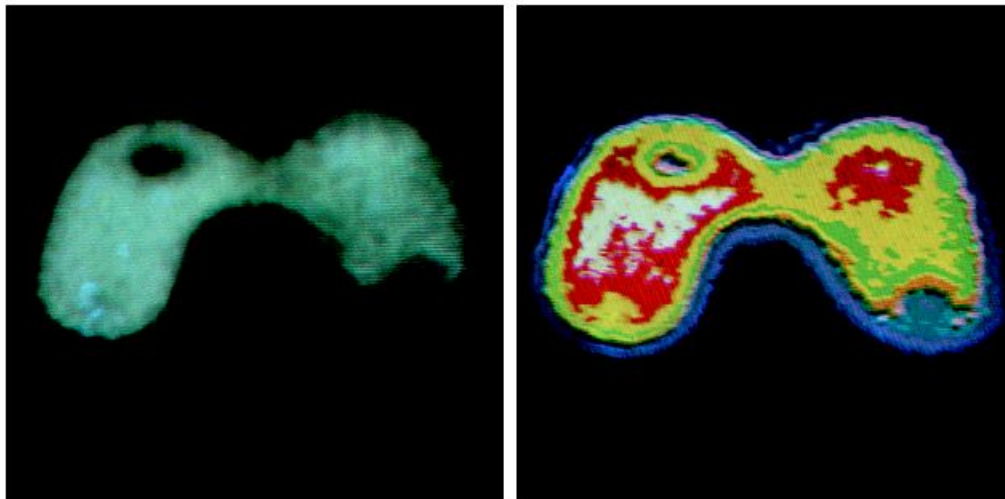


Color Image Processing

K K Singh

Preview

- Why use color in image processing?
 - Color is a **powerful descriptor**
 - Object identification and extraction
 - eg. Face detection using skin colors
 - Humans can **discern** thousands of color shades and intensities
 - c.f. Human discern only two dozen shades of grays



Visible light

- **Chromatic light** span the electromagnetic spectrum (EM) from 400 to 700 nm

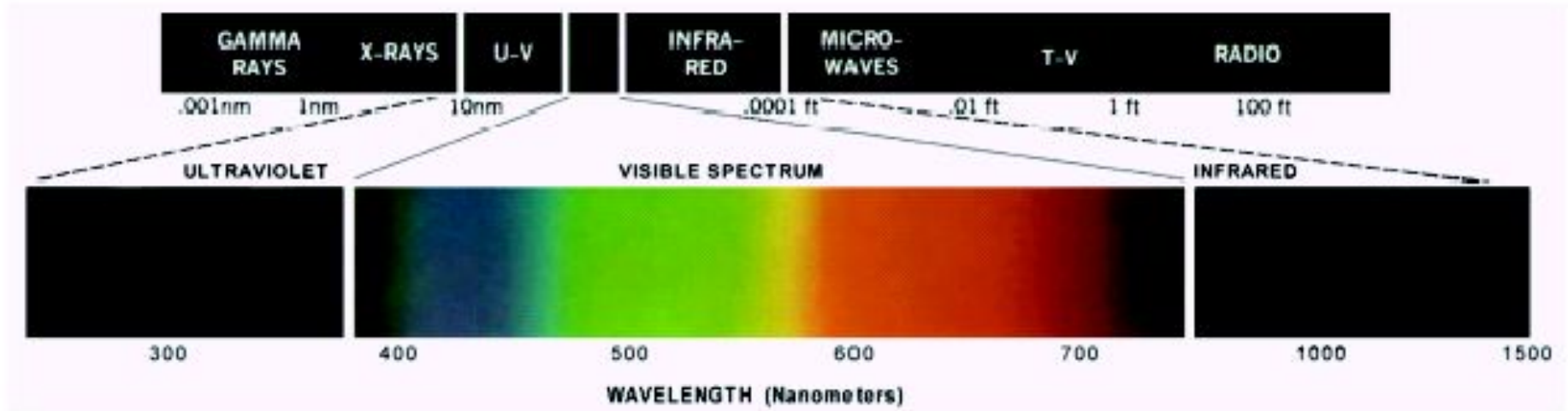
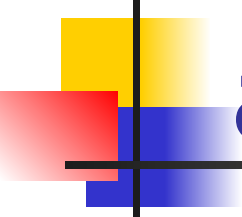


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)



Physical quantities to describe a chromatic light source

- **Radiance**: total amount of energy that flow from the light source, measured in **watts (W)**
- **Luminance**: amount of energy an observer *perceives* from a light source, measured in **lumens (lm)**
 - Far infrared light: high radiance, but 0 luminance
- **Brightness**: subjective descriptor that is hard to measure, similar to the achromatic notion of intensity

How human eyes sense light?

- 6~7M Cones are the sensors in the eye
- 3 principal sensing categories in eyes
 - Red light 65%, green light 33%, and blue light 2%

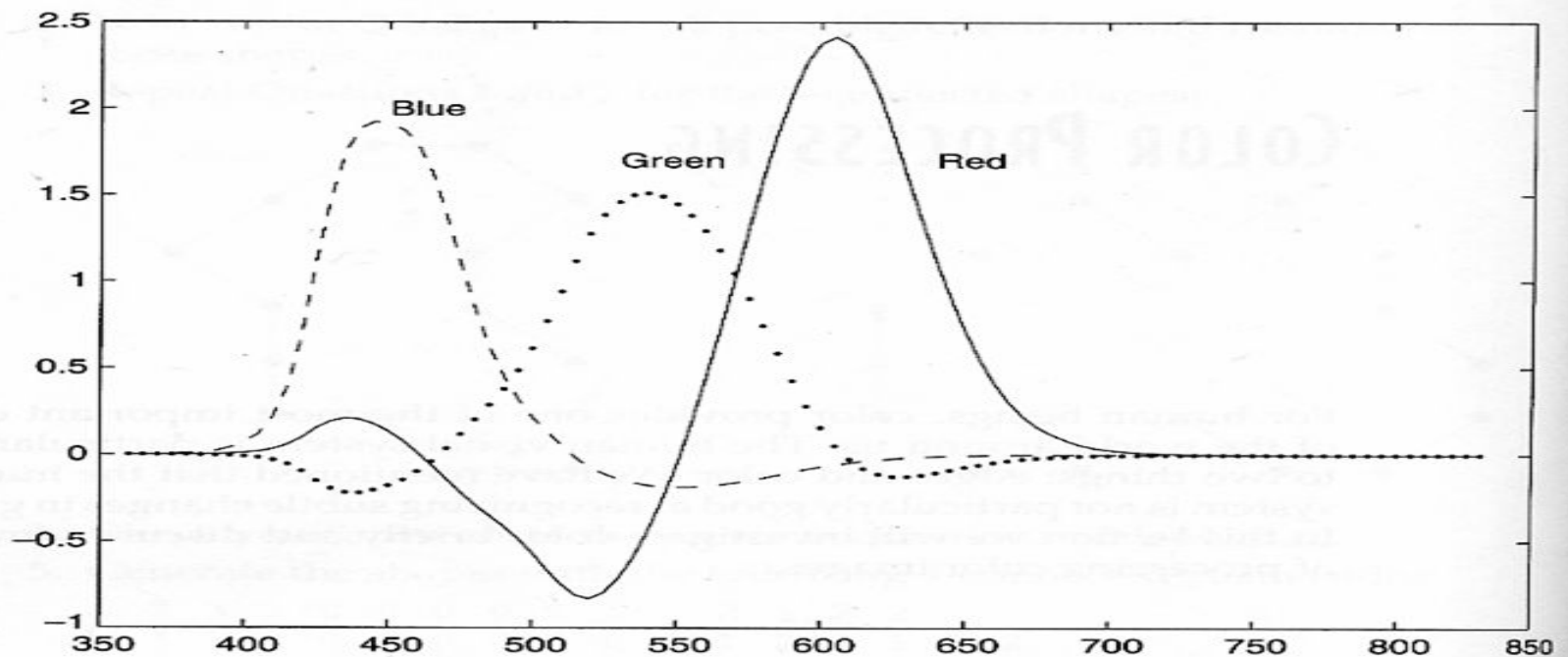
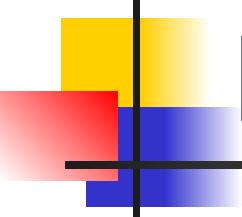


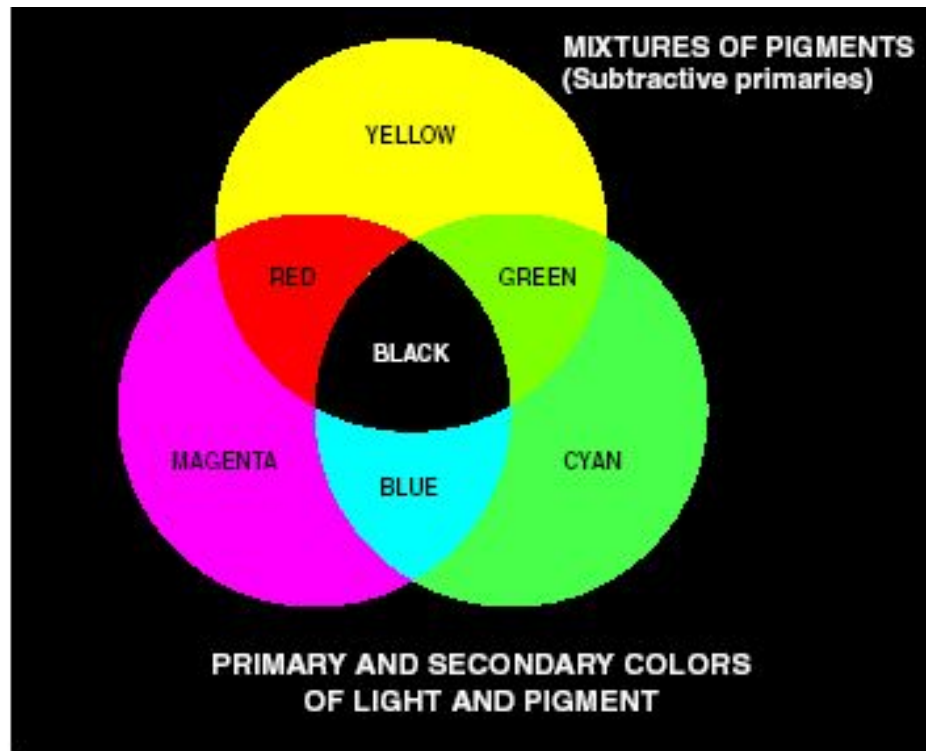
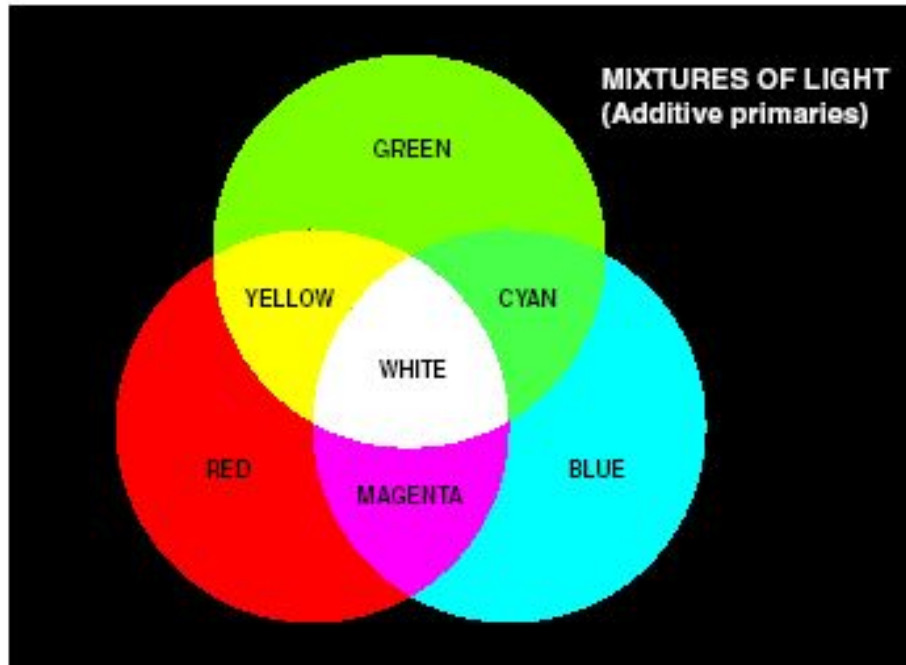
FIGURE B.1 RGB color-matching functions (CIE, 1931).

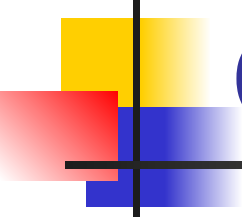


Primary and secondary colors

- In 1931, **CIE**(International Commission on Illumination) defines specific wavelength values to the **primary colors**
 - $B = 435.8 \text{ nm}$, $G = 546.1 \text{ nm}$, $R = 700 \text{ nm}$

Secondary colors: $G+B=\text{Cyan}$, $R+G=\text{Yellow}$, $R+B=\text{Magenta}$

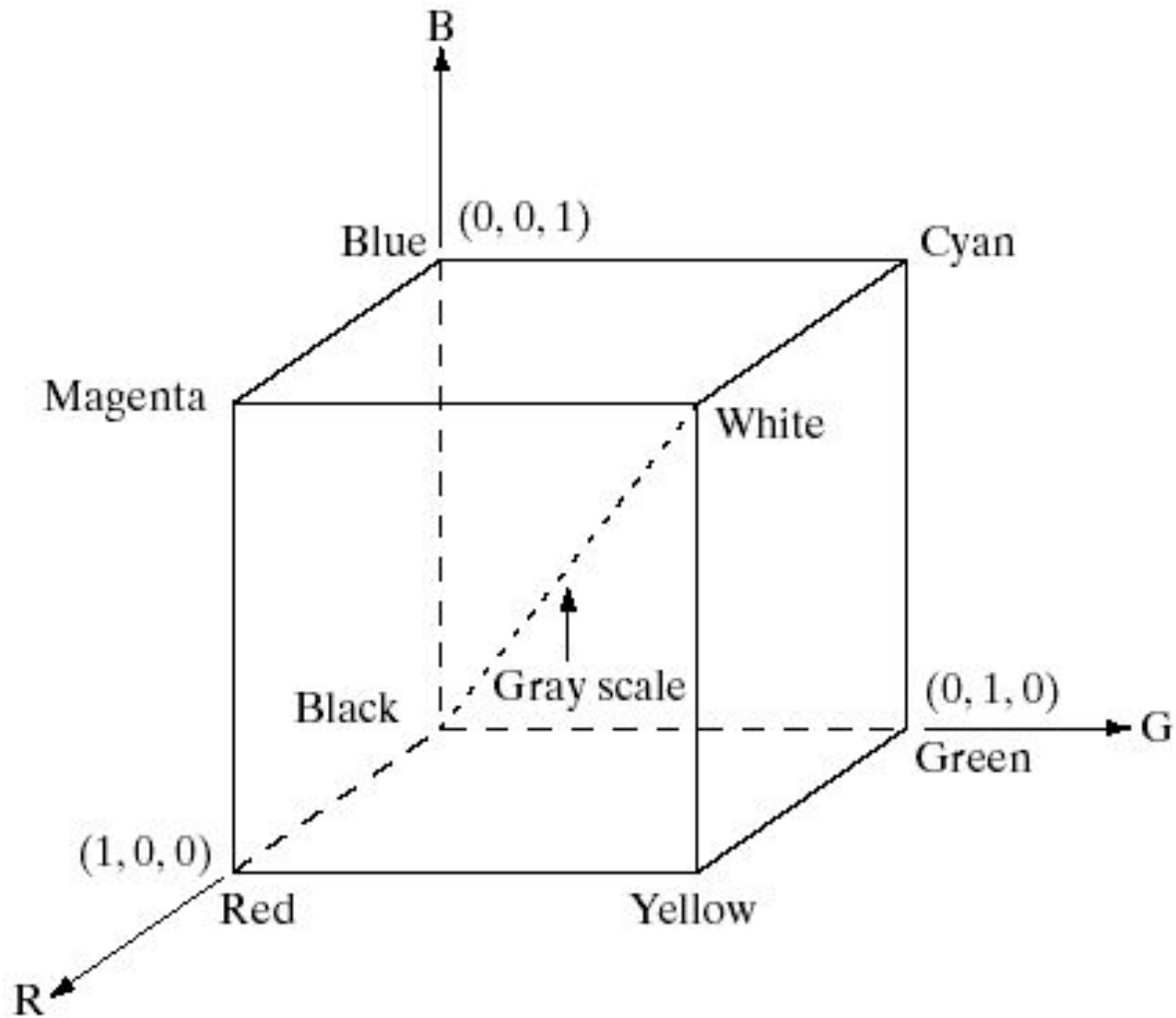




Color models

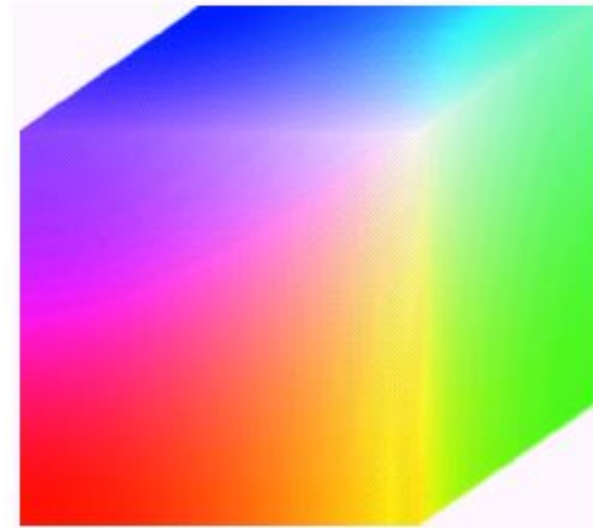
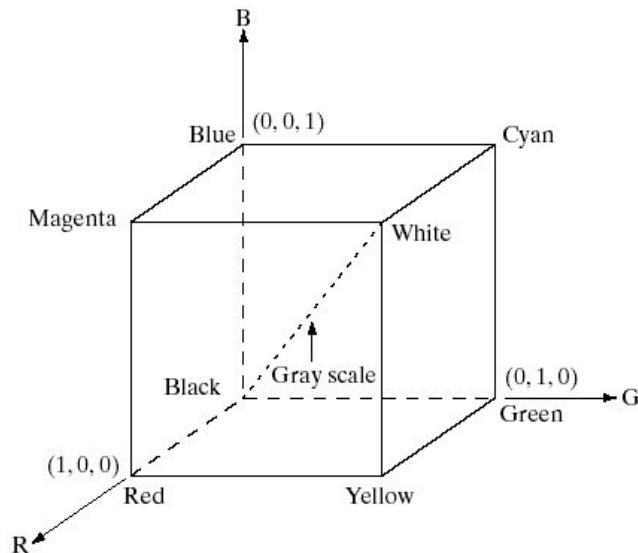
- Color model, color space, color system
 - Specify colors in a standard way
 - A **coordinate system** that each color is represented by a single point
- RGB model (monitor, video camera)
- CYM model (printer) Suitable for hardware or applications
- CYMK model
- HSI model - match the human description

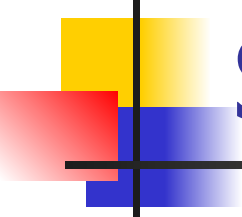
RGB color model



Pixel depth

- **Pixel depth**: the number of **bits** used to represent each pixel in RGB space
- **Full-color** image: 24-bit RGB color image
 - $(R, G, B) = (8 \text{ bits}, 8 \text{ bits}, 8 \text{ bits})$





Safe RGB colors

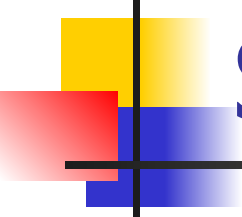
- **Subset of colors** is enough for some application
- **Safe RGB colors** (safe Web colors, safe browser colors)

Number System		Color Equivalents					
Hex	00	33	66	99	CC	FF	
Decimal	0	51	102	153	204	255	

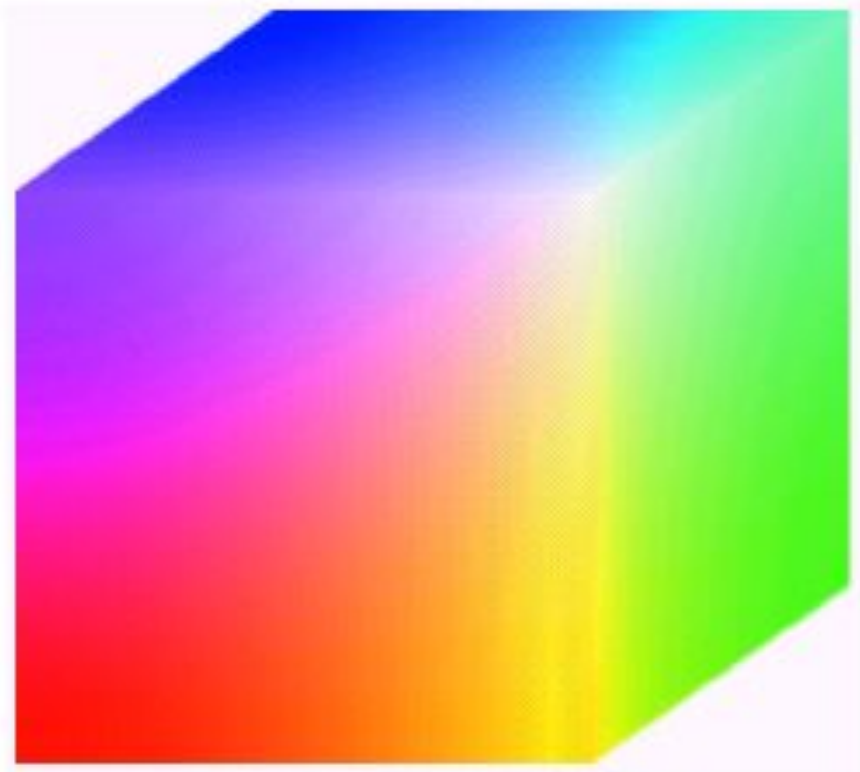
TABLE 6.1

Valid values of each RGB component in a safe color.

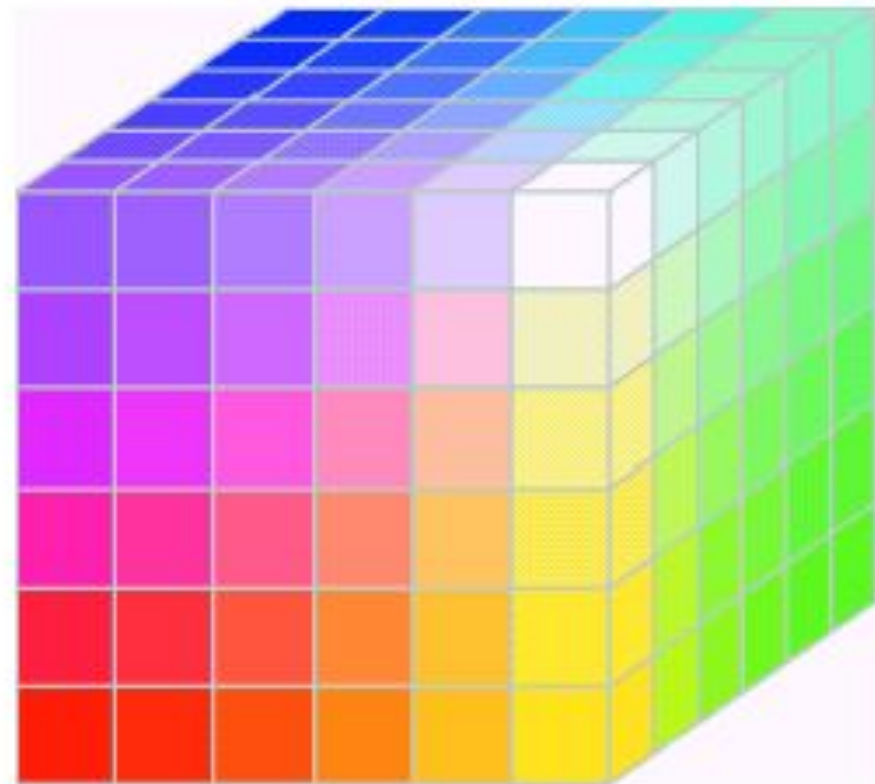
$$(6)^3 = 216$$



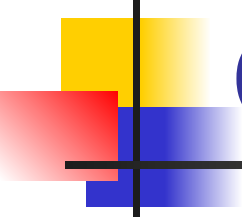
Safe RGB color (cont.)



Full color cube



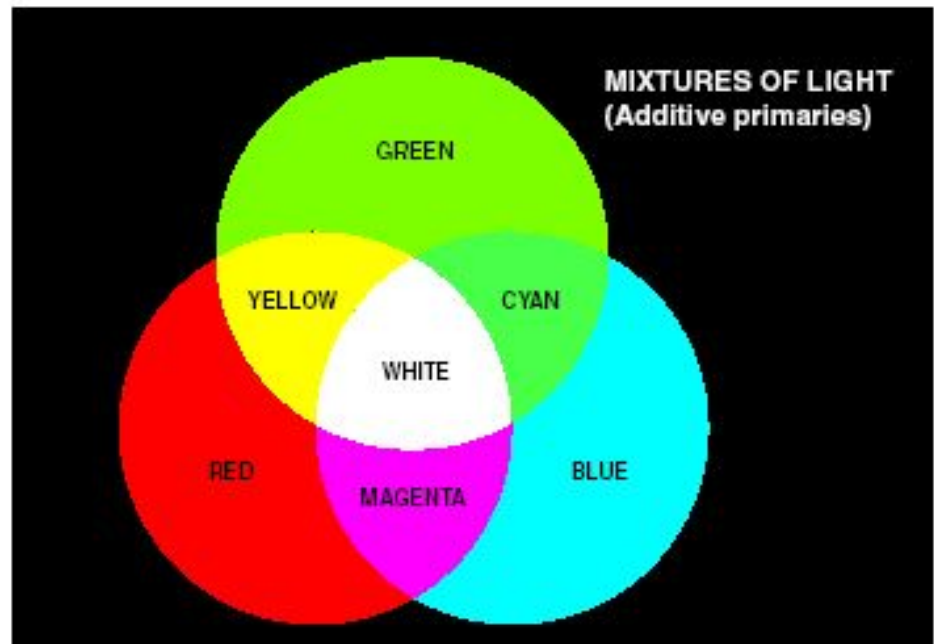
Safe color cube



CMY model (+Black = CMYK)

- **CMY**: secondary colors of light, or primary colors of pigments
- Used to generate hardcopy output

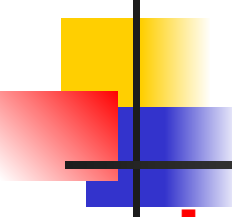
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$





HSI color model

- Will you describe a color using its R, G, B components?
- Human describe a color by its hue, saturation, and brightness
 - **Hue** : color attribute, represents dominant color as perceived by an observer.
 - **Saturation**: purity of color (white- $\rightarrow$ 0, primary color- $\rightarrow$ 1), represents the relative purity or the amount of white mixed with a hue.
 - **Brightness**: achromatic notion of **intensity**
- Hue and saturation together called **chromaticity**.



3D-polar Coordinate Colour Spaces

- ***Hue (dominant colour seen)***

- Wavelength of the pure colour observed in the signal.
- Distinguishes red, yellow, green, etc.
- More the 400 hues can be seen by the human eye.

- ***Saturation (degree of dilution)***

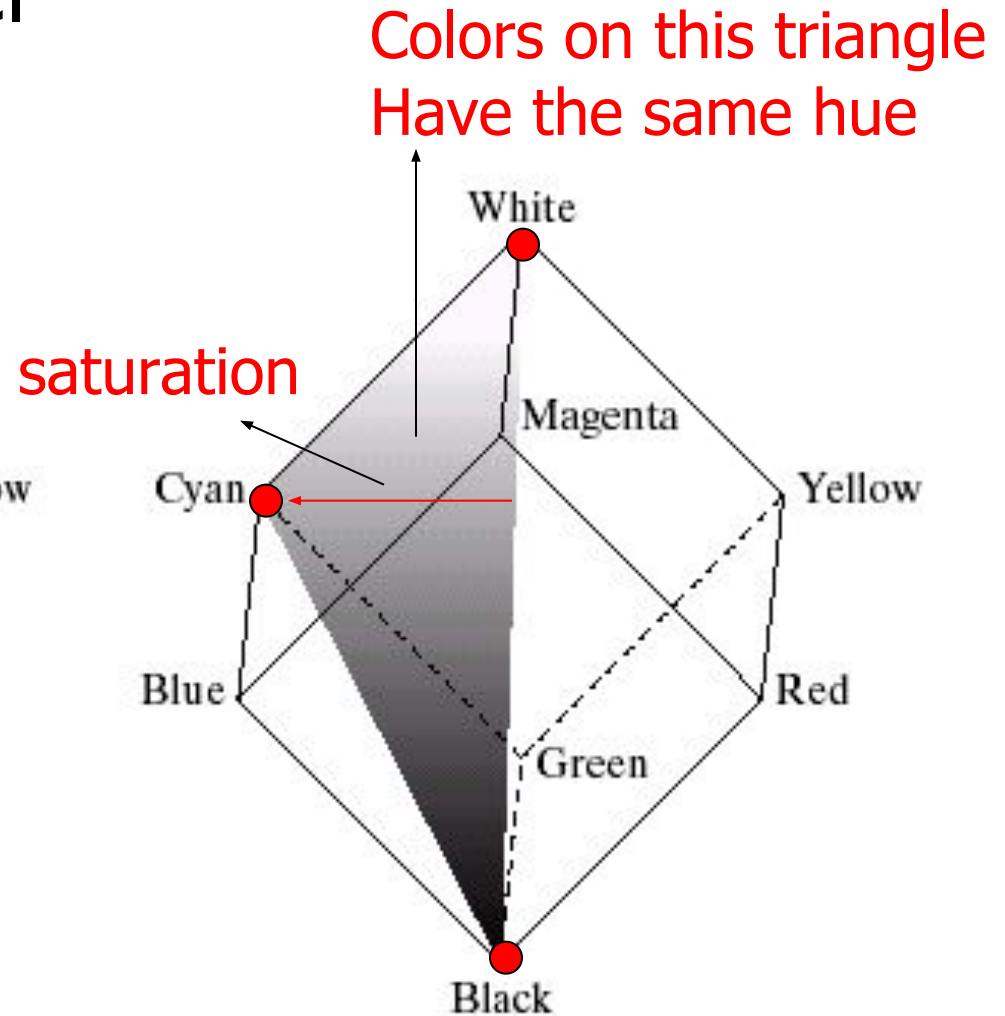
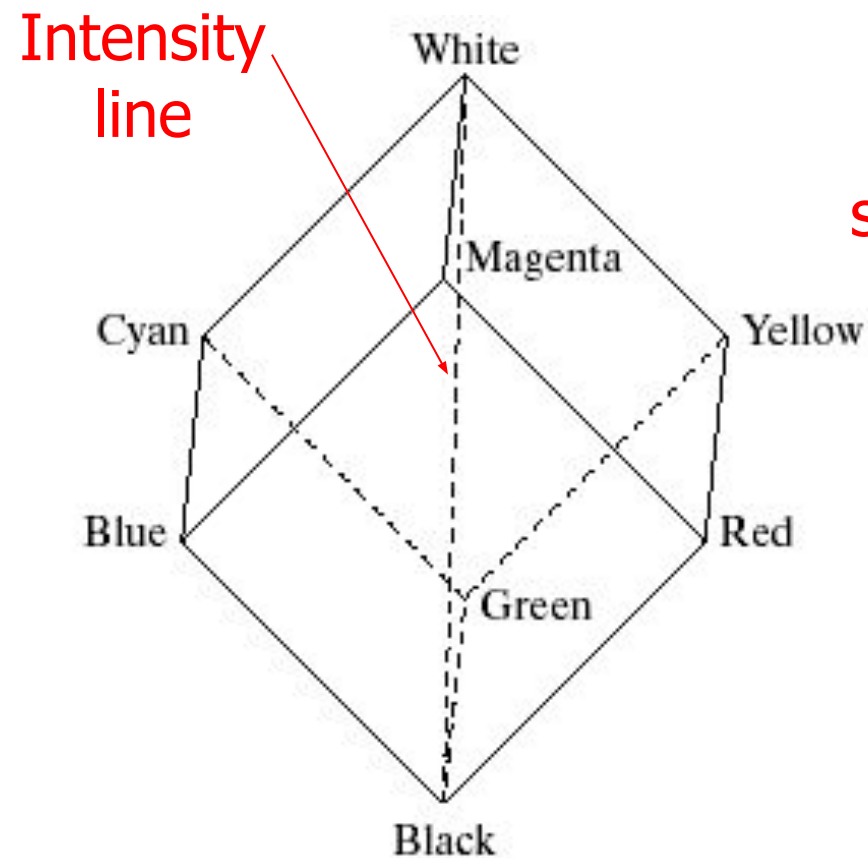
- Inverse of the quantity of “white” present in the signal. A pure colour has 100% saturation, the white and grey have 0% saturation.
- About 20 saturation levels are visible per hue.

- ***Brightness***

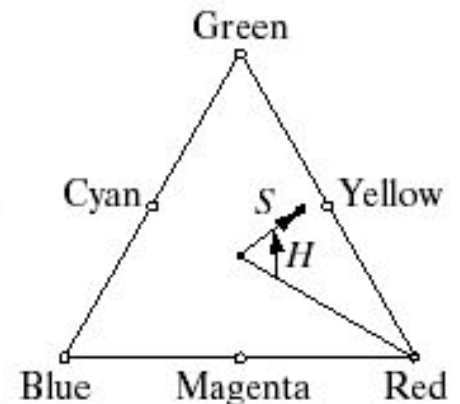
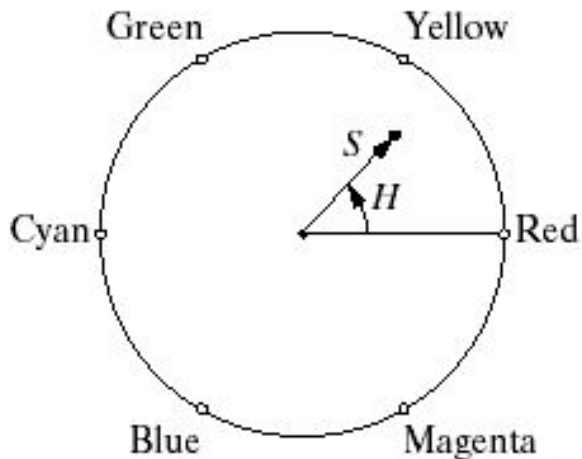
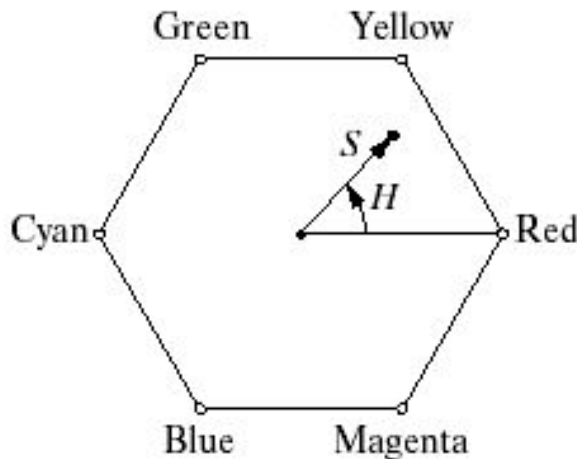
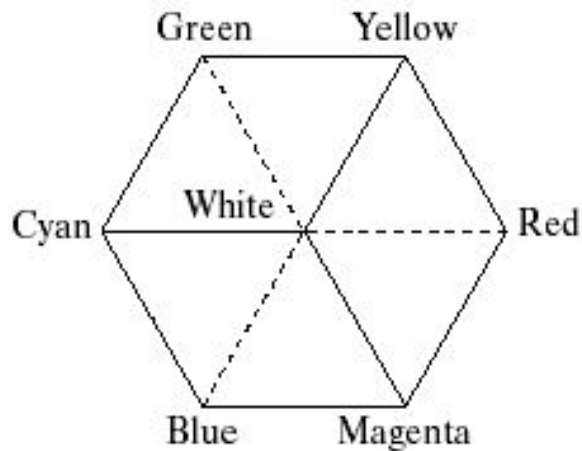
- Amount of light emitted.
- Distinguishes the grey levels.
- The human eye perceives about 100 levels.

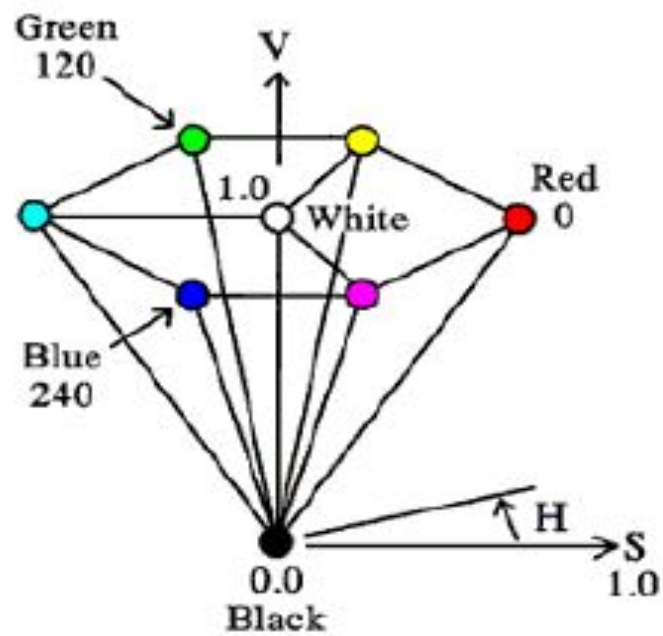
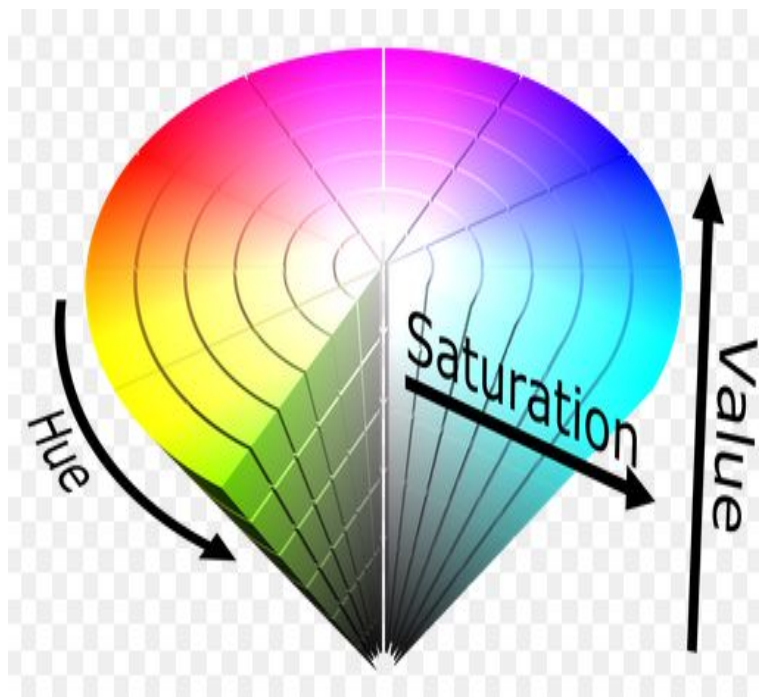
HSI color model (cont.)

- RGB -> HSI model

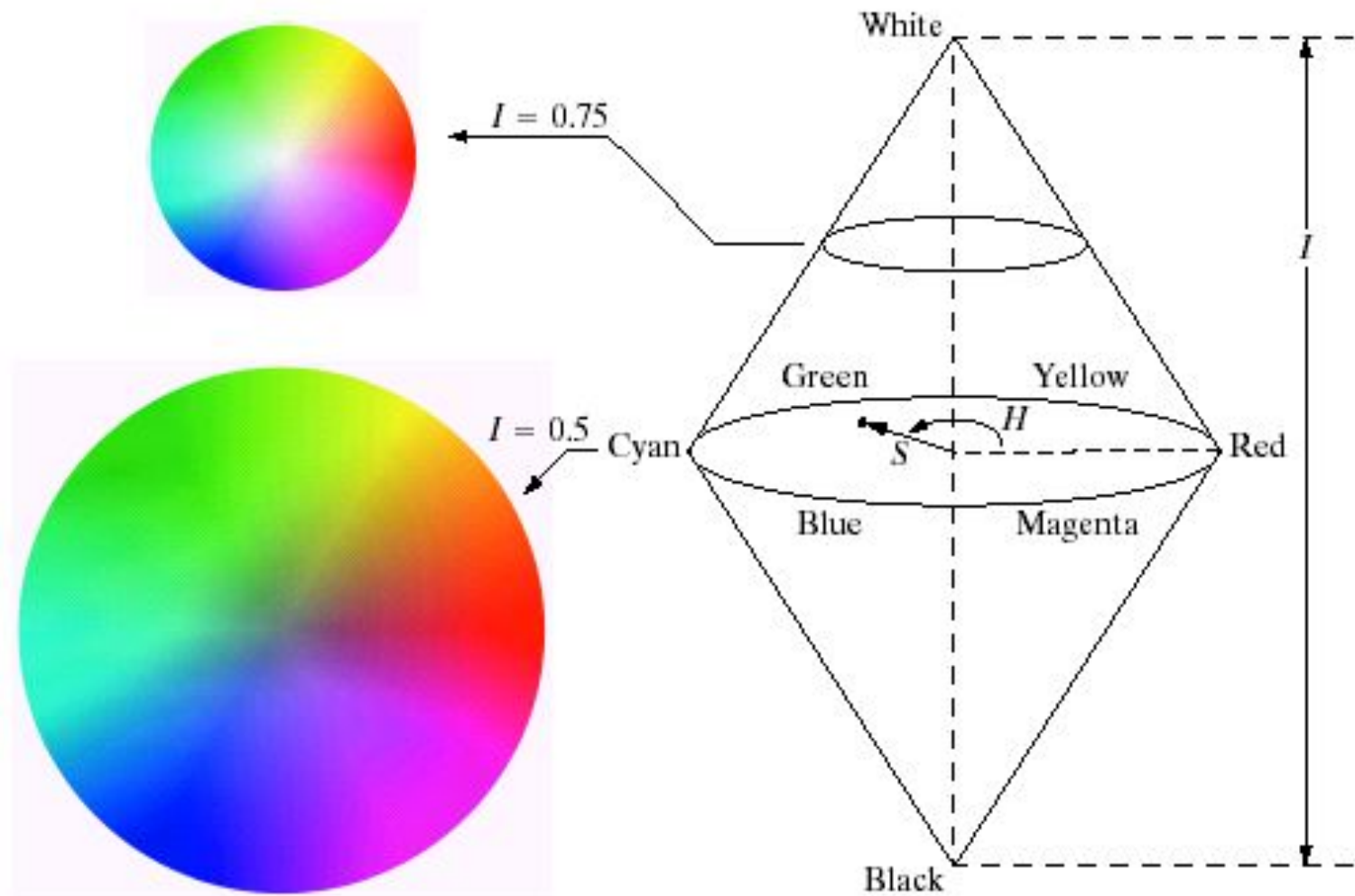


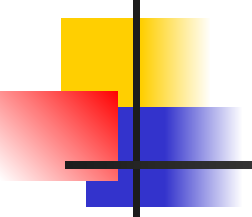
HSI model: hue and saturation





HSI model





Color Image Processing

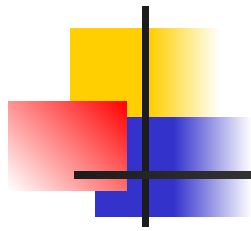
■ RGB to HSI Conversion

$$I = \frac{1}{3}(R + G + B), \quad \text{where } 0 \leq I, R, G, B \leq 1$$

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

$$\text{else.....} H = 360^\circ - H$$

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



RGB to HSV conversion formula , As per cv2.COLOR_BGR2HSV

The R, G, B values are divided by 255 to change the range from 0..255 to 0..1:

$$R' = R/255$$

$$G' = G/255$$

$$B' = B/255$$

$$C_{max} = \max(R', G', B')$$

$$C_{min} = \min(R', G', B')$$

$$\Delta = C_{max} - C_{min}$$

Hue calculation:

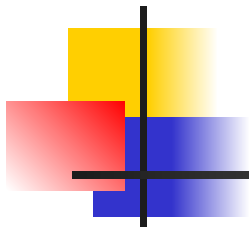
$$H = \begin{cases} 0^\circ & \Delta = 0 \\ 60^\circ \times \left(\frac{G' - B'}{\Delta} \bmod 6 \right) & , C_{max} = R' \\ 60^\circ \times \left(\frac{B' - R'}{\Delta} + 2 \right) & , C_{max} = G' \\ 60^\circ \times \left(\frac{R' - G'}{\Delta} + 4 \right) & , C_{max} = B' \end{cases}$$

saturation calculation:

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases}$$

Value calculation:

$$V = C_{max}$$



■ HSI to RGB Conversion

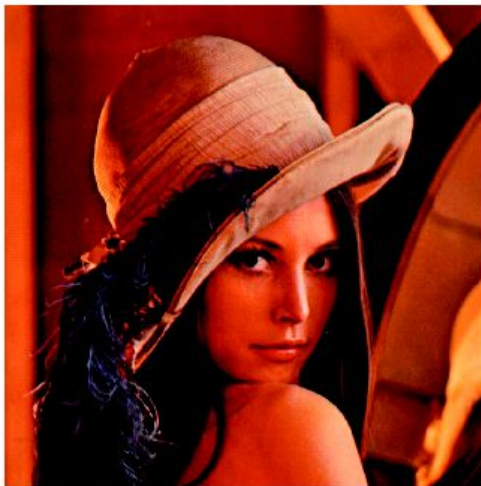
$$B = I(1 - S)$$

$$R = I \left[1 + \frac{S \cos H}{\cos(60^\circ - H)} \right] \quad \text{assume } 0^\circ \leq H \leq 120^\circ$$

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

$$\text{if } 120^\circ < H < 240^\circ, \quad H = H - 120^\circ$$

original



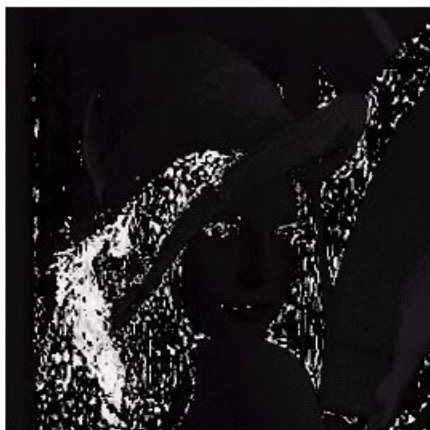
R



G



B



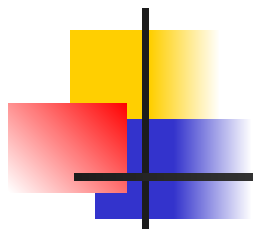
H



S



I



Thank
You