University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2007

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Vision/Color II, Virtual Trackball

Week 5, Wed Feb 7

http://www.ugrad.cs.ubc.ca/~cs314/Vjan2007

Reading for Last Time & Today

- RB Chap Color
- FCG Sections 3.2-3.3
- FCG Chap 20 Color
- FCG Sections 21.2.2, 21.2.4

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Reading for Next Time

- FCG Chap 3 Raster Algorithms
  - (except 3.2-3.4, 3.8)
- FCG Section 2.11 Triangles

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Midterm News

- midterm next time (Friday Feb 9)
  - closed book, no calculators
  - allowed to have one page of notes
    - handwritten, one side of 8.5x11" sheet
  - this room (DMP 301), 10-10:50
  - material covered
    - transformations, viewing/projection
  - sit where there is an exam
  - cell phones off

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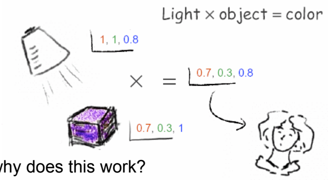
Review: RGB Component Color

- simple model of color using RGB triples
- component-wise multiplication
  - (a0,a1,a2) * (b0,b1,b2) = (a0*b0, a1*b1, a2*b2)



  - why does this work?
    - must dive into light, human vision, color spaces

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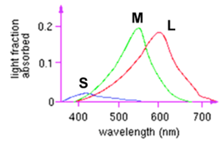
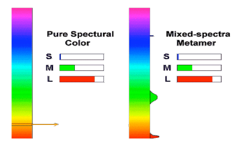
Review: Trichromacy and Metamers

- three types of cones
- color is combination of cone stimuli
  - metamer: identically perceived color caused by very different spectra





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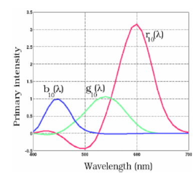
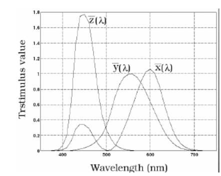
Review: Measured vs. CIE Color Spaces



- measured basis
  - monochromatic lights
  - physical observations
  - negative lobes



- transformed basis
  - "imaginary" lights
  - all positive, unit area
  - Y is luminance

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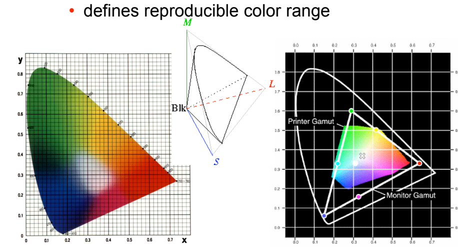
Review: Chromaticity Diagram and Gamuts

- plane of equal brightness showing chromaticity
- gamut is polygon, device primaries at corners
  - defines reproducible color range



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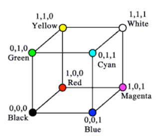
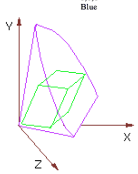
Review: RGB Color Space (Color Cube)

- define colors with (r, g, b) amounts of red, green, and blue
  - used by OpenGL
  - hardware-centric



- RGB color cube sits within CIE color space
  - subset of perceivable colors
  - scale, rotate, shear cube



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Vision/Color II

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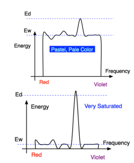
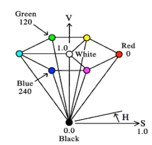
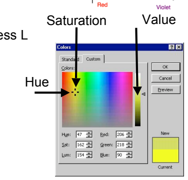
HSV Color Space

- more intuitive color space for people
  - H = Hue
    - dominant wavelength, "color"
  - S = Saturation
    - how far from grey/white
  - V = Value
    - how far from black/white
    - aka brightness B, intensity I, lightness L







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HSV and RGB

- HSV/HSI conversion from RGB
  - not expressible in matrix

$$I = \frac{R+G+B}{3} \qquad S = 1 - \frac{\min(R+G+B)}{I}$$

$$H = \cos^{-1}\left[\frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right]$$

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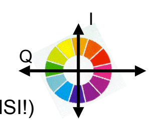
YIQ Color Space



- color model used for color TV
  - Y is luminance (same as CIE)
  - I & Q are color (not same I as HSI!)
  - use Y only for B/W backwards compatibility
  - conversion from RGB is linear

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.30 & 0.59 & 0.11 \\ 0.60 & -0.28 & -0.32 \\ 0.21 & -0.52 & 0.31 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- green much lighter than red
- red lighter than blue

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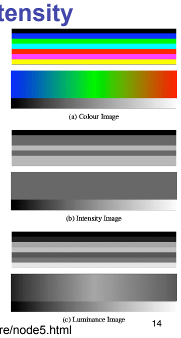
Luminance vs. Intensity

- luminance
  - Y of YIQ
  - 0.299R + 0.587G + 0.114B
- intensity/brightness
  - I/V/B of HSI/HSV/HSB
  - 0.333R + 0.333G + 0.333B



www.csse.uwa.edu.au/~robyn/Visioncourse/colour/lecture/node5.html

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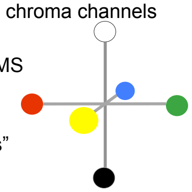
Opponent Color

- definition
  - achromatic axis
  - R-G and Y-B axis
  - separate lightness from chroma channels
- first level encoding
  - linear combination of LMS
  - before optic nerve
  - basis for perception
  - defines "color blindness"



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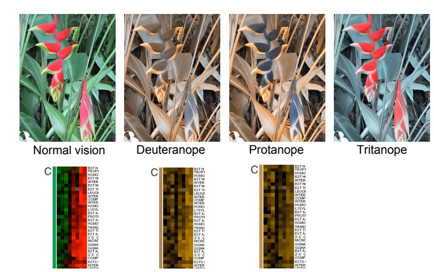
vischeck.com

- simulates color vision deficiencies



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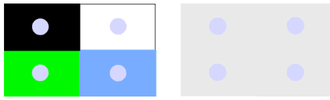
Adaptation, Surrounding Color

- color perception is also affected by
  - adaptation (move from sunlight to dark room)
  - surrounding color/intensity:
    - simultaneous contrast effect



Color/Lightness Constancy

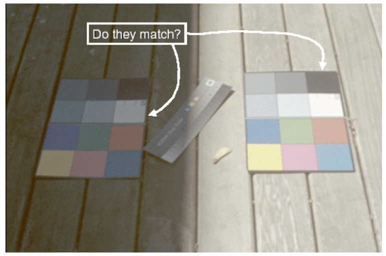


Image courtesy of John McCann

Color/Lightness Constancy

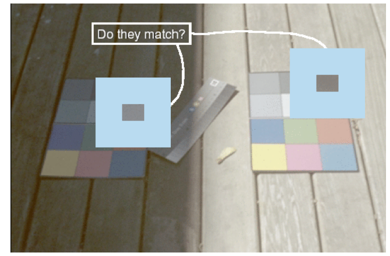
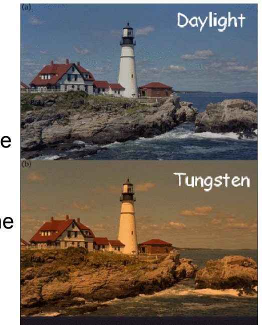


Image courtesy of John McCann

Color Constancy

- automatic "white balance" from change in illumination
- vast amount of processing behind the scenes!
- colorimetry vs. perception



From Color Appearance Models, fig 8-1

Stroop Effect

- **say what the color is as fast as possible**

  - **red**
  - **blue**
  - **orange**
  - **purple**
  - **green**

Stroop Effect

- **blue**
- **green**
- **purple**
- **red**
- **orange**

- interplay between cognition and perception

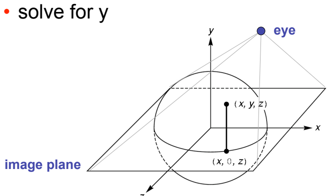
Virtual Trackball

Virtual Trackball

- interface for spinning objects around
  - drag mouse to control rotation of view volume
    - orbit/spin metaphor
    - vs. flying/driving with lookat
- rolling glass trackball
  - center at screen origin, surrounds world
  - hemisphere "sticks up" in z, out of screen
  - rotate ball = spin world

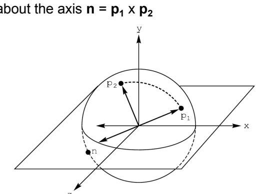
Virtual Trackball

- know screen click: (x, 0, z)
- want to infer point on trackball: (x,y,z)
  - ball is unit sphere, so ||x, y, z|| = 1.0
  - solve for y



Trackball Rotation

- correspondence:
  - moving point on plane from (x, 0, z) to (a, 0, c)
  - moving point on ball from $\mathbf{p}_1$ =(x, y, z) to $\mathbf{p}_2$ =(a, b, c)
- correspondence:
  - translating mouse from $\mathbf{p}_1$ (mouse down) to $\mathbf{p}_2$ (mouse up)
  - rotating about the axis $\mathbf{n} = \mathbf{p}_1 \times \mathbf{p}_2$



Trackball Computation

- user defines two points
  - place where first clicked $\mathbf{p}_1$ = (x, y, z)
  - place where released $\mathbf{p}_2$ = (a, b, c)
- create plane from vectors between points, origin
  - axis of rotation is plane normal: cross product
    - $(\mathbf{p}_1 - \mathbf{o}) \times (\mathbf{p}_2 - \mathbf{o})$: $\mathbf{p}_1 \times \mathbf{p}_2$ if origin = (0,0,0)
  - amount of rotation depends on angle between lines
    - $\mathbf{p}_1 \cdot \mathbf{p}_2 = |\mathbf{p}_1|\,|\mathbf{p}_2| \cos\theta$
    - $|\mathbf{p}_1 \times \mathbf{p}_2| = |\mathbf{p}_1|\,|\mathbf{p}_2| \sin\theta$
- compute rotation matrix, use to rotate world