Lesson 8: Colour

1. Colour Fundamentals

2. Colour Models

3. Acquiring Colour Images

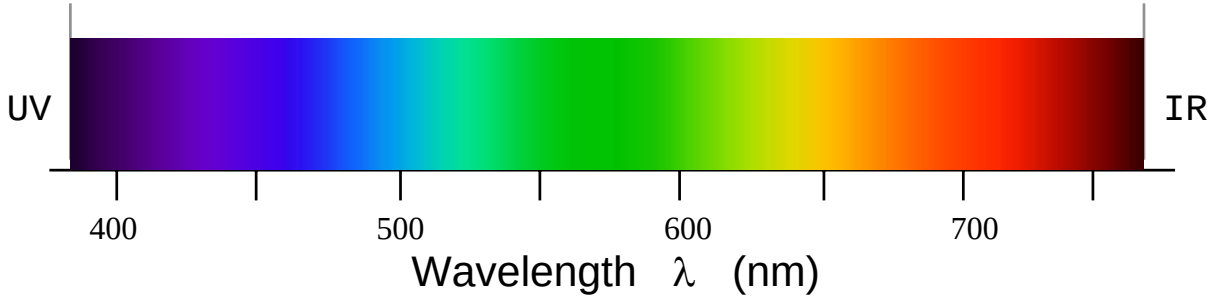
4. Colour Image Processing

Bibliography:

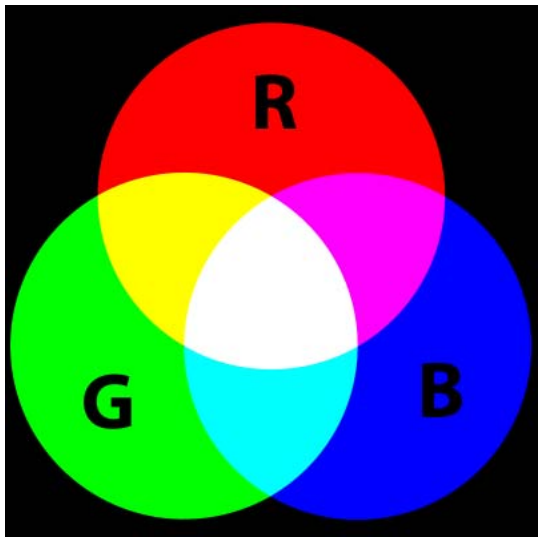
RC Gonzalez, RE Woods: **Digital Image Processing, 2nd ed.**, Prentice Hall, 2002

1. Colour Fundamentals

- Visible spectrum, wavelengths: 380-780 nm

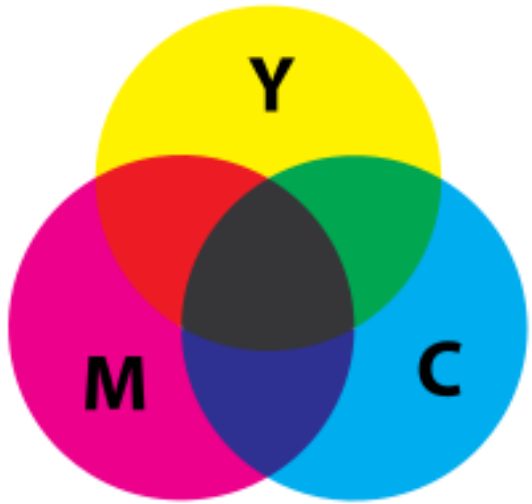


Primary Light Colours:
Red, Green, Blue



Additive colour mixing

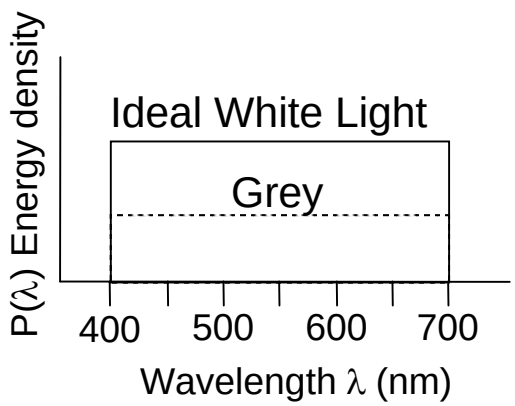
Primary Pigment Colours:
Cyan, Magenta, Yellow

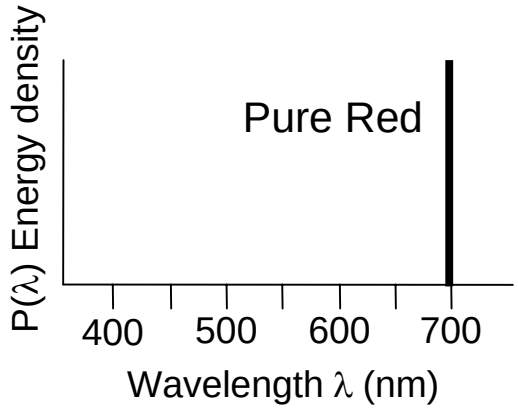


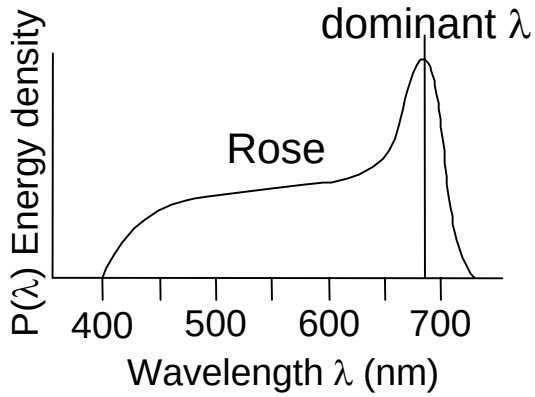
Substractive colour mixing

Colour Fundamentals

- The light reflected by an object usually contains several wavelengths





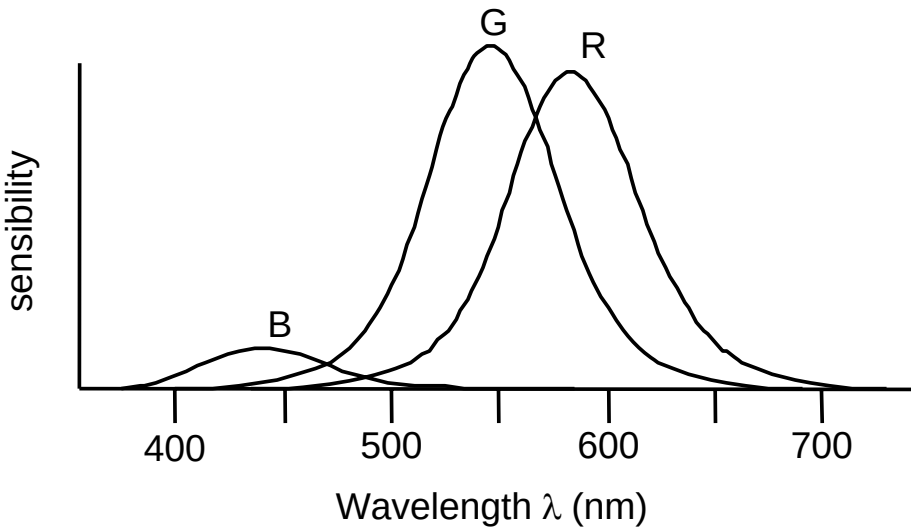


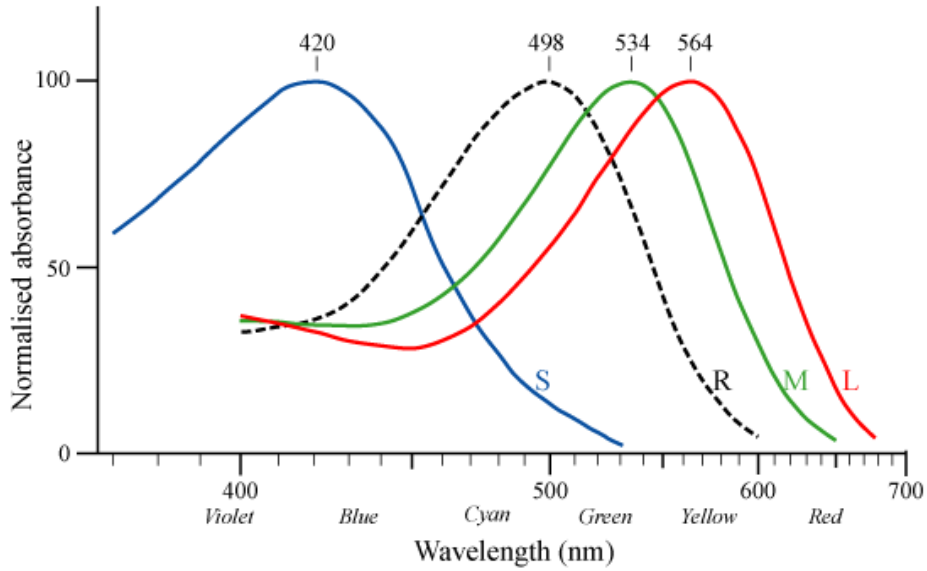
- Achromatic light (like B&W TV)
  - Intensity: amount of light
- Coloured light
  - Hue: dominant wavelength
  - Saturation: purity of colour (mixed with white?)
  - Intensity: amount of light

Pure red: 100% Saturation
White: 0% Saturation
Rose: middle Saturation

Colour Fundamentals

- Human retina has three types of cones, sensible to different wavelengths, with maximum sensibility at:
  - B (blue) 440 nm
  - G (green-yellow) 545 nm
  - R (red-yellow) 580 nm





- Our eyes are able to distinguish thousands of colours
- Less sensibility to blue than to green, yellow or red

Colour Fundamentals

- A colour can be defined by:
  - Hue, Saturation and Intensity
  - Tristimulus values: amount of Red, Greeen and Blue (RGB)
    - » ***Depends on the definition used for R, G and B***
- XYZ: CIE tristimulus values
    - » ***CIE: Commission Iternationale de l'Éclairage***
    - » Based on direct measurements of the human eye
    - » X - red, Y - green-yellow, Z - blue
- CIE trichromatic coefficients:

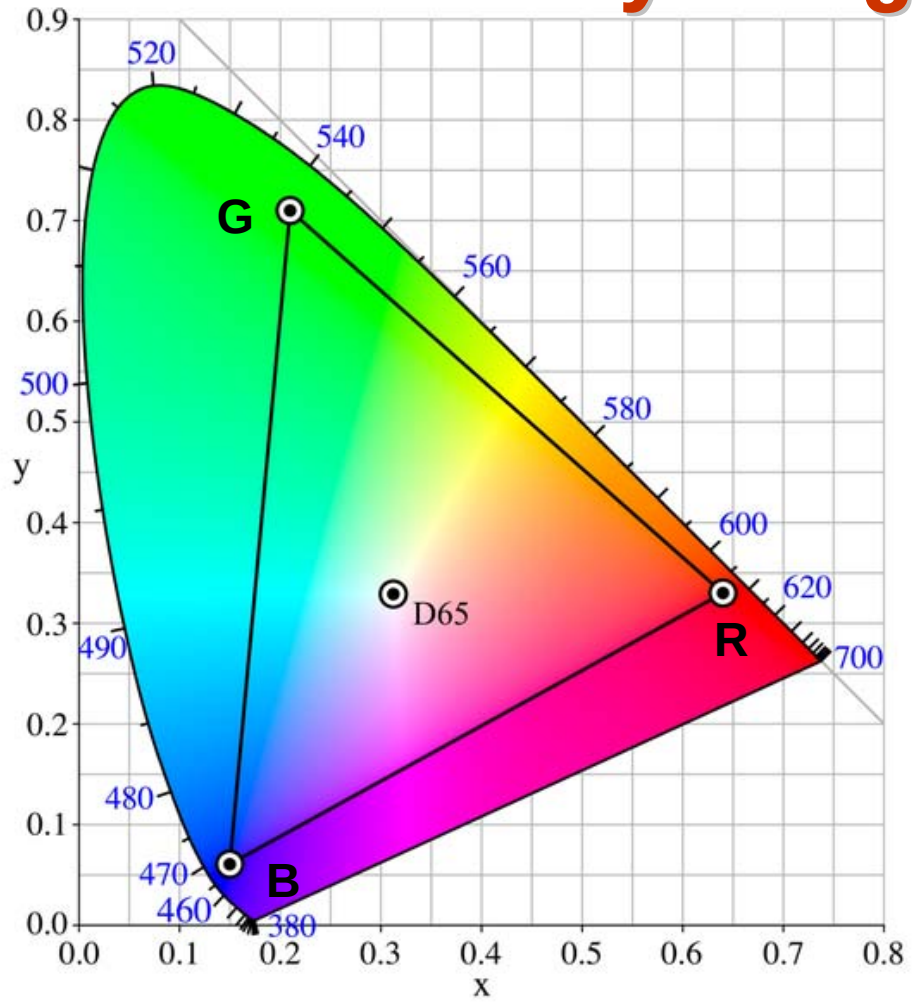
$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z} = 1 - x - y$$

- x and y define the chromaticity (hue and saturation) independent of the intensity

CIE Chromaticity Diagram



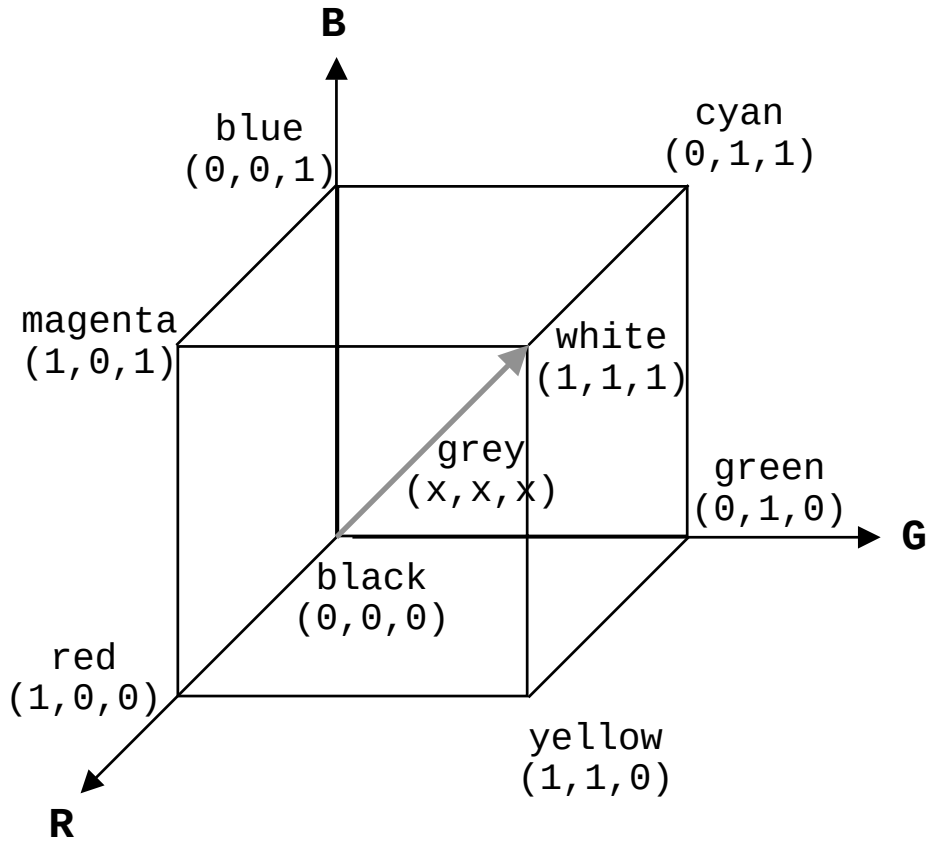
- Adding to colours gives the colours on the line that joins them
- Adding three colours gives the colours inside the triangle
- A monitor or TV cannot show all the colours visible to the eye

2. Colour Models

- Goal: normalized specification of colours
- A colour model is a 3D coordinate system and a subspace in which each colour is defined by a point
- Different models, for different applications:
  - XYZ: CIE standard
    - » Tristimulus values (human eye)
  - RGB: displays, cameras (sRGB, Adobe RGB,...)
    - » Red, Green, Blue
  - CMY or CMYK: printers, painting
    - » Cyan, Magenta, Yellow (and Black)
  - YIQ: NTCS television (USA)
    - » luminance (Y), In-phase, Quadrature
  - YUV: PAL television and S-VHS
    - » luminance (Y), hue (U), saturation (V)
  - HSI: Image processing
    - » Hue, Saturation, Intensity

Colour Models: RGB and CMY

- RGB model



- CMY model

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

Colour Models: Television

- YIQ (NTCS U.S.A.)
  - Y (luminance): b&w television
  - I (in-phase) and Q (quadature) define the chromaticity (with reduced bandwidth)

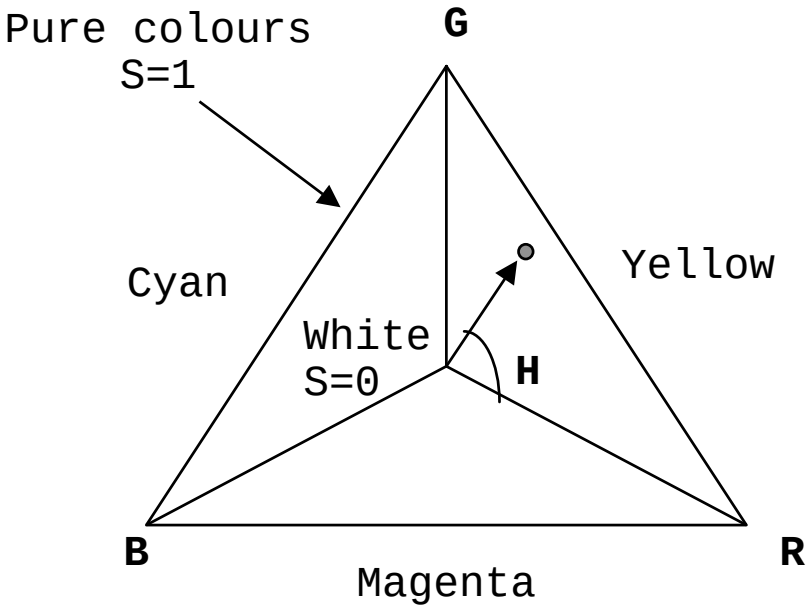
$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0,299 & 0,587 & 0,114 \\ 0,596 & -0,275 & -0,321 \\ 0,212 & -0,523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- YUV (PAL, Europe)
  - Y (luminance): b&w television
  - U and V define the chromaticity

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0,299 & 0,587 & 0,114 \\ -0,148 & -0,289 & 0.437 \\ 0,615 & -0,515 & -0.100 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

HSI model

- Hue, Saturation, Intensity
  - H is undefined for S=0 (grey)



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

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

$$if\ B > G, H = 360 - H$$

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

HSI model

$$Sector \quad RG \quad (0 < H \leq 120)$$

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

$$R = I\left(1 + \frac{S\cos(H)}{\cos(60 - H)}\right)$$

$$G = 3I - R - B$$

$$Sector \quad GB \quad (120 < H \leq 240)$$

$$H = H - 120$$

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

$$G = I\left(1 + \frac{S\cos(H)}{\cos(60 - H)}\right)$$

$$B = 3I - R - G$$

$$Sector \quad BR \quad (240 < H \leq 360)$$

$$H = H - 240$$

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

$$B = I\left(1 + \frac{S\cos(H)}{\cos(60 - H)}\right)$$

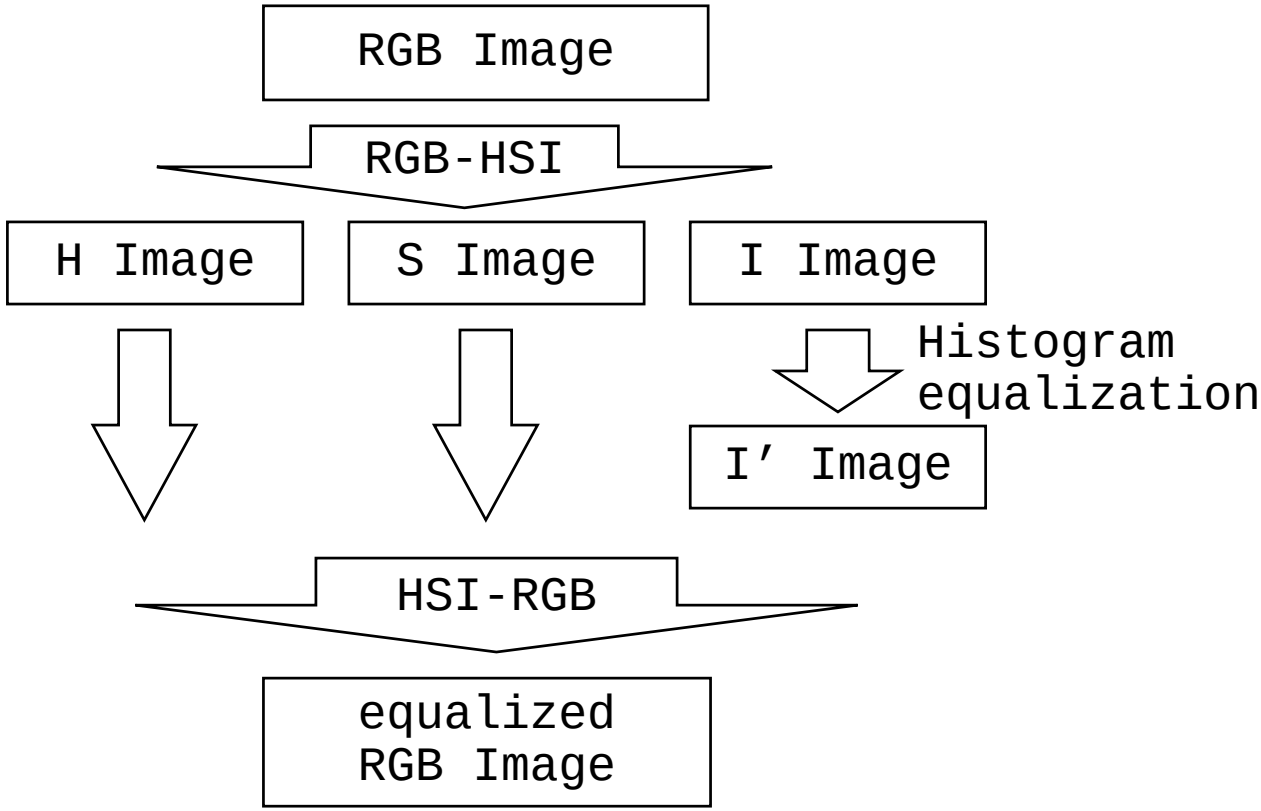
$$R = 3I - G - B$$

3. Acquiring Colour Images

- Colour Cameras:
  - Old analog cameras: NTCS, PAL, S-VHS
    - » Need an acquisition card with conversion to RGB or HSI
  - Digital cameras:
    - » 1 CCD (with colour filter array) or 3 CCDs
    - » USB 2.0, IEEE 1394 (Firewire), Camera-Link, GigaEthernet

4. Colour image processing

- Normally uses HSI model
- Classical processing can be applied to I image
- Example: Histogram equalization



Colour image processing

- Chromaticity is defined by Hue and Saturation, independent of the Intensity
- Colour segmentation
  - Can be performed using H
  - Seed pixels: regions with: th_inf <= H <= th_sup
  - Pixels with low S cannot be properly labelled
    - » (for S=0, H is undefined)
  - For pixels with very low I, S and H are not reliable