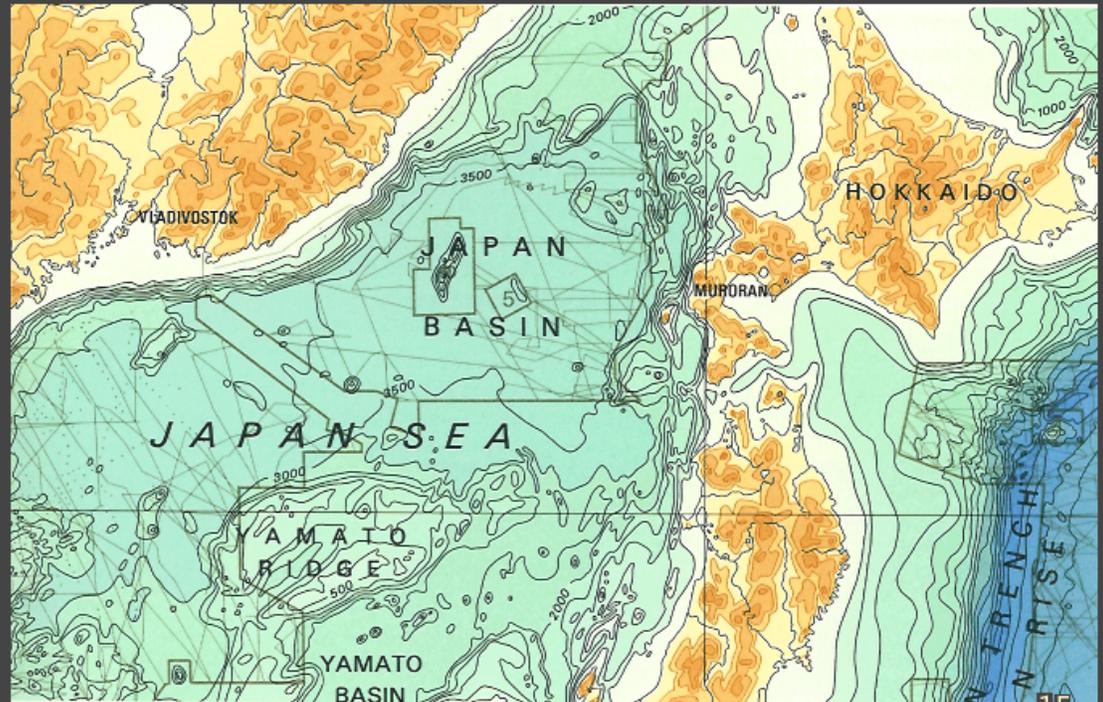
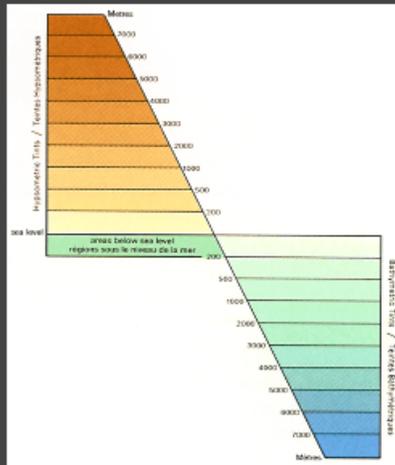


[Edward Tufte, Envisioning Information, p.82]

Minimal Saturation for Large Areas

large continuous areas in pastel

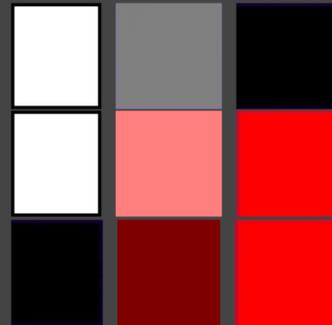
- diverging colormap (bathymetric/hypsometric)



Coloring Ordered Data

innate visual order

- greyscale/luminance
- saturation
- brightness



unclear 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

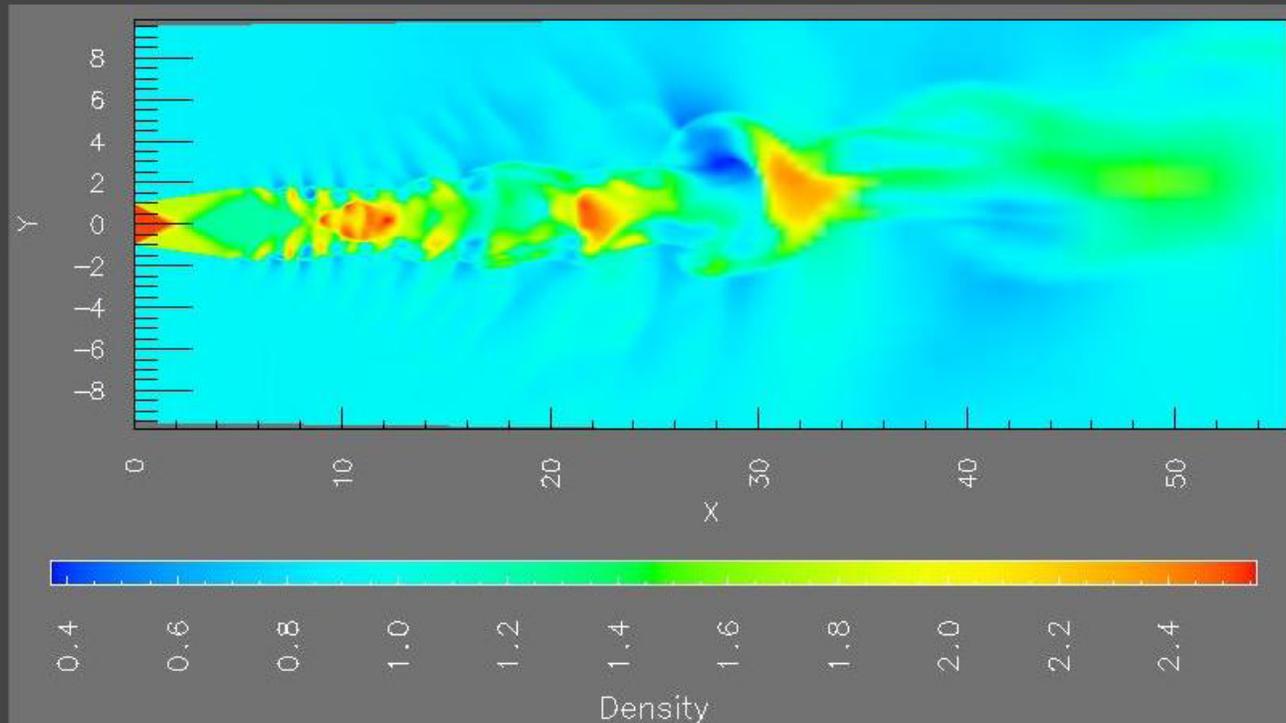


[www.research.ibm.com/visualanalysis/perception.html]

Rainbow Colormap Advantages

low-frequency segmentation

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



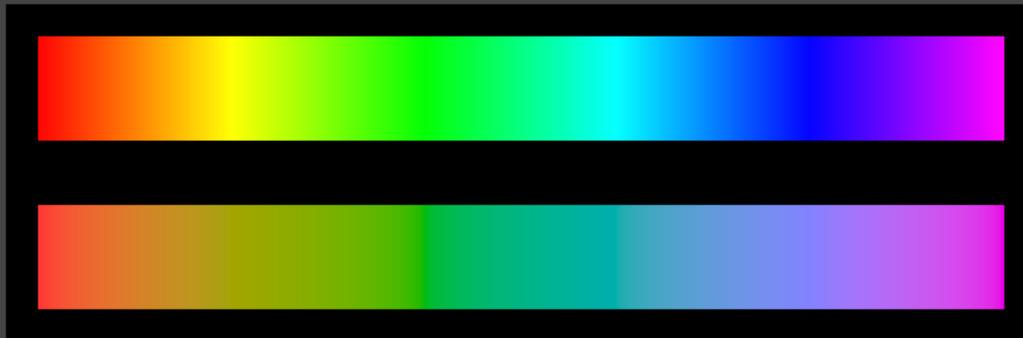
Rainbow Colormap Disadvantages

segmentation artifacts

- popular interpolation perceptually nonlinear!

solution

- create perceptually isolinear map



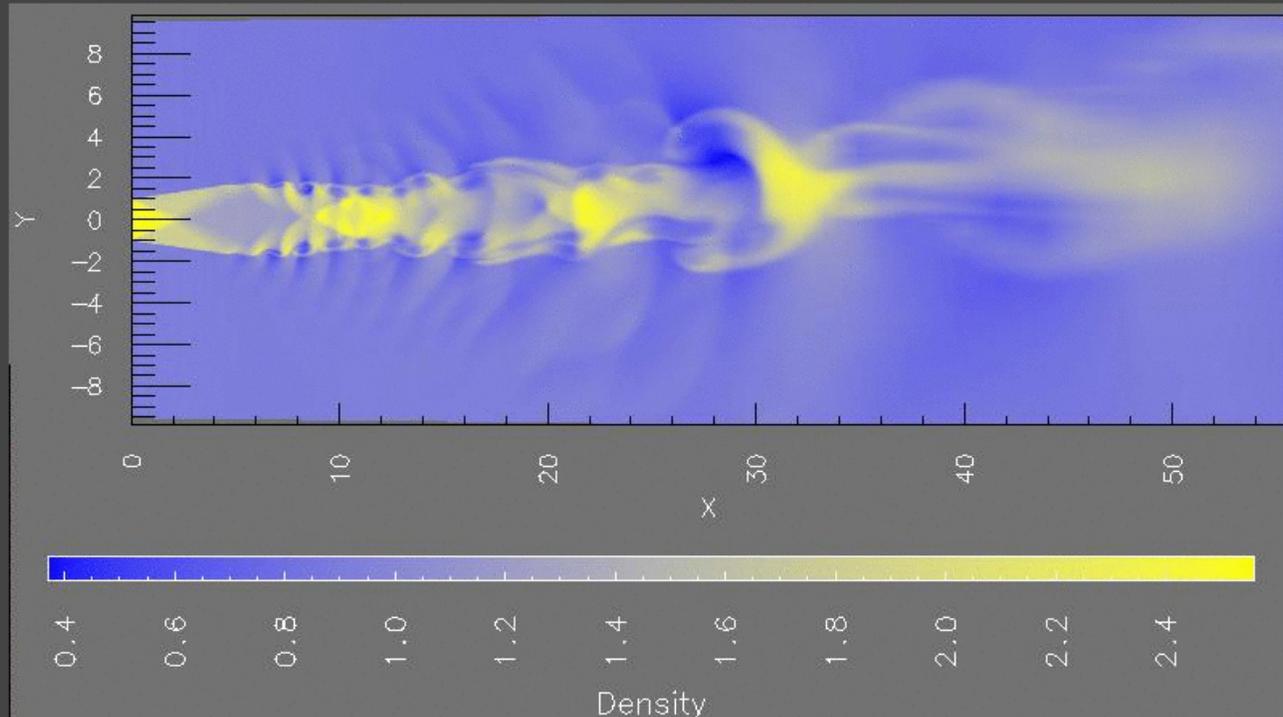
[Kindlmann, Reinhard, and Creem.

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

Non-Rainbow Colormap Advantages

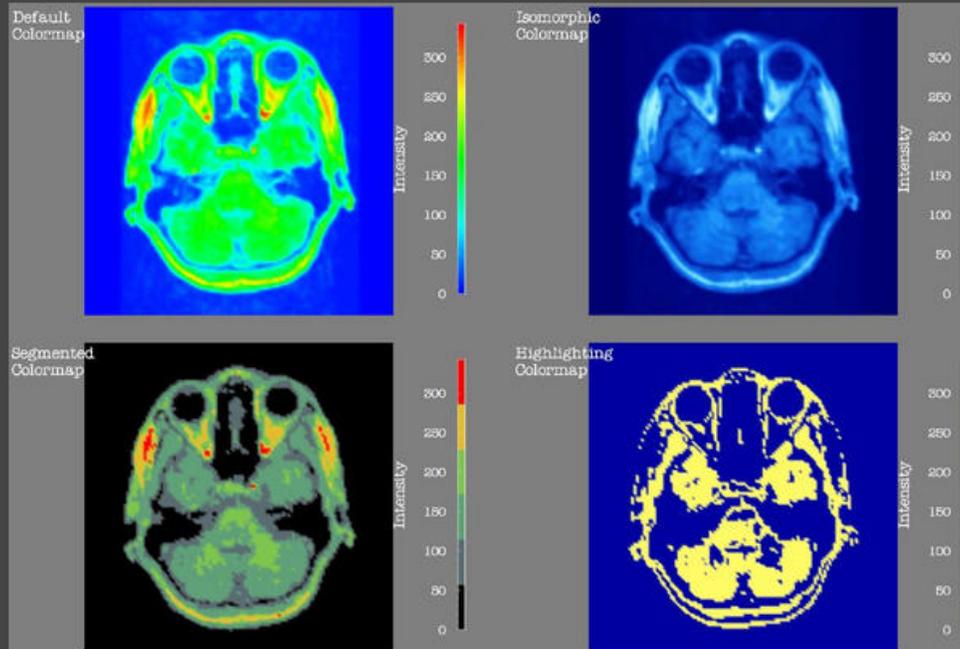
high-frequency continuity

- interpolating between just two hues



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

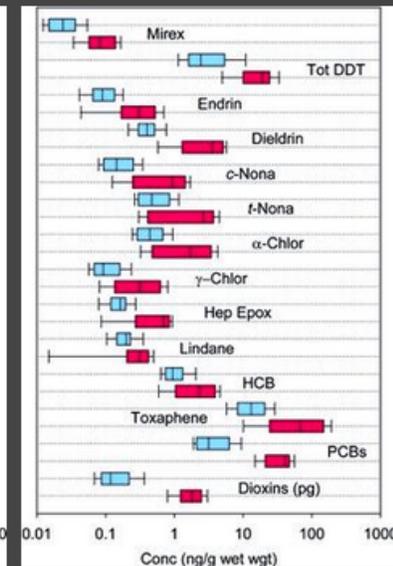
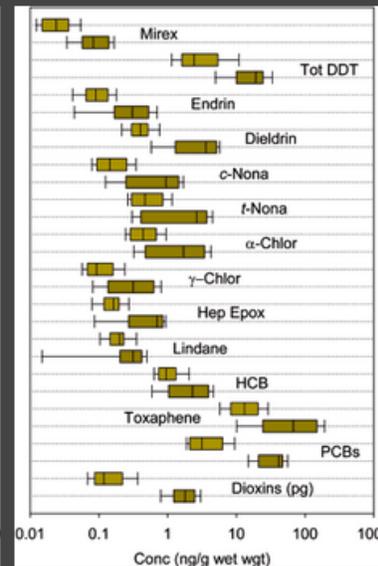
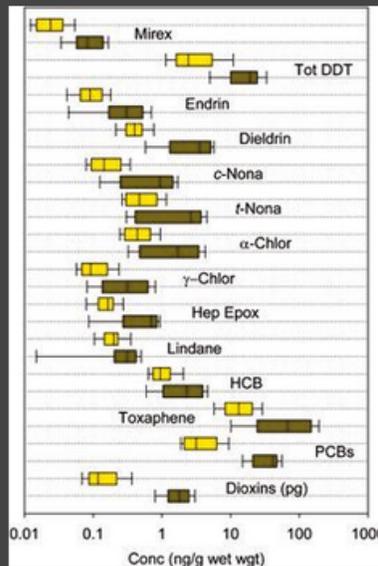
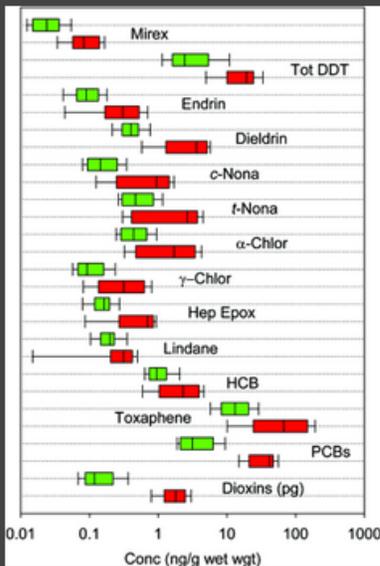
Color Deficiency Examples: vischeck

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, 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

protanope

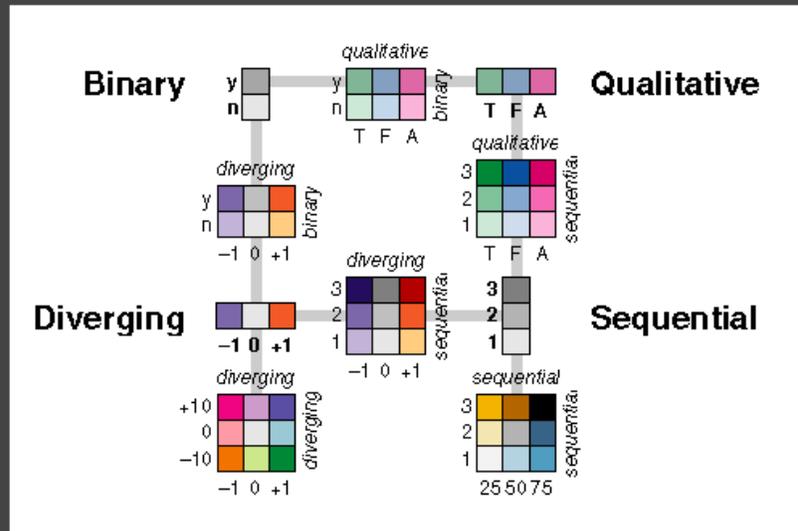
deuteranope

tritanope

Qty	Limit	Dest	Status	Ex Qty	Qty	Limit	Dest	Status	Ex Qty	Qty	Limit	Dest	Status	Ex Qty	Qty	Limit	Dest	Status	Ex Qty
+ 20,000	29.96			10,000	+ 20,000	29.96			10,000	+ 20,000	29.96			10,000	+ 20,000	29.96			10,000
+ 80,000	MKT			13,000	+ 80,000	MKT			13,000	+ 80,000	MKT			13,000	+ 80,000	MKT			13,000
+ 20,000	MKT		Cxl:Trd	15,000	+ 20,000	MKT		Cxl:Trd	15,000	+ 20,000	MKT		Cxl:Trd	15,000	+ 20,000	MKT		Cxl:Trd	15,000
- 200,000	30		Cor:Yes	86,000	- 200,000	30		Cor:Yes	86,000	- 200,000	30		Cor:Yes	86,000	- 200,000	30		Cor:Yes	86,000
+ 20,000	29.96	DOT		13,000	+ 20,000	29.96	DOT		13,000	+ 20,000	29.96	DOT		13,000	+ 20,000	29.96	DOT		13,000
+ 20,000	29.96	Port		17,000	+ 20,000	29.96	Port		17,000	+ 20,000	29.96	Port		17,000	+ 20,000	29.96	Port		17,000
+ 20,000	29.96	Joe G.	Cxl:Trd	20,000	+ 20,000	29.96	Joe G.	Cxl:Trd	20,000	+ 20,000	29.96	Joe G.	Cxl:Trd	20,000	+ 20,000	29.96	Joe G.	Cxl:Trd	20,000
20,000	29.96	DOT		13,000	20,000	29.96	DOT		13,000	20,000	29.96	DOT		13,000	20,000	29.96	DOT		13,000
+ 20,000	29.96	Port	Cxl:Brk	0	+ 20,000	29.96	Port	Cxl:Brk	0	+ 20,000	29.96	Port	Cxl:Brk	0	+ 20,000	29.96	Port	Cxl:Brk	0
20,000	29.96	Joe G.		13,000	20,000	29.96	Joe G.		13,000	20,000	29.96	Joe G.		13,000	20,000	29.96	Joe G.		13,000
80,000	29.96	DOT		10,000	80,000	29.96	DOT		10,000	80,000	29.96	DOT		10,000	80,000	29.96	DOT		10,000
- 200,000	MKT			200,000	- 200,000	MKT			200,000	- 200,000	MKT			200,000	- 200,000	MKT			200,000
+ 20,000	MKT	Joe G.		25,000	+ 20,000	MKT	Joe G.		25,000	+ 20,000	MKT	Joe G.		25,000	+ 20,000	MKT	Joe G.		25,000

[Courtesy of Brad Paley]

Cartographic Color Advice



[Brewer, www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html]