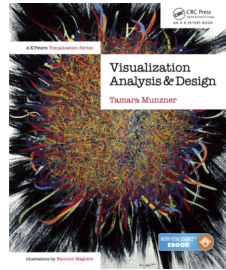


Some Challenges of Color

Tamara Munzner
Department of Computer Science
University of British Columbia

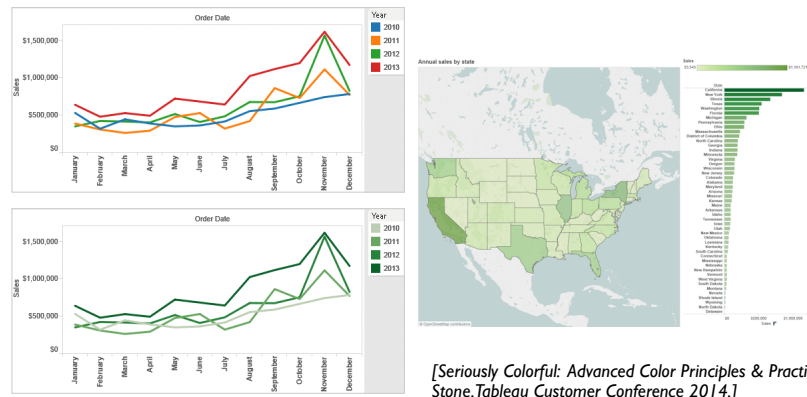
THINK Conference 33, Santa Cruz CA
5 November 2017

www.cs.ubc.ca/~tmm/talks.html#vad17color-short



@tamaramunzner

Categorical vs ordered color

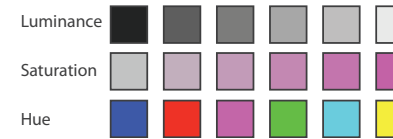


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[Seriously Colorful: Advanced Color Principles & Practices. Stone. Tableau Customer Conference 2014.]

Decomposing color

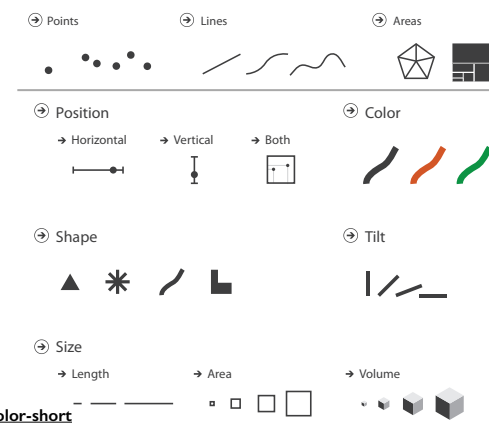
- first rule of color: do not talk about color!
 - color is confusing if treated as monolithic
- decompose into three channels
 - ordered can show magnitude
 - luminance: how bright
 - saturation: how colorful
 - categorical can show identity
 - hue: what color
- channels have different properties
 - what they convey directly to perceptual system
 - how much they can convey: how many discriminable bins can we use?



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Definitions: Marks and channels

- marks
 - geometric primitives
- channels
 - control appearance of marks
 - can redundantly code with multiple channels

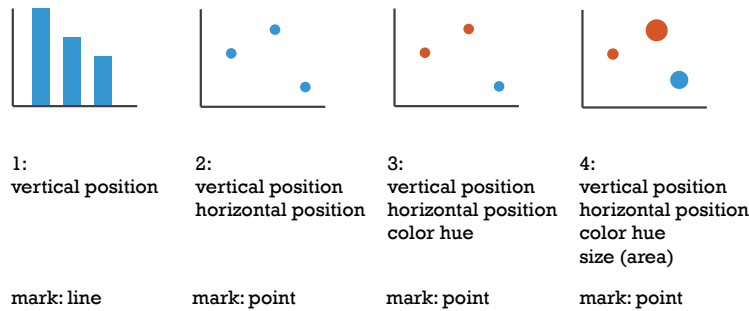


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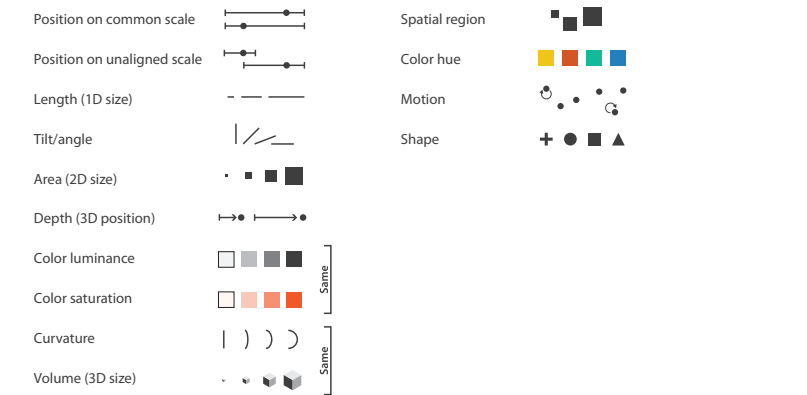
Visual encoding

- analyze idiom structure
 - as combination of marks and channels



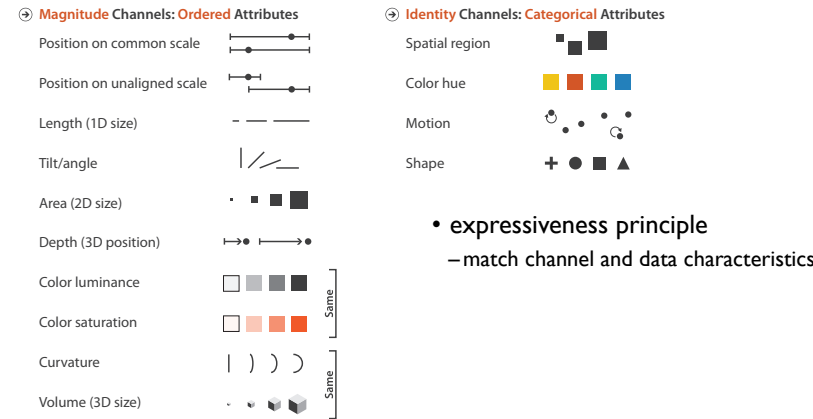
www.cs.ubc.ca/~tmm/talks.html#vad17color-short

Channels



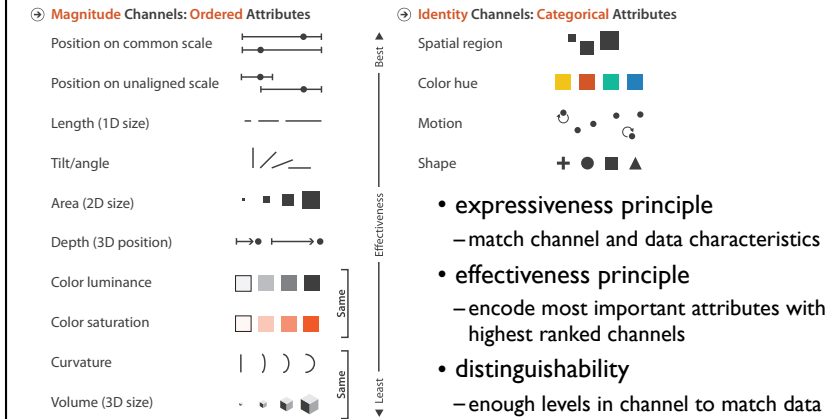
www.cs.ubc.ca/~tmm/talks.html#vad17color-short

Channels: Matching Types



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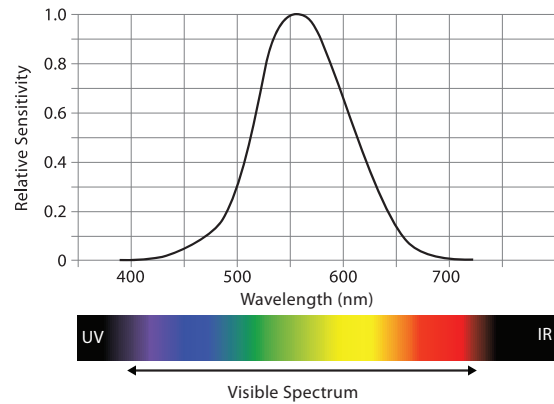
Channels: Rankings



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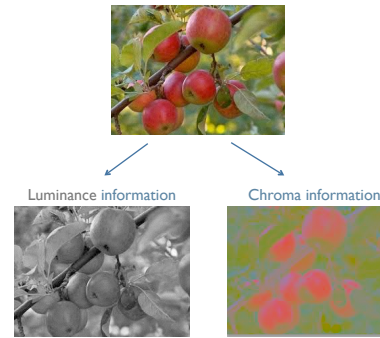
Spectral sensitivity



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Luminance

- need luminance for edge detection
 - fine-grained detail only visible through luminance contrast
 - legible text requires luminance contrast!
- intrinsic perceptual ordering

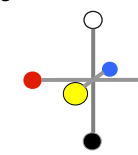


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[Seriously Colorful: Advanced Color Principles & Practices. Stone. Tableau Customer Conference 2014.]

Opponent color and color deficiency

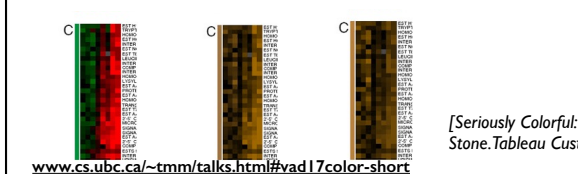
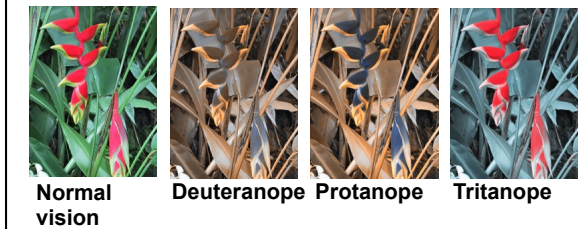
- perceptual processing before optic nerve
 - one achromatic luminance channel (L*)
 - edge detection through luminance contrast
 - 2 chroma channels
 - red-green (a*) & yellow-blue axis (b*)
- “color blind”: one axis has degraded acuity
 - 8% of men are red/green color deficient
 - blue/yellow is rare



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[Seriously Colorful: Advanced Color Principles & Practices. Stone. Tableau Customer Conference 2014.]

Designing for color deficiency: Check with simulator



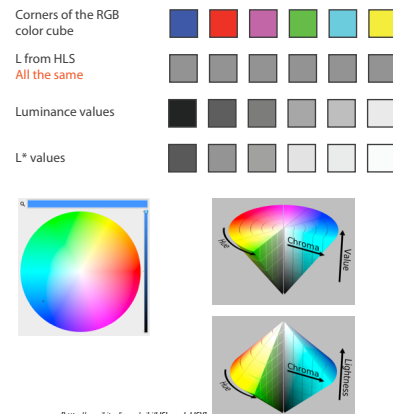
www.cs.ubc.ca/~tmm/talks.html#vad17color-short

[Seriously Colorful: Advanced Color Principles & Practices. Stone. Tableau Customer Conference 2014.]

<http://rehue.net>

Color spaces

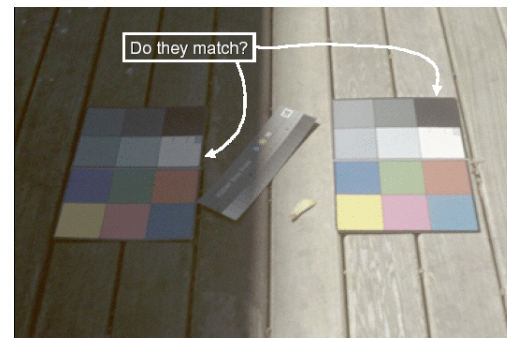
- CIE L*a*b*: good for computation
 - L* intuitive: perceptually linear luminance
 - a*b* axes: perceptually linear but nonintuitive
- RGB: good for display hardware
 - poor for encoding
- HSL/HSV: somewhat better for encoding
 - hue/saturation wheel intuitive
 - beware: only pseudo-perceptual!
 - lightness (L) or value (V) ≠ luminance or L*
- Luminance, hue, saturation
 - good for encoding
 - but not standard graphics/tools colorspace



www.cs.ubc.ca/~tmm/talks.html#vad17color-short

https://en.wikipedia.org/wiki/HSL_and_HSV

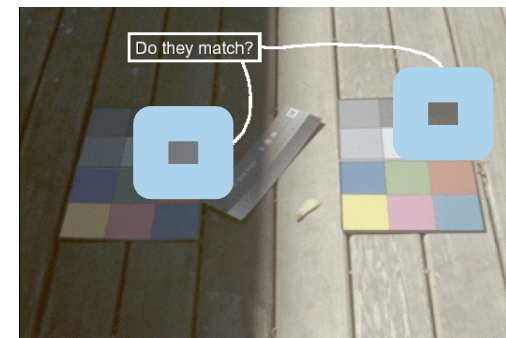
Color/Lightness constancy: Illumination conditions



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Image courtesy of John McCann

Color/Lightness constancy: Illumination conditions

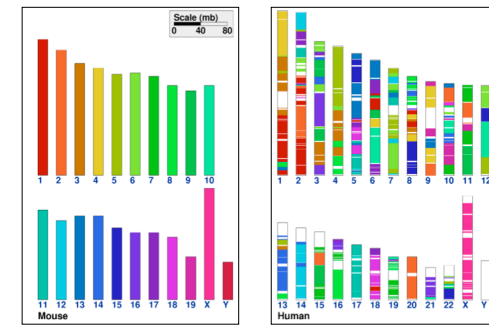


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Image courtesy of John McCann

Categorical color: limited number of discriminable bins

- human perception built on relative comparisons
 - great if color contiguous
 - surprisingly bad for absolute comparisons
- noncontiguous small regions of color
 - fewer bins than you want
 - rule of thumb: 6-12 bins, including background and highlights

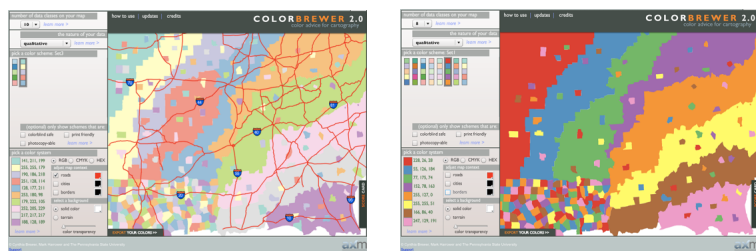


www.cs.ubc.ca/~tmm/talks.html#vad17color-short

[Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. BMC Bioinformatics, 8:82, 2007.]

ColorBrewer

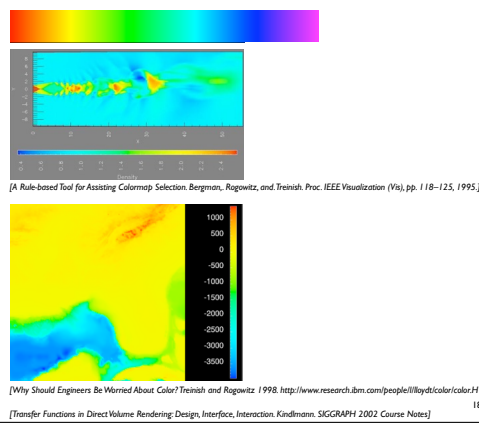
- <http://www.colorbrewer2.org>
- saturation and area example: size affects salience!



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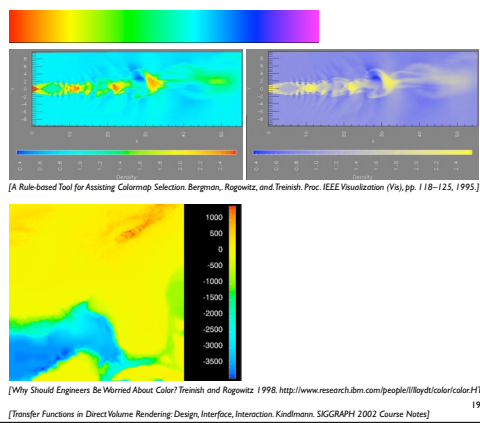
Ordered color: Rainbow is poor default

- problems
 - perceptually unordered
 - perceptually nonlinear
- benefits
 - fine-grained structure visible and nameable



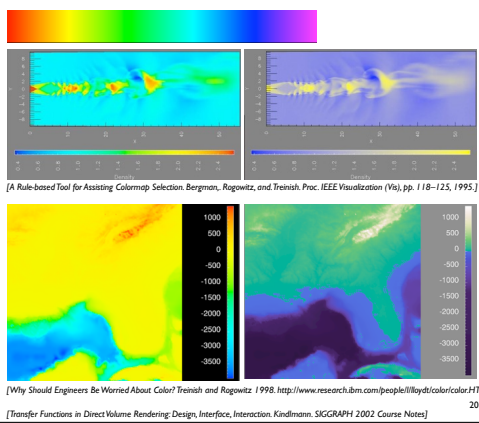
Ordered color: Rainbow is poor default

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- benefits
 - fine-grained structure visible and nameable
- alternatives
 - large-scale structure: fewer hues



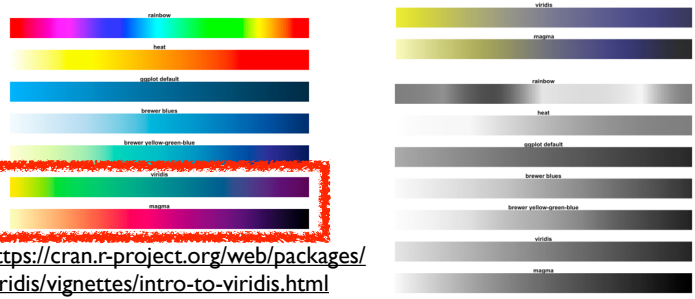
Ordered color: Rainbow is poor default

- problems
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- benefits
 - fine-grained structure visible and nameable
- alternatives
 - large-scale structure: fewer hues
 - fine structure: multiple hues with monotonically increasing luminance [eg viridis R/python]



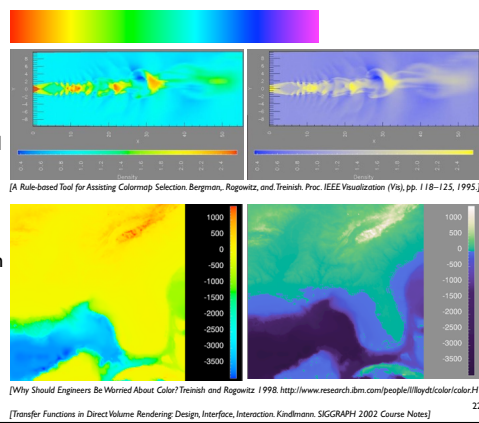
Viridis

- colorful, perceptually uniform, colorblind-safe, monotonically increasing luminance



Ordered color: Rainbow is poor default

- problems
 - perceptually unordered
 - perceptually nonlinear
- benefits
 - fine-grained structure visible and nameable
- alternatives
 - large-scale structure: fewer hues
 - fine structure: multiple hues with monotonically increasing luminance [eg viridis R/python]
 - segmented rainbows for binned or categorical



Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014
 - Chap 10: Map Color and Other Channels
- ColorBrewer, Brewer.
 - <http://www.colorbrewer2.org>
- Color In Information Display. Stone. IEEE Vis Course Notes, 2006.
 - <http://www.stonesc.com/Vis06>
- A Field Guide to Digital Color. Stone. AK Peters, 2003.
- Rainbow Color Map (Still) Considered Harmful. Borland and Taylor. IEEE Computer Graphics and Applications 27:2 (2007), 14–17.
- Visual Thinking for Design. Ware. Morgan Kaufmann, 2008.
- Information Visualization: Perception for Design, 3rd edition. Ware. Morgan Kaufmann / Academic Press, 2004.
- <https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>

www.cs.ubc.ca/~tmm/talks.html#vad17color-short

How?

Encode	Manipulate	Facet	Reduce
<ul style="list-style-type: none"> Arrange Express Order Use 	<ul style="list-style-type: none"> Map from categorical and ordered attributes Color Hue Saturation Luminance Size, Angle, Curvature, ... Shape Motion Direction, Rate, Frequency, ... 	<ul style="list-style-type: none"> Change Select Navigate Superimpose Embed 	<ul style="list-style-type: none"> Filter Aggregate Embed

What? Why? How?

What? Why? How?

domain

- abstraction
- idiom
- algorithm

What? Why? How?

More Information

- this talk
 - <http://www.cs.ubc.ca/~tmm/talks.html#vad17color-short>
- book page (including tutorial lecture slides)
 - <http://www.cs.ubc.ca/~tmm/vadbook>
 - 20% promo code for book+ebook combo: HVN17
 - <http://www.crcpress.com/product/isbn/9781466508910>
 - illustrations: Eamonn Maguire
- papers, videos, software, talks, courses
 - <http://www.cs.ubc.ca/group/infovis>
 - <http://www.cs.ubc.ca/~tmm>

