The Art and Science of Depiction

Introduction to Color Vision

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Introduction to color vision

I wonder if we all see colors the same.

Like, green to you might look red to me, even though I call it green too!

OK, what color is that rock to you?

Grey!

Wrong!
Plan

• Physical spectrum
• Trichromatic vision
  – Cones
  – Metamerism
  – Chromatic adaptation
  – Color blindness
• Color Opponents
Physical spectrum

- 1666, Newton
- Pittoni, Allegory, 1925
Physical spectrum

Electromagnetic Spectrum

Cosmic Rays | Gamma Rays | X-rays | UV | Light | Infra-Red | Microwaves | TV | Radio

Visible Spectrum

Wavelength (nm)

400 | 500 | 600 | 700
Light source spectrum
Reflectance Spectrum

- Objects do not have a “color”
- They have a reflectance spectrum
Reflected spectrum

- Depends on light source and reflectance
- Multiply

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Trichromatic vision

- Maxwell, Young, Helmholtz
- Cones
Cone spectral sensitivity

- Short, Medium and Long wavelength
Cones distribution

- LMS 40:20:1
- No S (blue) in retina center
Cones do not “see” colors
Cones do not “see” colors

- Different wavelength, different intensity
- Same response
Response comparison

- Different wavelength, different intensity
- But different response for different cones
Complex spectrum
Summary

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**Metamerism**

- Different spectrum
- Same response
Color matching

(A) Bipartite white screen

Primary lights

Test light

Surround field

(B) Surround field

Primary lights

Test light

Subject
Color synthesis

Additive
red, green, blue

Subtractive
cyan, magenta, yellow
Future discussion

• Limited gamut
Metamerism & light source

- Metamers under a given light source
- May not be metamer under a different lamp
- Because different spectrum
Metamerism & light source

(A) Tungsten bulb

(B) Blue sky

Introduction to Color Vision
Metamerism & light source

- Metamers under a given light source
- May not be metamer under a different lamp
- Because different spectrum
- Problem when buying cloths under neon lighting
Plan

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• Color Opponents
Chromatic adaptation

- Von Kries adaptation
- Different gain control on L, M, S

Gain control:
*1.33, *1, *1

0.75, 1, 1

0.15, 1, 0.2

0.2, 1, 0.2

0.75, 1, 1

0.2, 1, 0.2

0.2, 1, 0.2

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**Color blindness**

- **Dalton**
- **8% male, 0.6% female**
- **Genetic**
- **Dichromate (2% male)**
  - One type of cone missing
  - L (protanope), M (deuteranope), S (tritanope)
- **Anomalous trichromat**
  - Shifted sensitivity
We are all color blind

- Center of retina
- No S (blue)
- We compensate via gaze movement
- Not well understood
Color blindness test
**Color blindness test**

- Maze in subtle intensity contrast
- Visible only to color blinds
- Color contrast overrides intensity otherwise
Color blind impressions

- A normal scene
- B protanope L
- C deuteranope M
- D tritanope S
Color blindness & Painting

- Restricted to blue-yellow

Goethe after a color-blind
Color blindness & Painting

- Restricted to blue-yellow

Meryon, *Le Vaisseau Fantôme*
Color blindness & Painting

• Restricted to blue-yellow
**Color blindness & Painting**

- Image reproduction (after Gauguin)
- Different strategies

![Paintings illustrating normal color vision, color blind (perceived), and color blind (confusion)]
Plan

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Color Opponents

- Hering
- A color can be “blue-green”, “yellow-red”, “yellow-green”, etc
- But never “yellow-blue” or “red-green”
- Suspected two opponents:
  - Blue-yellow axis
  - Red-Green axis
Color opponents wiring

- Sums for brightness
- Differences for color opponents
Double center surround opponents

- Center-surround
- Color opponents
Color reparameterization

• The input is LMS
• The output has a different parameterization:
  – Light-dark
  – Blue-yellow
  – Red-green
Color reparameterization

- The input is LMS
- The output has a different parameterization:
  - Light-dark
  - Blue-yellow
  - Red-green
- A later stage may reparameterize:
  - Brightness
  - Hue
  - Saturation
Opponents and image compression

- JPG, MPG
- Color opponents instead of RGB
- Compress color more than luminance
Blue-yellow opponent and painting

- Often used to depict night
- (S cones share properties with rods…)
- Van Gogh
  Café at Night
Red-green opponent and painting

- Jawlensky
Opponent and painting

- Degas