Shadows

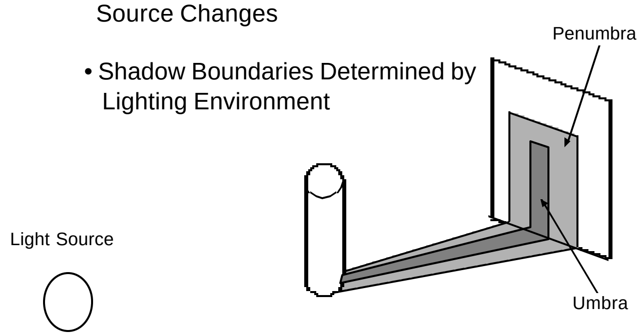
Lecture 14

Shadows

Shadows

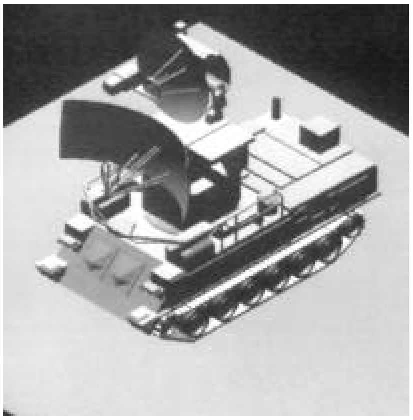
Lecture 14

- Increase Realism by Adding Detail
  - Stop “floating” objects
  - Emphasize illumination direction
- Re-compute Shadows Each Time Light Source Changes
- Shadow Boundaries Determined by Lighting Environment



Shadows

Lecture 14

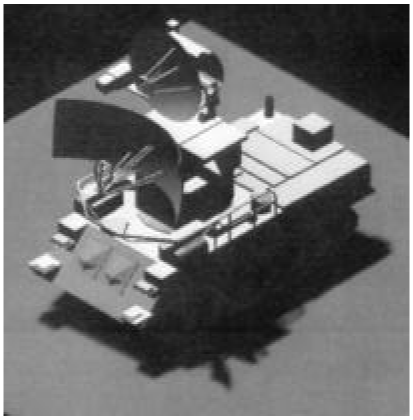


Target on Ground Plane Without Shadow

3

Shadows

Lecture 14



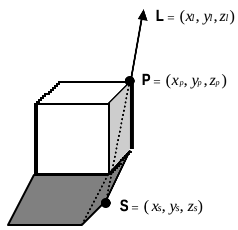
Target on Ground Plane With Shadow

4

Shadows

Lecture 14

- Shadows on a Ground Plane
  - Single Point Source
  - Infinite Distance (Parallel Rays)



$$\mathbf{S} = \mathbf{P} - a\,\mathbf{L}$$

Since $z_s = 0$,
$0 = z_p - a z_l$
$a = z_p / z_l$

$$x_s = x_p - (z_p / z_l)\, x_l$$
$$y_s = y_p - (z_p / z_l)\, y_l$$
$$z_s = 0$$

$$\begin{bmatrix} x_s \\ y_s \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & -x_l/z_l & 0 \\ 0 & 1 & -y_l/z_l & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_p \\ y_p \\ z_p \\ 1 \end{bmatrix}$$

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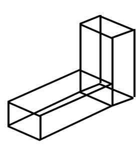
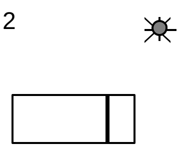
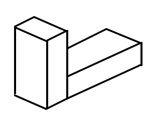
Shadows

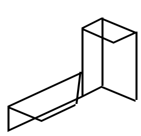
Lecture 14

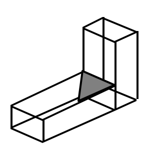
- Non-raytracing Technique
- Determines “Hard” Edge (Umbra) Only
- Computes New “Shadow” Polygons

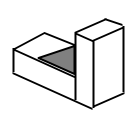
1

Simple Polygon Model

2

Top View with Light Source

3

View From Light Source

4

Illuminated Polygons

5

Shadow Polygon

6

View From Arbitrary Position

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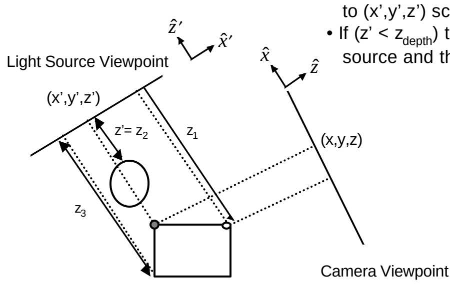
Shadows

Lecture 14

- Zbuffer Transform
  - Simple two-step approach
    - Render depth map from illumination viewpoint
    - Render from camera viewpoint
      - If point is visible…
        - Transform (x,y,z) screen coords from camera view to (x',y',z') screen coords from light view
        - If ($z' < z_{depth}$) then a surface is between the light source and the point, so shadow the point



$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = [{}_lT_c] \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

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Color Models

Lecture 14

Color Models

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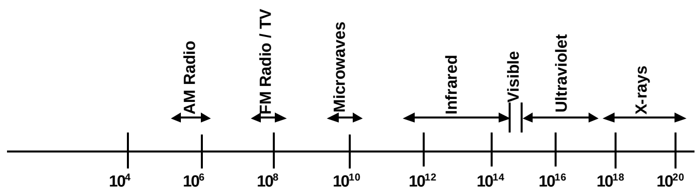
Color Models

Lecture 14

- Electromagnetic Spectrum



- Visible Wavelengths (ROY G BIV)
  - Red ~ 670 nm ~ 4.3×10^{14} Hz
  - Violet ~ 420 nm ~ 7.5×10^{14} Hz

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Color Models

Lecture 14

- **Color of an Object Determined by Reflected Wavelengths**
- **White = All Wavelengths/Frequencies**

$$c = l \cdot u$$

$$c = 3\times10^{10} \text{ cm/sec}$$

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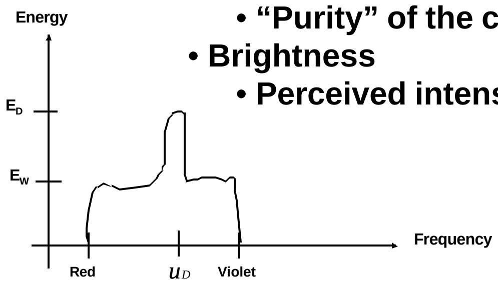
Color Models

Lecture 14

- **Color Description**
  - **Hue**
    - **Dominant wavelength/frequency**
  - **Saturation**
    - **“Purity” of the color**
  - **Brightness**
    - **Perceived intensity**



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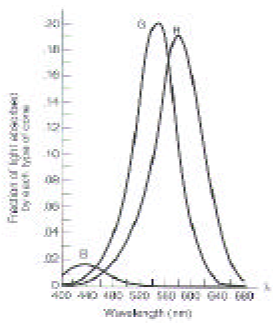
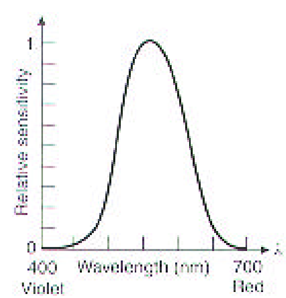
Color Models

Lecture 14

- Colors Not in a Rainbow?
  - Color combination from multiple sources
  - Human perception
    - Tristimulus Theory





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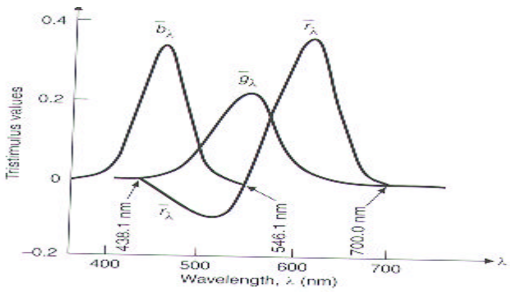
Color Models

Lecture 14

- Color Matching
  - Choose weights for three sources (primaries)
  - Combine sources to produce sample color
  - If no match can be obtained, add a primary to sample
    - Negative weight



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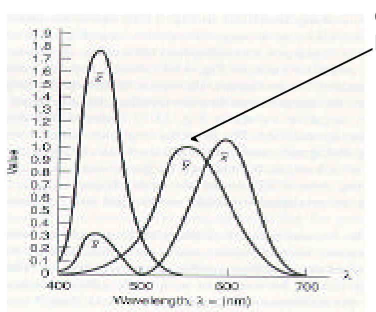
Color Models

Lecture 14

- International Commission on Illumination (CIE)
  - Define three primaries (imaginary colors)
  - Combine primaries with positive weights

$$C_l = X\mathbf{X} + Y\mathbf{Y} + Z\mathbf{Z}$$



Chosen to match Luminous efficiency

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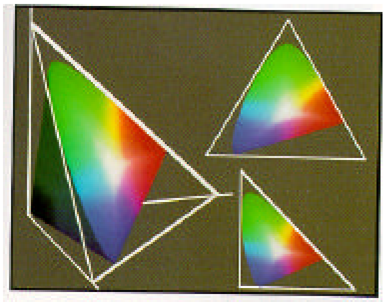
Color Models

Lecture 14



• Normalize against Luminance (X+Y+Z)

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \qquad z = \frac{Z}{X+Y+Z}$$

$$(x + y + z = 1)$$

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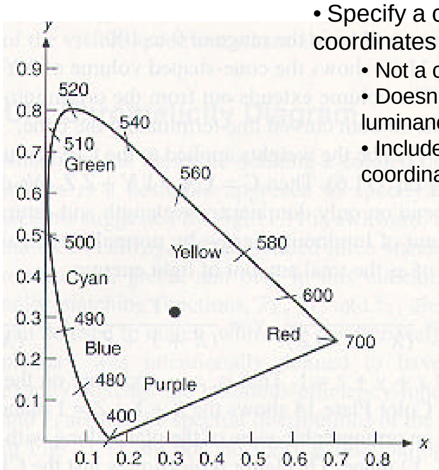
Color Models

Lecture 14



• Specify a color with chromaticity coordinates (x,y)

- Not a complete color palette
- Doesn't account for color changes due to luminance
- Include luminance information in coordinate (x,y,Y)

$$X = \frac{x}{y}Y$$

$$Y = Y$$

$$Z = \frac{(1-x-y)}{y}Y$$

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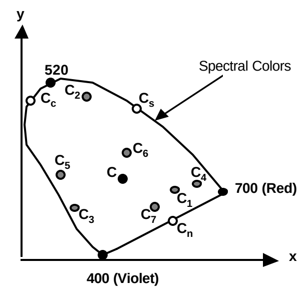
Color Models

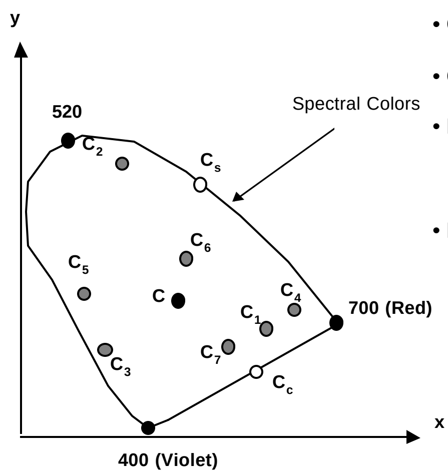
Lecture 14

- Chromaticity Diagram
  - Compare color gamuts for different primaries
  - Identify complementary colors
  - Determine dominant wavelength and purity of a given color



Color Models

Lecture 14



- Color Gamut ==> C_1, C_2, C_3
- Complementary Colors ==> C_4, C_5
- Dominant Wavelength
  - C_6 ==> C_s
  - C_7 ==> C_c
- Purity ==> Distance from C
  - C_4 very pure
  - C_6 not very pure

C_n

Color Models

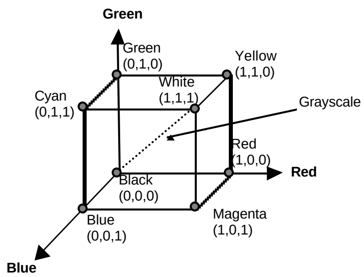
Lecture 14

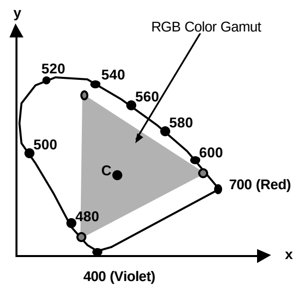
- RGB Color Model
  - Additive Primaries

$C_l = R\mathbf{R} + G\mathbf{G} + B\mathbf{B}$

Chromaticity Coordinates

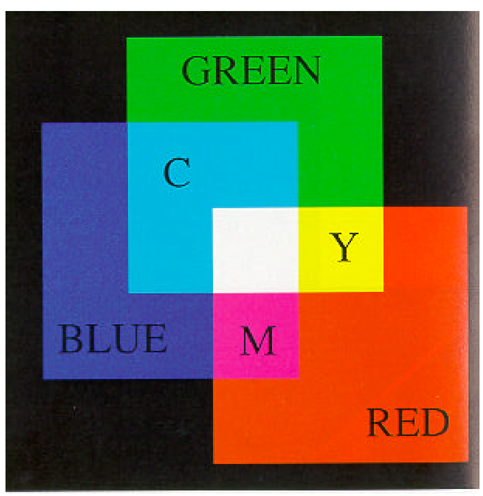
R	(0.735, 0.265)
G	(0.274, 0.717)
B	(0.167, 0.009





Color Models

Lecture 14



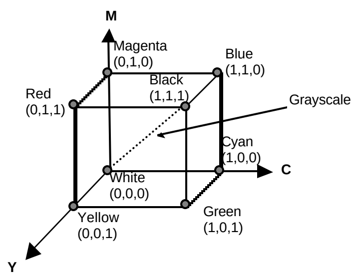
Color Models

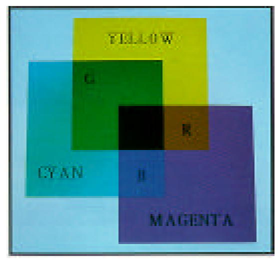
Lecture 14

- CMY Color Model
  - Cyan, Magenta, Yellow
  - Complements of RGB
  - Subtractive Primaries
  - Hardcopy Devices
  - Combining Pigments

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Cyan = White - Red = Green + Blue





Color Models

Lecture 14

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  - Subtractive Primaries
  - Hardcopy Devices
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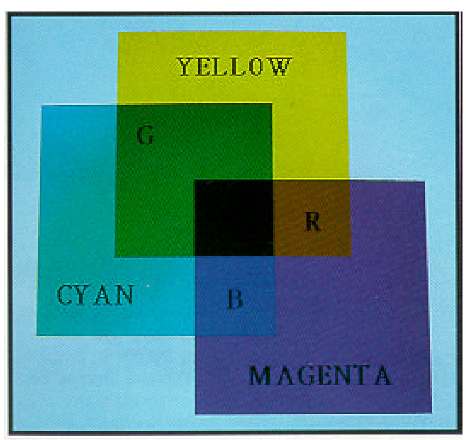

Color Models

Lecture 14

- YIQ Color Model
  - Re-coded RGB for NTSC transmission efficiency
  - Y component is luminance (CIE)
  - Black and white TV displays only the Y component
    - Largest bandwidth in the NTSC video signal (4 MHz)
  - Chromaticity encoded in I and Q

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

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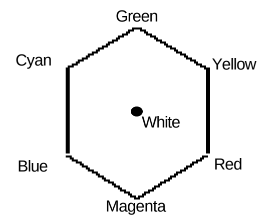
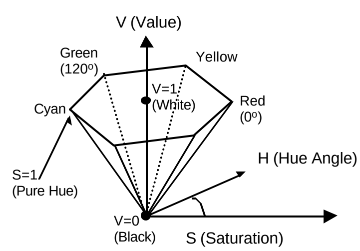
Color Models

Lecture 14

- HSV Color Model
  - User intuitive
  - Shades
    - Addition of black pigment to a given hue
  - Tints
    - Addition of white pigment to a given hue
  - Tones
    - Addition of both black and white to a hue



- Vary H (Hue) ==> Select Color
- Decrease S (Saturation) ==> Add white
- Decrease V (Value) ==> Add Black



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