Color Perception and Applications

SIGGRAPH ‘99 Course:  
Fundamental Issues of Visual Perception  
for Effective Image Generation

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Overview

• Characteristics of Color Perception  
• Mechanisms of Color Perception  
• Color Specification  
• Using Color to Represent Information
Characteristics of Color Perception

- Fundamental, independent visual process
  - after-images
  - color deficient vision
- Relative, not absolute
- Interactions between color and other visual properties

Physiology: Receptors

- Rods
  - active at low light levels (scotopic vision)
  - only one wavelength sensitivity function
- Cones
  - active at normal light levels
  - three types: sensitivity functions with different peaks
Cone Sensitivity Functions

- Glassner ‘95, p. 16.

Physiology: Ganglia

- Transform incoming SML into opponent color responses
  - G - R
  - Y - B (Y = R+G)
  - W (W = R+G)

- Characteristics
  - concentric receptive fields
  - logarithmic response of receptors
  - adaption
**Physiology: Brain**

- **Lateral geniculate nuclei**
  - assemble data for single side of visual field
  - 2 monochromatic layers => magnocellular path
  - 4 chromatic layers => parvocellular path

- **Visual cortex**
  - visual area 1: blobs
  - visual area 2: thick stripes
  - visual area 4

**Visual Pathway**

- Murch, ‘87.
Parvocellular Division

• Role in vision
  – discrimination of fine detail
  – color
• Characteristics
  – color: sensitive to wavelength variations
  – acuity: small RF centers
  – speed: relatively slow response

Color Models

• Device-derived
  – convenient for describing display device levels
  – RGB, CMY
• Intuitive
  – based in familiar color description terms
  – HSV, HSB, HLS
• Perceptually uniform
  – device independent, perceptually uniform
  – CIELUV, CIELAB, Munsell
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Uses of Color

- Show classification
- Mimic reality
- Show value
- Draw attention
- Show grouping
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Perceptual Distortions

• Color-deficiency
• Interactions between color components
  – saturation - brightness (Helmholtz-Kohlraush effect)
  – brightness - hue (Bezold-Brucke Phenomenon)
• Simultaneous contrast
  – brightness
  – hue
• Small field achrominance
• Effects of color on perceived size
Bezold-Brucke Phenomenon

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- Hurvich ‘81, pg. 73.
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Small Field Achrominance

• Wandell ‘95, cp. 3.
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Color-size Illusion

- Cleveland and McGill ‘83.
Some Color Scales

- Univariate
  - color model component
  - optimal scales
  - double-ended
- Multivariate
  - color model components
  - Census Bureau TVCM
  - complementary display parameters
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• Olson ‘97, fig. 11-8.
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Evaluating Color Scales

• Trumbo’s Principles
  – *Order*: ordered values should be represented by ordered colors
  – *Separation*: significantly different levels should be represented by distinguishable colors
  – *Rows and columns*: to preserve univariate information, display parameters should not obscure one another
  – *Diagonal*: to show positive association, displayed colors should group into three perceptual classes: diagonal, above, below
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• Tufte ‘83, pg. 153.
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Evaluating Color Scales (cont.)

- Ware’s experiments
  - metric (quantitative) judgements
  - surface (qualitative) judgements
  - redundant color scales
Ware’s Color Scales

- Ware ‘88.
Considerations

• Consider goals
• Consider data
• Consider audience
• Consider color connotations
Final Consideration

- Does this work?
Principles of Color Representation

- Avoid distortions
- Exploit the familiar
- Emphasize the interesting
- Say it again (redundant mappings)
- Select appropriate level of detail
Color Models: Device-derived

- Red-Green-Blue
Color Models: Intuitive

- Hue-Saturation-Value
- Hue-Lightness-Saturation

Color Models: Perceptually Uniform

- CIELUV
Opponent Channel Recoding

Long (R) → - → R - G
Medium (G) + Yellow → Achromatic
Short (B) - → Y-B