

Color

Lecture 7 CPSC 533C, Fall 2004

4 October 2004

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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.

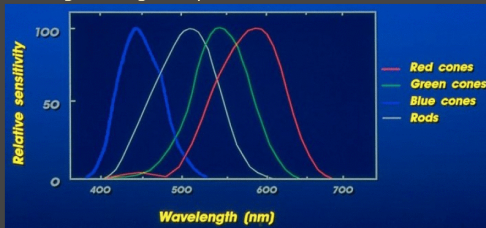
Face-based Luminance Matching for Perceptual Colormap Generation. Gordon Kindlmann, Erik Reinhard, Sarah Creem. IEEE Visualization 2002. <http://www.cs.utah.edu/~gk/papers/vis02>

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Trichromacy

cone response is a function of wavelength for a given spectrum

- multiple by response curve
- integrate to get response



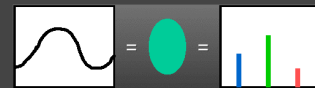
[Stone, SIGGRAPH 2001 course notes, graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf

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Metamerism

brain sees only cone response

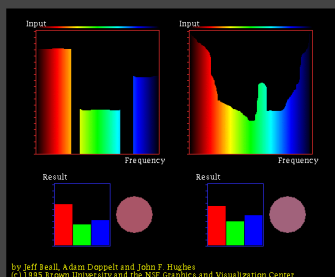
different spectra appear the same



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

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Metamerism Demo



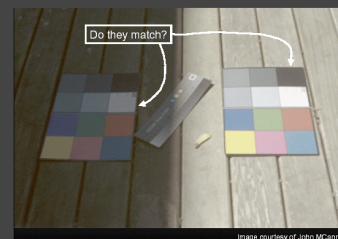
by Jeff Beall, Adam Doppelt and John F. Hughes
(C) 1999 Brown University and the NSF Graphics and Visualization Center

[www.cs.brown.edu/exploratories/freeSoftware/repository/edu/brown/cs/exploratories/applets/spectrum/metamers_java_browser.html]

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Color/Brightness Constancy

segmentation: relative judgements

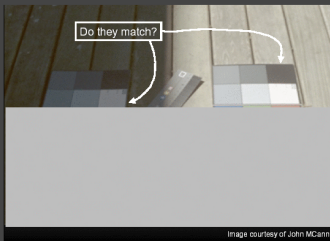


[courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

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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]

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Color/Brightness Constancy

segmentation: relative judgements

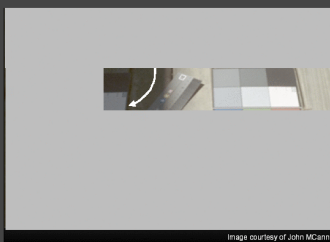


[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

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Color/Brightness Constancy

segmentation: relative judgements

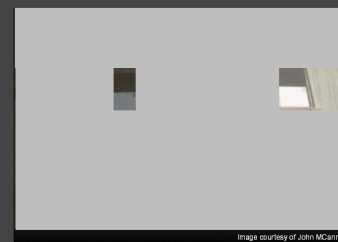


[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

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Color/Brightness Constancy

segmentation: relative judgements

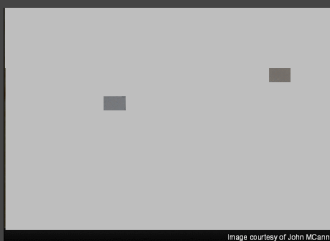


[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

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Color/Brightness Constancy

segmentation: relative judgements

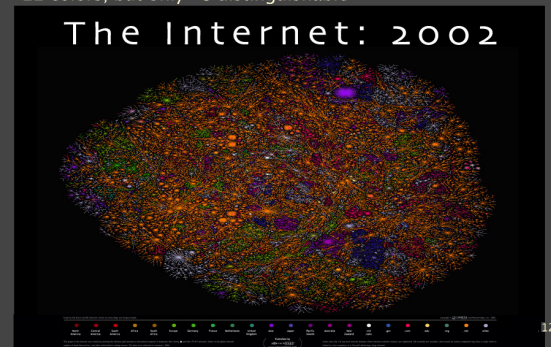


[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

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Coloring Categorical Data

22 colors, but only ~8 distinguishable



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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



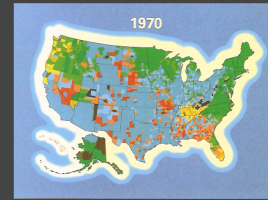
[Colin Ware, Information Visualization: Perception for Design.
Morgan Kaufmann 1999. Figure 4.21]

choose bins explicitly for maximum mileage

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Minimal Saturation for Large Areas

avoid saturated color in large areas
· "excessively exuberant"

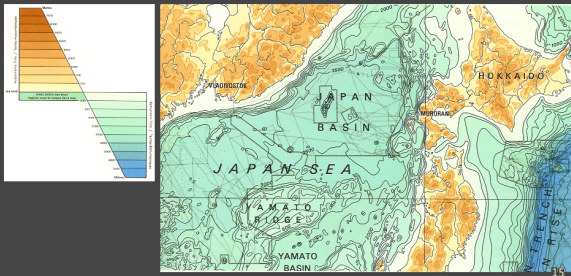


[Edward Tufte, Envisioning Information, p.82]

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Minimal Saturation for Large Areas

large continuous areas in pastel
· diverging colormap (bathymetric/hypsometric)

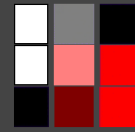


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Coloring Ordered Data

innate visual order

- greyscale/luminance
- saturation
- brightness



unclear visual order

- hue



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Coloring Quantitative Data

continuous field

side by side patches highly distinguishable
· channel dynamic range: high

mediocre
· hue (rainbow)

good
· greyscale/luminance
· saturation
· brightness



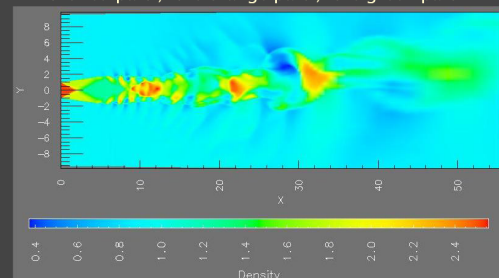
[www.research.ibm.com/visualanalysis/perception.html]

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Rainbow Colormap Advantages

low-frequency segmentation

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

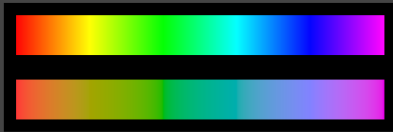


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color?]
<http://www.research.ibm.com/people/l/lloyd/color/color.HTM>

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Rainbow Colormap Disadvantages

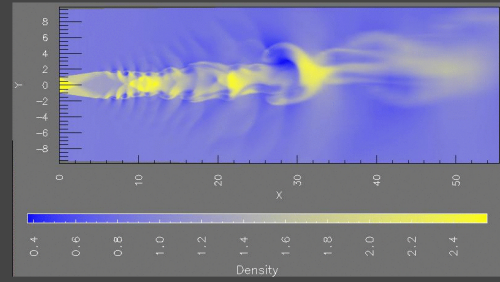
- segmentation artifacts
 - popular interpolation perceptually nonlinear!
- solution
 - create perceptually isilinear map



[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

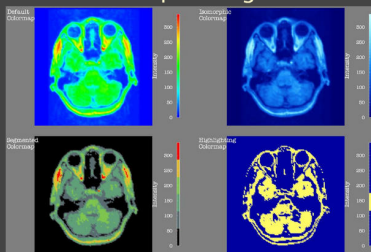
- high-frequency continuity
 - interpolating between just two hues



[Rogowitz and Treinish, How NOT to Lie with Visualization,

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!

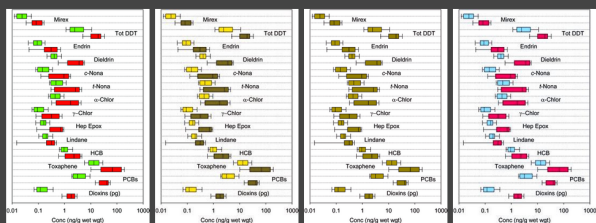
- protanope
 - deutanope
 - has red/green deficit
 - 10% of males!
- tritanope
 - has yellow/blue deficit

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

- test your images

Color Deficiency Examples: vischeck

original protanope deutanope 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

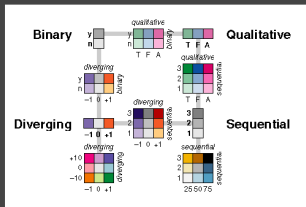
- red/green could have domain meaning
 - then distinguish by more than hue alone
 - redundantly encode with saturation, brightness

original protanope deutanope tritanope

Job	Limit	Dist	Status	Ex Obs	Job	Limit	Dist	Status	Ex Obs	Job	Limit	Dist	Status	Ex Obs	Job	Limit	Dist	Status	Ex Obs
20,000	93.95			10,000	20,000	93.95			10,000	20,000	93.95			10,000	20,000	93.95			10,000
80,000	HKT			15,000	80,000	HKT			15,000	80,000	HKT			15,000	80,000	HKT			15,000
20,000	HKT			15,000	20,000	HKT			15,000	20,000	HKT			15,000	20,000	HKT			15,000
200,000	38			85,000	200,000	38			85,000	200,000	38			85,000	200,000	38			85,000
20,000	93.95	DOT		13,000	20,000	93.95	DOT		13,000	20,000	93.95	DOT		13,000	20,000	93.95	DOT		13,000
20,000	93.95	Port		17,000	20,000	93.95	Port		17,000	20,000	93.95	Port		17,000	20,000	93.95	Port		17,000
20,000	93.95	Job O		15,000	20,000	93.95	Job O		15,000	20,000	93.95	Job O		15,000	20,000	93.95	Job O		15,000
20,000	93.95	DOT		13,000	20,000	93.95	DOT		13,000	20,000	93.95	DOT		13,000	20,000	93.95	DOT		13,000
20,000	93.95	Port		17,000	20,000	93.95	Port		17,000	20,000	93.95	Port		17,000	20,000	93.95	Port		17,000
20,000	93.95	Job O		15,000	20,000	93.95	Job O		15,000	20,000	93.95	Job O		15,000	20,000	93.95	Job O		15,000
80,000	93.95	DOT		15,000	80,000	93.95	DOT		15,000	80,000	93.95	DOT		15,000	80,000	93.95	DOT		15,000
200,000	HKT			85,000	200,000	HKT			85,000	200,000	HKT			85,000	200,000	HKT			85,000
20,000	HKT			25,000	20,000	HKT			25,000	20,000	HKT			25,000	20,000	HKT			25,000

[Courtesy of Brad Paley]

Cartographic Color Advice



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