Visualization Analysis & Design

**Color (Ch 10)**

**Channels**

- **Magnitude Channels**: Ordered attributes (Identity Channels: Categorical attributes)
- **Color channels**: Limited number of discriminable bins
- **Shape**: Limited number of discriminable bins

**Decomposing color**

- First rule of color: do not (just) talk about color!
  - Color is confusing if treated as monolithic
  - Decompose into three channels:
    - Ordered can show magnitudes
    - Luminance: how bright (BW)
    - Saturation: how colorful
    - Hue: what color

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**Categorical vs ordered color**

- Human perception built on relative comparisons
- Great if color contiguous

**Categorical color: limited number of discriminable bins**

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**Idiom design choices: Beyond spatial arrangement**

- How?
- Encode Manipulate Facet ...
- Why?
- What?
- How?
- Why?

**Idiom design choices: Visual encoding**

- Arrange Express Separate
- Order Align
- Use

**Plan for today**

- Last week reading Q&A
  - Tables, LineUp, Bertifier
- Small group exercises
  - Two Numbers
  - Break
  - Color
- This week reading Q&A
  - Color, ArteryViz, Rainbows Revisted

Next week

- To read & discuss (async, before next class)
  - VAD book, Ch 9: Networks and Trees
  - Paper: Glyphs Explorer (design study)
  - Pre-proposal meetings
- 11/1/21 full class slot plus some extra slots
  - Exact timing TBD when I see final number of groups (10-15 min)
  - Stay tuned on Plaza for signup link.

Q&A / Backup Slides

**Channels: What’s up with color?**

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- Channels have different properties
  - What they convey directly to perceptual system
  - How much they can convey
  - How many discriminable bins can we use?
Interaction between channels: Not fully separable

- color channel interactions
  - hue heavily affects value
  - small regions need high saturation
  - large regions need low saturation
- saturation & luminance
  - not separable from value
  - also not separable from transparency

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 thumbs 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

Viridis / Magma: sequential colormaps

- monotonically increasing luminance, perceptually uniform
  - K. Phuus, D3
- benefits
  - fine-grained structure visible and nameable
  - alternatives
    - large-scale structure fewer hues

Sequential

- large-scale structure: fewer hues

Diverging

- large-scale structure: fewer hues

Bivariate

- large-scale structure: fewer hues

Color Palettes

- categorical
  - aim for maximum distinguishability
  - aka qualitative, nominal
Opponent color and color deficiency

- perceptual processing before optic nerve
- one achromatic luminance channel (L*)
- red-green (a*) & yellow-blue axis (b*)
- fine-grained detail only visible through luminance contrast
- legible text requires luminance contrast!

Color palette design considerations: univariate

- segmented
- diverging
- sequential
- categorical

- continuous
- diverging or sequential or cyclic
- single-hue or two-hue or multi-hue
- perceptually linear?
- ordered by luminance?
- colorblind safe?

Visualization Analysis & Design

Color (Ch 10) II

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Opponent color and color deficiency

- perceptual processing before optic nerve
- one achromatic luminance channel (L*)
- edge detection through luminance contrast
- legible text requires luminance contrast!
- one achromatic luminance channel (L*)
- edge detection through luminance contrast
- 2 chroma channels
- red-green (a*) & yellow-blue axis (b*)
- colorblind:
  - degrading acuity, one axis
  - 8% of men are red-green color deficient
  - blue/yellow is rare

Decomposing color

- decompose into three channels
  - ordered can show magnitude
  - luminance how bright (B)
  - saturation how colorful
  - categorical can show identity
  - hue what color

Color palette design considerations: univariate

- color palettes: univariate
- categorical
  - continuous
- diverging
  - sequential
  - ordered
  - sequential
- bivariate
  - categorical
  - continuous
  - diverging

Color palettes: univariate

- ordered
- sequential
- diverging
- categorical

Color maps: bivariate

- ordered
- sequential
- diverging
- categorical

Luminance

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

Color palettes: categorical

- red
- green
- blue
- yellow

Opponent color and color deficiency

- one achromatic luminance channel (L*)
- edge detection through luminance contrast
- 2 chroma channels
- red-green (a*) & yellow-blue axis (b*)

Designing for color deficiency: Check with simulator

- redundancy encode
  - vary luminance
  - change shape

Color deficiency: Reduces color to 2 dimensions

- Normal
- Deuteranope
- Protanope
- Tritanope

Designing for color deficiency: Avoid encoding by hue alone

- a with Apple Store
- b with Apple Store

Color Encoding

- hue
- saturation
- luminance

Designing for color deficiency: Blue-Orange is safe.
HSL/HSV
• HSL/HSV: somewhat better for encoding
  – hue/saturation wheel intuitive
• saturation
  – in HSV (single-cone) desaturated = white
  – in HSL (dual-cone) desaturated = grey
• luminance vs saturation
  – channels not very separable
  – typically not crucial to distinguish between these with encoding/decoding
  – key point is hue vs luminance/saturation

Many color spaces
• Luminance (L*), hue (H), saturation (S)
  – good for encoding
  – but not standard graphics/tools colorspace
• RGB: good for display hardware
  – poor for encoding & interpolation
• CIE LAB (L*a*b*): good for interpolation
  – hard to interpret, poor for encoding
  – HSL/HSV somewhat better for encoding
    – hue/saturation wheel intuitive
    – beware: only pseudo-perceptual!
    – lightness (L) or value (V) ≠ luminance (L*)

Interaction with the background
• marks with high luminance on a background with low luminance
• marks with medium luminance on a background with high luminance
• change luminance of marks depending on background

Color/Lightness constancy: Illumination conditions

Bezold Effect: Outlines matter
• given L, a*, b*, can we tell what color it is?
  – no, it depends
  – chromatic adaptation
  – luminance adaptation
  – simultaneous contrast
  – spatial effects
  – viewing angle
  – …

Color Appearance
• Color naming
Color naming

- Nameability affects
  - Communication
  - Memorability
- Can integrate into color models
  - In addition to perceptual considerations

Color is just part of vision system

- Does not help perceive
  - Position
  - Shape
  - Motion
  -...

Map other channels

- Size
  - Aligned length best
  - Length accurate
  - 2D area ok
  - 3D volume poor
- Shape
  - Complex combination of lower-level primitives
  - Many bins
- Motion
  - Highly separable against static
  - Great for highlighting (binary)
  - Use with care to avoid irritation