Lecture 09 - Color Models (Chapter 19)

I. Introduction - so far we have been limited to RGB selection of colors, however this has issues. (1) It is not great for non-electronic mediums (2) It isn't natural to seeing.

A. Properties of light
   i. Light is radiant energy often described as a wave
      ii. The frequency of the wave describes its "color"

   ![Frequency Chart]

   "Red" ≈ 7.1 x 10^14 Hz "Violet" ≈ 7.7 x 10^14 Hz

   
   *Wavelength is distance traveled between oscillations of a wave. It more conveniently describes color but is material dependent.

   In a vacuum - "Red" is about 700 nm "Violet" is 400 nm

   For an object, materials absorb some frequencies and reflect others. What we perceive as an objects color is the combination of frequencies in the reflection. "Blue" is the dominant frequency of the perceived color.

B. Psychological Characteristics of color - other sensations
   i. Brightness - total light energy or luminance of the light
      ii. Purity or Saturation - proximity to a pure hue. E.g. Pastel colors have low purity/brightness and appear nearly "white"
      iii. Chromaticity collectively refers to purity and hue.
   iv. Intensity of energy

   ![Energy Diagram]

   White light
   
   Hue - Dominant Frequency
   Brightness - area under the curve
   Purity = E_D - E_W

C. Color Models - methods for explaining properties or behavior of color. No model is perfect.
   i. RGB  Mix primary colors. Color Gamut is expressiveness of color model
   ii. Two primary colors that combine to white light are complimentary colors.
   iii. No set can express all colors - 3 sufficient for most purposes.
   iv. Artists mix black or white to lighten or darken (tints or shades). Shades are created by adding black, while tints are mixed with white. Tones are added white and black.
10. Standard Color Primaries and the Chromaticity Diagram

i. 3 standard primaries were defined in 1931 by CIE (Commission Internationale de l'Éclairage). They are entirely imaginary and defined mathematically.

ii. XYZ color model - derived by amounts of imaginary colors mixed together, just like RGB color model.

iii. Normalized XYZ values - easier to express

\[ x = \frac{X}{X+Y+Z} \quad y = \frac{Y}{X+Y+Z} \quad z = \frac{Z}{X+Y+Z} \quad \text{where} \quad x+y+z = 1 \]

So we only need \( x, y \) to define a color. Usually with a luminance \( L \):

\[ x = \frac{X}{L} \quad y = \frac{Y}{L} \quad z = 1 - x - y \]

iv. Chromaticity Diagram - plot of \( x, y \) values for normalized XYZ model.

V. Color Gamut - polygonal region of chromaticity diagram

VI. Dominant wave length - draw straight line from \( C \) to chromaticity curve. 1/p point ends on purple line (look at complement on opposite side).

VII. Purity - distance of color from \( C \). Distance of spectral color to \( C \) purity up to 100% is a spectral color.
II. The RGB color model — for emitting devices (emitting = additive process)

A. One theory of visible states we perceive a combination of 3 colors — red, green, blue.
   This is the basis for electronics being RGB.

B. Can represent as a unit cube on R, G, B axis.

   Color is weighted sum of color components. (Vectors)

   \[ \mathbf{x} = (x, y, z) \text{ in R, G, B} \]
   \[ \mathbf{y} = (0.67, 0.33) \text{ in R, G, B} \]
   \[ \mathbf{z} = (0.34, 0.54) \text{ in R, G, B} \]

C. Color gamut

III. CMY + CMYK — for output devices of physical pigments (subsiding — subtractive process) printer

A. Cyan, Magenta, Yellow, K is black component for purity.

B. Color cube.

C. Conversion between RGB and CMYK:

\[
\begin{bmatrix}
C \\
M \\
Y \\
K
\end{bmatrix} = \begin{bmatrix}
1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1
\end{bmatrix} \begin{bmatrix}
R \\
G \\
B \\
K
\end{bmatrix}
\]

For \( K = \frac{-R}{-G - B} \) and subtract out of \( (CMY) \)

Otherwise:

\( K = \frac{-R}{-G - B} \)

and subtract out of \( R, G, B \).
IV. HSSV color model - Intensive for artists

A. Hue, Saturation, Value

i. In relation to color model RGB

- Forms a hexagon:
  - Red, Yellow, Green, Cyan, Blue, Magenta

ii. Hue - H - angle about cone

- Saturation - S - distance from center, designates purity. Allows adding tones to colors

- Value - V - 0 is apex of cone (black), 1 is top white. Allows adding shades to colors

So adding shade is reducing V, adding tint is increasing S.

In other words:

B. HLS - Hue, Lightness, Saturation. Similar to HSSV but double cone model.

C. YIQ - For sending color as a signal. Y is from XYZ, I - a phase, Q = quadrature.