Information Visualization

Color

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Lecture 12/13, 13 & 25 Feb 2020


Upcoming

• Foundations 4: out Feb 13, due Feb 26 (right after reading week)
• Programming 3: out Feb 13, due Mar 4 (1 week after reading week)
• D3 videos/readings week 6
  – Color and Sex legends with D3.js (30 min)
  – Scatter Plot with Mersos (46 min)
  – Circles on a Map (42 min)
  – Line Charts with Multiple Lines (42 min)
• Quiz 6, due by Fri Feb 14, 8am
• Team formation, due by Fri Feb 14 11:59pm

Outline

• Color in vision theory
  • Color channels in vis
    – Decomposition
    – L*a*b*
    – Other color spaces
    – Color deficiency
    – Interaction with others
  • Practical advice
    – Colormaps
    – Tools and programming libraries

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• Practical advice
  – Colormaps
  – Tools and programming libraries

Opponent process

• 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 in Vision Theory

Light

If I tell you the wavelength, can you tell what color you are seeing?

Color/Lightness constancy: Illumination conditions

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If I tell you the wavelength, can you tell what color you are seeing?

Color/Lightness constancy: Illumination conditions

Color Appearance

• Given L, a, b, can we tell what color it is?
• If I tell you the wavelength, can you tell what color you are seeing?

Color/Lightness constancy: Illumination conditions

Contrast with background

Black and blue? White and gold?

Eye anatomy

Cone and Rod Cells on Retina

~120 million rods: black vs. white
~5-6 million cones: color
R 63% - G 31% - B 6%

Channels: the big picture

Magnitude Channels: Ordered Attributes
  • Position on common scale
  • Length (1D size)
  • Area (2D size)
  • Depth (3D spatial)

Identity Channels: Categorical Attributes
  • Color hues
  • Shape
  • Color saturation
  • Transparency
  • Volume (3D spatial)

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**Color Appearance**
- Given L, a, b, can we tell what color it is?
- Chromatic adaptation
- Luminance adaptation
- Simultaneous contrast
- Spatial effects
- Viewing angle
- ...

**Cognition (beyond retina, in brain)**
- Given the L, a, b values, the lighting conditions, the surroundings, viewing angle ...
- Can you tell me what this color is?
  - Middle part of an apple
  - Bottom part of an apple
  - The branch

**Name the colours**

**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

**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, python)

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**Ordered color: Rainbow is poor default**

- Problems
  - perceptually unordered
  - cannot order non-categorical
- Benefits
  - fine-grained structure visible and
  - small regions need high saturation
- Alternatives
  - large-scale structure: fewer hues
  - fine structure: multiple hues with
  - monotonically increasing luminance
  - segmented rainbows for binned or
  - categorical

**Ordered color: how many bins?**

- Many color spaces
  - HSL/HSV: somewhat better for encoding
  - hue/saturation wheel intuitive
  - beware: only pseudo-perceptual!
  - lightness (L) or value (V) ≠ luminance or L*
  - luminance, fix saturation
  - good for encoding
  - but not standard graphics tools colormap.
  - CE \( L^*V^* \): good for comparison
  - \( L^* \) pseudo-perceptually linear
  - \( V^* \) pseudo-perceptually hue-nonsensitive
  - RGB: good for display hardware,
  - poor for encoding

**Opponent color and color deficiency**

- Perceptual processing before optic nerve
  - one achromatic luminance channel (L*)
  - edge detection through luminance contrast
  - 2 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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**Ordered color: What about the background?**

- Marks with high luminance on a background with high luminance
  - edge detection through luminance contrast
  - colorblind-safe, monotonically

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**Designing for color deficiency**

- Blue-Orange is safe

**Designing for color deficiency: Avoid encoding by hue alone**

- redundantly encode
  - vary luminance
  - change shape

**How to use color in visualization**

- Use color encoding:
  - Is this channel categorical?
  - Is this channel sequential?
  - Are you putting a lot of data on this channel?

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Colormaps

- Categorical
- Sequential
- Diverging
- Bivariate

http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html

Color Encoding

- Encode
- Map

Tools and Libraries in Practice

Adobe Color Picker
- https://color.adobe.com/create
- For general design purpose, not particularly for visualization

ColorBrewer
- http://www.colorbrewer2.org
- Limited customization: 2 parameters

Colorgorical
- http://vrl.cs.brown.edu/color
- Highly customized: #colors, perceptual distance, name uniqueness, hue, lightness range...
- Only targeted at categorical data

Color management in D3
- D3-color
  - https://github.com/d3/d3-color
  - Conversion to/from different color spaces
  - Low-level computations
- D3-scale
  - https://github.com/d3/d3-scale
  - Customizes your own color scale using d3.scaleSequential() and d3.scaleOrdinal()
  - Use case: generate color schemes using the web tools mentioned before, then use d3-scale to implement it

ColorBrewer
- http://www.colorbrewer2.org
- saturation and area example: size affects salience!
- Limited customization: 2 parameters

Credits
- Visualization Analysis and Design (Ch 10)
- Enrico Bertini, NYU Tandon
- Alex Lex & Miriah Meyer, http://dataviscourse.net/
- Jeffrey Heer https://courses.cs.washington.edu/courses/cse512/19sp/
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