Image Processing Lecture-6

Color image processing

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Color

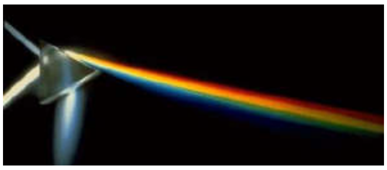
- It is an important descriptor for object recognition and extraction.
- Human eye is more efficient when assessing color + intensity information compared to intensity only case.
- Color images can be investigated in two main groups:
  - •Full color
  - •Pseudo color

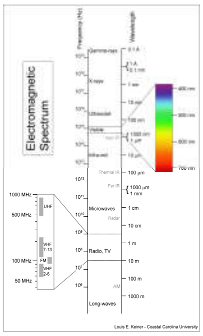
Images captured via a color image sensor.

Images constructed via coloring gray-tone images.

Color – Electromagnetic Spectrum

- Optical Prism (Isaac Newton-1666)





- The light is not colored, it only has intensity.

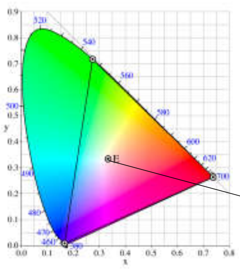
Color perception

- 3 basic qualities are used to describe the quality of a chromatic light source:
  - •Radiance: the total amount of energy that flows from the light source (measured in watts)
  - •Luminance: the amount of energy an observer perceives from the light source (measured in lumens). Note we can have high radiance, but low luminance
  - •Brightness: a subjective (practically unmeasurable) notion that embodies the intensity of light
- Approximately 66% of these cones are sensitive to red light, 33% to green light and 6% to blue light
- Specifying colors systematically can be achieved using the CIE chromacity diagram

CIE* Chromacity Diagram

- On this diagram the x-axis represents the proportion of red and the y-axis represents the proportion of green used
- The proportion of blue used in a colors is calculated as:

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

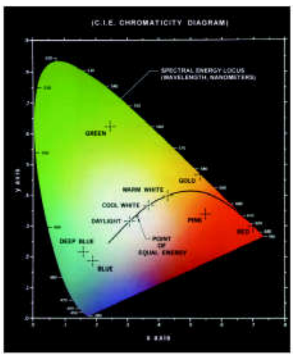


CIE RGB renk uzayı

x=0.33, y=0.33, z=0.33

*CIE: Int. Commission on Illumination

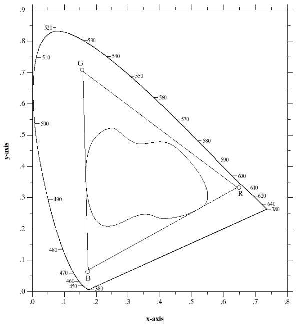
CIE* Chromacity Diagram



Green: 62% green, 25% red and 13% blue

Red: 32% green, 67% red and 1% blue

CIE* Chromacity Diagram



- Any color located on the boundary of the chromacity chart is fully saturated
- The point of equal energy has equal amounts of each color and is the CIE standard for pure white
- Any straight line joining two points in the diagram defines all of the different colors that can be obtained by combining these two colors additively
- This can be easily extended to three points. This means the entire color range cannot be displayed based on any three colors
- The triangle shows the typical color gamut produced by RGB monitors. The strange shape is the gamut achieved by high quality color printers

Color Models

- From the previous discussion it should be obvious that there are different ways to model color. We will consider two very popular models used in color image processing:
- RGB (Red, Green, Blue):
  - Color monitors.
- CMY (Cyan, Magenta, Yellow), CMYK (Cyan, Magenta, Yellow, blacK)
  - Color printers.
- HSI (Hue, Saturation, Intensity)
  - Human like color assessment.
- YIQ
  - Color NTSC broadcasting.
- YCbCr
  - Color digital TV broadcasting.

Color Models - RGB

In the RGB model each color appears in its primary spectral components of red, green and blue

The model is based on a Cartesian coordinate system

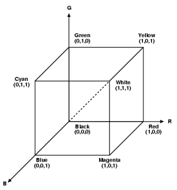
RGB values are at 3 corners

Cyan magenta and yellow are at three other corners

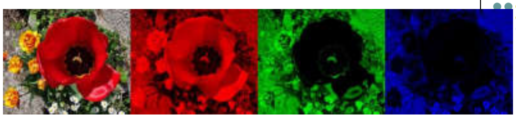
Black is at the origin

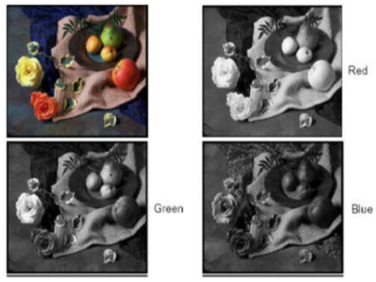
White is the corner furthest from the origin

Different colors are points on or inside the cube represented by RGB vectors



Color Models - RGB





Color Models - CMY

- RGB <-> CMY color spaces:

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

- CMYK is used since the C, M and Y are not able to produce exact black color. Thus, color printers used this color model.

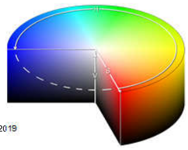
Renk Modelleri - HSI

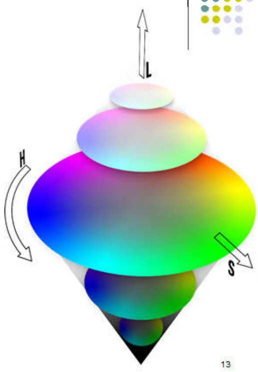
- RGB is useful for hardware implementations and is serendipitously related to the way in which the human visual system works
- However, RGB is not a particularly intuitive way in which to describe colors
- Rather when people describe colors they tend to use hue, saturation and brightness
- RGB is great for color generation, but HSI is great for color description

Color models - HSI

The HSI model uses three measures to describe colors:

- **Hue:** A color attribute that describes a pure color (pure yellow, orange or red)
- **Saturation:** Gives a measure of how much a pure color is diluted with white light
- **Intensity:** Brightness is nearly impossible to measure because it is so subjective. Instead we use intensity. Intensity is the same achromatic notion that we have seen in grey level images





Color Models - HSI

RGB → HSI

$$H = \begin{cases} \theta & \text{if } B \le G \\ 360 - \theta & \text{if } B > G \end{cases}$$

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

$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R,G,B)\right]$$

$$I = \frac{1}{3}(R+G+B)$$

Color Models - HSI

HSI → RGB

$(0° \le H < 120°)$

$$B = I(1-S)$$

$$R = I\left[1 + \frac{S\cos H}{\cos(60° - H)}\right] \quad G = 3I - (R+B)$$

$(120° \le H < 240°)$

$$H = H - 120°$$

$$R = I(1-S)$$

$$G = I\left[1 + \frac{S\cos H}{\cos(60° - H)}\right] \quad B = 3I - (R+G)$$

$(240° \le H \le 360°)$

$$H = H - 240°$$

$$G = I(1-S)$$

$$B = I\left[1 + \frac{S\cos H}{\cos(60° - H)}\right] \quad R = 3I - (G+B)$$

Color Models - YUV

- PAL, NTSC, SECAM composite color video standards use this approach.
- Y is luma, U and V are chrominance components.
- YUV component can be obtained using RGB color space.
- Y is average intensity computed by the weighted average of R,G and B where as U and V is computed by subtracting Y from Blue and Red, respectively.

RGB → YUV :

$$\begin{aligned} Y &= 0.299*R + 0.587*G + 0.114*B \\ U &= 0.436*(B-Y)/(1-0.114) \\ V &= 0.615*(R-Y)/(1-0.299) \end{aligned} \qquad \begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$R, G, B \in [0,1]$ $\quad Y \in [0,1], \quad U \in [-0.436, 0.436], \quad V \in [-0.615, 0.615]$

YUV → RGB :

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & -0.39465 & -0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y \\ U \\ V \end{bmatrix}$$

If the image is digital this model is called as YCbCr color space.

Color Models - Comparison

Color Models – MATLAB Functions

In MATLAB:

- RGB → ...
  - YCbCr **rgb2ycbcr**
  - YIQ **rgb2ntsc**
  - HSI **rgb2hsv**
- ... → RGB
  - YCbCr **ycbcr2rgb**
  - YIQ **ntsc2rgb**
  - HSI **hsv2rgb**

Grayscale image construction from the RGB Color Model

$$Y = \frac{R+G+B}{3}$$

$$Y = 0.299R + 0.587G + 0.114B \quad , \quad \text{according to NTSC standard}$$