CIS 4930/6930-902
Scientific Visualization

Using Color in Visualization

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slides credits Kristin Potter (U of Oregon), Chris Johnson (U of Utah), Miriah Meyer (U of Utah)
ADMINISTRATIVE

first assignment due today
next assignment out by Tuesday
project 1 presentations Tuesday
SUGGESTED PRESENTATION FORMAT

describe the data/questions you want to answer

describe your visualization

answer the question
DISCUSSION

Hans Rosling: The best stats you've ever seen
(HUMAN) VISIBLE LIGHT

<table>
<thead>
<tr>
<th>Waveband</th>
<th>Color</th>
<th>Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra Violet</td>
<td>Violet</td>
<td>400-455</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>455-492</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>492-577</td>
</tr>
<tr>
<td></td>
<td>Yellow</td>
<td>577-597</td>
</tr>
<tr>
<td></td>
<td>Orange</td>
<td>597-620</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>620-700</td>
</tr>
</tbody>
</table>

nm 400 short wavelength high frequency

nm 500

nm 600

nm 700 long wavelength low frequency

infra red
**Color != Wavelength**

but rather, a combination of wavelengths and energy
CONE RESPONSE
Rippin’ the Rainbow a New One

We tear into this show with a dark scene from 1665. A young Isaac Newton, hoping to ride out the plague by heading to the country to puzzle over the deep mysteries of the universe, finds himself wondering about light. And vision. He wants to get to the bottom of where color comes from—is it a physical property in the outside world, or something created back inside your eyeball somewhere? James Gleick explains how Newton unlocked the mystery of the rainbow. And, as Victoria Finlay tells us, sucked the poetry out of the heavens.

Jonah Lehrer restores some of the lost magic by way of Giotto—who turned a simple observation into a deep thought, even though color starts in the brain.
COLOR ABSTRACTION, REPRESENTATION
SPACE OF HUMAN COLOR
CIE (International Commission on Illumination) standardized a set of color-matching functions that form the basis for most color measurement instruments.

Experiments done in the 1920’s and 1930’s humans can mimic any pure (visible) light by addition and subtraction of three primary lights.
CIE color space

with RGB, addition and subtraction were required to get all visible wavelengths in nature, light adds (but does not subtract)

any three primaries (additive) can produce only a subset of all visible colors
ADDITIVE COLOR

(like we see in light)
primary: RGB
secondary: CMY
**RGB COLOR SPACE**

very common color space
not perceptually uniform
actual color is device-dependent
SUBTRACTIVE COLOR
(used in painting)
primary: RYB
secondary: OGV
SUBTRACTIVE COLOR
(used in print ink)
primary: CMY
secondary: RGB
approx black = C+M+Y
true black = C+M+Y+K
actual color is device-dependent
HSV \([B, L, I]\) (ADDITIVE)

Hue, Saturation, [Value, Brightness, Lightness, Intensity]

polar coordinate representations of RGB space
conical or cylindrical shaped space
more intuitive than RGB for color tuning
**HSV [B, L, I] (ADDITIVE)**

- **hue**: what people think of as color
- **saturation**: amount of white mixed in
- **luminance**: amount of black mixed in
  - lightness vs value (or brightness)
- **intensity**, in computer vision applications
**CIE LAB/LUV**

mathematically defined & perceptually based to include all perceivable colors

- **a**: red to green
- **b**: yellow to blue
- **L**: lightness (black to white)
IN THIS CLASS...

- hue
- saturation
- luminance
COLOR DEFICIENCIES & LIMITATIONS
COLOR BLINDNESS

deficiency in color vision
typically caused by faulty cone development
found more in men than women
photopigment genes carried in x-chromosome
5-8% of men and 0.5% of women
How different age groups are using the internet

With the growth of social media networks such as Facebook and Twitter, traditional blogging has been usurped by micro-blogging, quick and short 140 character updates instead of lengthy, in-depth articles online. However, while teens and young adults seem to be shunning blogging, it is still strong among the over 30s...

Source: http://www.pewinternet.org
MONOCHROMACY

total color blindness, very rare
1 dimensional color vision
2 or 3 cone pigments are missing

rod monochromacy: non-functioning or missing cones (achromatopsia)

cone monochromacy: multiple deficient cones
DICHRROMACY

2 dimensional color vision

1 cone pigment is missing

protanopia: absence of red receptors
deuteranopia: absence of green receptors
tritanopia: absence of blue receptors
TYPES: TRICHOMEACY

3 dimensional color vision

1 cone is altered in spectral sensitivity—impairment rather than loss

protanomaly: shift in red, poor red-green discrimination

deuteranomaly: shift in green, poor red-green discrimination (most common form of color deficiency)

tritanomaly: poor blue-yellow discrimination
**TAKEAWAY**

Even if you aren’t colorblind, someone you’re working with could be.

**Be sure to design with colorblindness in mind by:**

- varying hue, saturation, brightness
- using monochrome color schemes
- using cues besides/in addition to color
- software solution, vischeck ([http://www.vischeck.com](http://www.vischeck.com))
CONTRAST SENSITIVITY
CONTRAST SENSITIVITY
**TAKEAWAY**

We have higher contrast sensitivity in the luminance than in the chrominance channel. Show preference to luminance for encoding detail.
COLOR RELATIVITY
COLOR RELATIVITY
COLOR RELATIVITY
COLOR RELATIVITY
COLOR RELATIVITY
COLOR RELATIVITY
SUCCESSIVE CONTRAST

look at a dot

then look at a dot
LUMINANCE CONTRAST

Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

Showing small yellow text on a white background is a bad idea.
There is insufficient luminance contrast.
EQUILUMINANT COLORS

strong contrast: shapes seen by color sensitive cells

equiluminance: hides positions from light sensitive cells

flickering/movement caused by this disconnect
“the smaller the mark, the less distinguishable are the colors”

- Jacques Bertin
Figure 1. Stimulus From the High-Saturation Group

WHICH AREA IS LARGER, RED OR GREEN?
Takeaway

We have a strong propensity to assume our judgments of color are absolute, when in fact they are extremely relativistic.

Do your best to not place data in difficult contexts. Use color sparingly.
GUIDELINES

color is a relative medium—if encoding ordinal data with color, place marks on solid, neutral background because of contrast effects, it is difficult to perceive absolute luminance of noncontiguous regions
for text, ideally use 10:1 ratio, 3:1 minimum
GUIDELINES

in small regions use bright, highly saturated colors
for points and lines use just two saturation levels
use low saturation pastel colors for large regions
and backgrounds
WHAT IS A COLORMAP?

specifies a mapping between color and values
also called a transfer function

categorical vs ordered
sequential vs diverging
segmented vs continuous
univariate vs bivariate

EXPRESSIVENESS: MATCH COLORMAP TO ATTRIBUTE TYPE CHARACTERISTICS!
GUIDELINES

categorical colors are easier to remember if they are nameable
ordered colormaps should vary along saturation or luminance
bivariate colormaps are difficult to interpret if at least one variable is not binary
HUES FOR CATEGORIES
DISTINGUISHABILITY
only good at distinguishing 6-12 simultaneous colors
ORDER THESE COLORS…
ORDER THESE COLORS...
ORDER THESE COLORS…
GUIDELINES

Luminance and saturation are most effective for ordinal data because they have an inherent ordering.

Hue is great for categorical data because there is no inherent ordering, but limit the number of hues to 6-12 for distinguishability.

The number of hues and distribution on the colormap should be related to which and how many structures in the data to emphasize.
RAINBOW COLOR MAPS: CHALLENGES
RAINBOW COLORMAPS: CHALLENGES

zero crossing not explicit
RAINBOW
COLORMAPS:
CHALLENGES
COLOR SECTION GUIDELINES
RAINBOW GUIDELINES

poor

better

[Color spectrum diagrams]
• **Complementary**—high contrast creates a vibrant look

• **Analogous**—often found in nature and are harmonious and pleasing to the eye

• **Triad**—vibrant, even if you use pale or unsaturated versions of your hues

• **Split-complementary**—same strong contrast as the complementary but less tension

• **Rectangle**—rich color scheme offers plenty of possibilities for variation

LOOK TO NATURE
SIMPLICITY

choose one color to be used in larger amounts
be selective about the base color
use other colors to add interest
AVOIDANCE OF COLOR

use neutrals (work with any scheme)
black, white, grey

use diagrammatic marks (may be better encoding channels)
size, shape, texture, length, width, orientation, curvature and intensity
GET IT RIGHT IN BLACK AND WHITE.

Maureen Stone
TOOLS FOR COLOR
Color Converter

Select a color space and enter your values for accurately convert your selection to Rgb, Cmy, Cmyk, Hsl, Xyz, Lab, Lch and Yxy.

Note: ColorMine uses the sRgb color space. More information on sRgb vs AdobeRrgb.

Rgb

We've recently added support for device specific ICC Profiles for conversions to Cmyk based on your feedback. This is a new feature so please let us know if you have any questions or problems with it using the feedback form below.

Color Space: 
R: 0
G: 0
B: 0

Cmyk Profile: 
No Profile

Convert
Vischeck simulates colorblind vision.

Daltonize corrects images for colorblind viewers.

How do babies see the world? Visit TinyEyes.

LET’S CRITIQUE SOME VISUALIZATIONS!

