Lecture 7: Color and its use
Color

• Most powerful element in map symbolization
• Invokes unconscious, perceptual and cognitive responses
• Both input (eye) and output (video) concern in cartography
• Color rendering methods use additive and subtractive color
• Color models
  • Hardware
    • RGB
    • CMYK
  • User-oriented
    • HSV
    • Munsell
    • HVC
Some maps use colors to tell you a lot.

I used blue where it’s cold and red where it’s hot.
Color context
Context and illumination

Not just a good idea, it’s the law

• $c = 299\,792\,458 \text{ m/s}$
• $c = 670\,444\,951 \text{ miles per hour}$
• Eye can process up to
  • Movies run at 24 FPS
  • TV runs at 30 FPS = 33 milliseconds/frame
  • Using 50 FPS, light can travel 5,995,849m between frames
• Effect on light is motion blur at high velocities
Wave theory of EMR: Polarization

Dual Orthogonal Fluctuating fields
EMR Theory: A Duality
Particle Theory of EMR Photons
EMR has a wavelength

- Wavelength ($\lambda$) = $c / v$
- Frequency (f) = $1 / \lambda$
- Amplitude (A)
Intensity of EMR = Brightness

- Energy content = $E = f(\#\;\text{photons})$
- $E = \frac{hc}{\lambda}$
  - Planck's constant ($h$)
- 6.626 x $10^{-34}$ Joules/second
- Basic energy equation
- E.g. UV and visible light on skin
- UV shorter $\lambda$
Electromagnetic spectrum
“Pure” sunlight: absorption features

Light interactions

• Shadowing (depth)
• Reflection
• Refraction
• Scattering
• Absorption
• Re-emission
Spectrum and Absorption

Dominant factor controlling leaf reflectance

Primary absorption bands

Chlorophyll absorption

Water absorption

Leaf pigments

Cell structure

Water content

Visible

Near-Infrared

Shortwave Infrared

Blue

Green

Red

Reflectance (%)

Wavelength (μm)
Light: Electrical and magnetic dimensions (Polarization)
Fig. 2. The mean absorbance spectra of outer segments of the four classes of human photoreceptors. Curves labelled as follows: ‘498’, mean of eleven rods; ‘420’, mean of three blue-sensitive cones; ‘534’, mean of eleven green-sensitive cones; ‘564’, mean of nineteen red-sensitive cones.
Theories of color perception

• Trichromatic theory
  • RGB cones
• Opponent-process theory
  • Light-dark and two color scales, red-green and blue-yellow
• Both theories have value
• Nerves fire at a constant rate
• Above standard is excitation, below is inhibition
Simultaneous contrast
Almond illusion
Rendering color

• Depends on medium, but one major contrast
• Subtractive color
   • Assumes background color is white, uses filtering pigments to add to surface to create color
   • Add little color, unsaturated and light
   • Add full color, saturated and darker
   • Non-primary colors are blends of MCY
• Additive color
   • Assumes background is black
   • Adds illumination to achieve color
   • More color more saturated, more light brighter
   • Non-primary colors are blends of RGB
Offset color lithographic printing
Raster graphics
Raster imaging technologies

Delta

Phosphors on glass faceplate
Electron guns
Blue
Green
Red
Metal mask

In-line

Phosphors on glass faceplate
Electron guns
Blue
Green
Red
Metal mask

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Display details

- Pixelization
- Aliasing and anti-aliasing
- Dithering
- Frame buffers and the refresh rate
- Movement periodicity

https://www.youtube.com/watch?v=smDpCsVVgPA
Liquid Crystal Display

TFTs for red, green, and blue

Fluorescent Lamp
Liquid Crystal Material
TFT Layer (Thin Film Transistors)
Polarized Glass

Pixel composed of red, green, and blue subpixels

Intensity of light is altered as TFTs apply electrical current to liquid crystals
Light Emitting Diodes

- LED panels: conventional (using discrete LEDs) and surface-mounted device (SMD) panels
- A cluster of red, green, and blue diodes is driven together to form a full-color pixel, usually square
- Pixels are spaced evenly apart and are measured from center to center for absolute pixel resolution
- Largest LED display in the world is over 500 meters long in Suzhou, China
- Largest LED television in the world is the Center Hung Video Display at Cowboys Stadium, which is 49 m × 22 m
- LED TVs using SMD pixels of red, green, and blue diodes mounted in a single package, which is then mounted on the driver PC board
- Individual diodes are smaller than a pinhead and are set very close together
- Reduces maximum viewing distance by 25% from the discrete diode screen at the same resolution
Color models: Cube
Color production and reproduction

• Requires measurement
• Based on standards
• Names are subjective
• Applies to foveal zone only
• Requires color MODEL
Color models: Wheel (Hue and Saturation)
CMYK: Subtractive primaries
Cyan, magenta, yellow, black
HSV color model: Perceptual, but not all equal value

Hue: Wavelength
Saturation: Amount of pigment
Value: Intensity or brightness
Saturation
Intensity
Munsell color model
Munsell layers
CIE color model

- Commission Internationale de l’Eclairage
- Objective way to specify color
- Based on three numbers Yxy
- Two dimensional space for range of hue and saturation
- Central white-point (or equal energy)
- Uses RGB theory, color combinations and human subjects for color repetition
- Attempt to rectify perceptual difference in luminescence as a function of hue
CIE color spaces
CIE stimulus adjustment
Diverging
Qualitative
Summary

• Color is complex and powerful
• Light behaves as both a wave and particles
• Light interacts with all aspects of map viewing
• Colors can be additive or subtractive
• Color models allow color specification and control
• Covered RGB, CMYK, HSV, Munsell and CIE
• Colorbrewer recommends color sequences for sequential, diverging and qualitative color sets
• Don’t forget: Hue suggests class, saturation and intensity suggest value