Color Models :

- The color models are also known as "color space" or "color system".
  - Provide specification of color in some standard form.
  - It is a specification of coordinal system and a subspace where each color is represented by a single point.
  - Nowadays, each color model is used or oriented towards hardware or application where the goal is to manipulate the colors.

Hardware : color monitor & printers
Color manipulations : color graphics for animation.

- In terms of digital image processing, the hardware oriented models are most commonly used.
- We have different hardware oriented models for DIP such as

RGB : Red, Green, Blue — commonly used in digital cameras → color printers
CMY : Cyan, magenta, Yellow
CMYK : Cyan, magenta, yellow, black
HSI : Hue, saturation & intensity → human description & interpretation of color.

↳ Advantage: decouples the color & grayscale information in an image making it suitable for Grayscale applications.

RGB Color model :

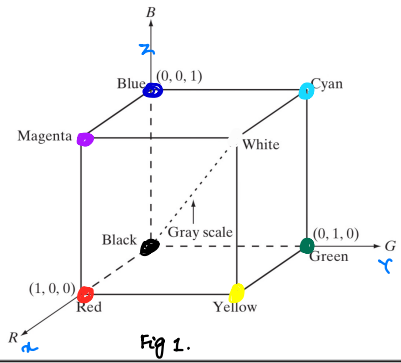


Fig 1.

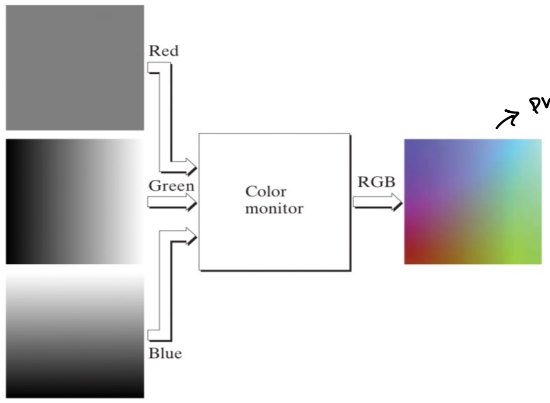
- each color ⇒ Red, Green & Blue.
- This model is based on cartesian coordinate system.
- The schematic of RGB model is shown in Fig 1. Here R is on x-axis, Green on y-axis & Blue on z-axis.

(x, y, z)
(R, G, B)

(x, y, z)

- The coordinates of R is (1,0,0)
  G is (0,1,0)
  B is (0,0,1)
  K (Black) is (0,0,0)
  White is (1,1,1)

For the Yellow color the coordinates are such as
Y = R+G ⇒ (1,1,0)
Cyan = G+B ⇒ (0,1,1)
Magenta = R+B ⇒ (1,0,1)



→ Phosphorous screen produced composite color image.

a
b

FIGURE 6.9
(a) Generating the RGB image of the cross-sectional color plane (127, G, B). (b) The three hidden surface planes in the color cube of Fig. 6.8.

each color in RGB is represented in 8 bits.

R → 8 bits (0–255)
G → 8 bits "
B → 8 bits "

24 bits

- No of bits to represent each pixel in an image in "RGB" color space is known as "pixel depth". So pixel depth in RGB is **24 bits.**
- A 24 bit color image ⇒ full color image.
- The total no; of colors in a 24 bit RGB image is $2^{24} = 16777216$

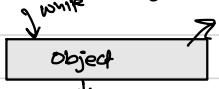
CMY / CMYK Color models :

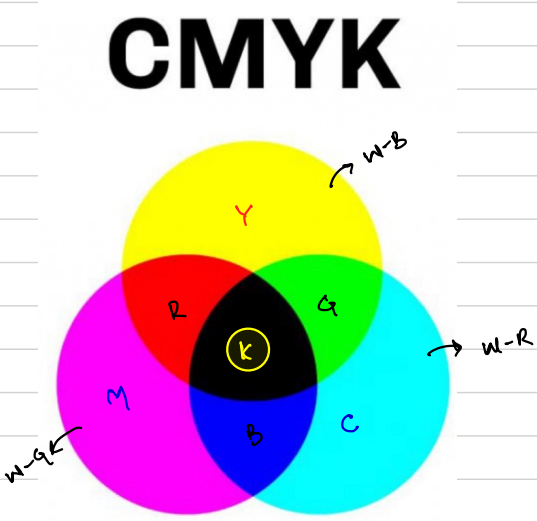
- RGB is an additive color model ⇒ we obtain a color by adding various ratio of R, G & B.
- CMY/CMYK is a subtractive color model. Here, we subtract the color from white to obtain a cyan, magenta and yellow.
- Combine C, M & Y, we get K (black).

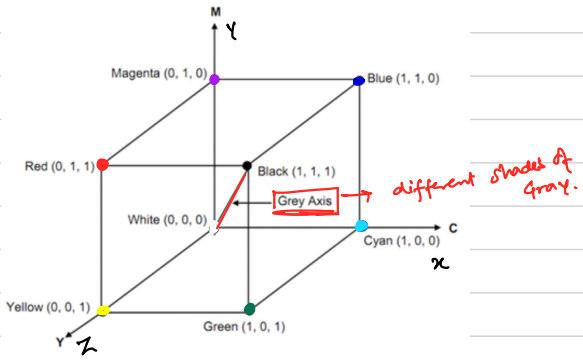
$$\begin{aligned} C &= W - R \\ M &= W - G \\ Y &= W - B \end{aligned} \Rightarrow \begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

* white

- These colors are obtained by reflection of light e.g.,
- There is an object and white light falls on this object; if this object absorb red color then the object reflects "cyan" and this object will appear as "cyan"







(x, y, z)
C = (1, 0, 0)
M = (0, 1, 0)
Y = (0, 0, 1)
K = (1, 1, 1) → C+M+Y

- Used in color printers

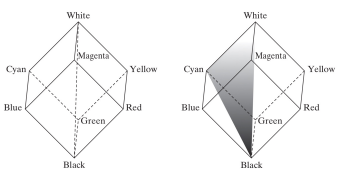
- **HSI Color Model:** It depends on human perception, which means, when views a color object, it is described by Hue, saturation & brightness.
  - A human eye decouples the intensity information from the color objects.

  Hue: A color component that describes pure color e.g. red, green, yellow

  Saturation: It describes how much a pure color is diluted by mixing white color.

  Intensity: It is the chromatic notation of brightness & black and white Range

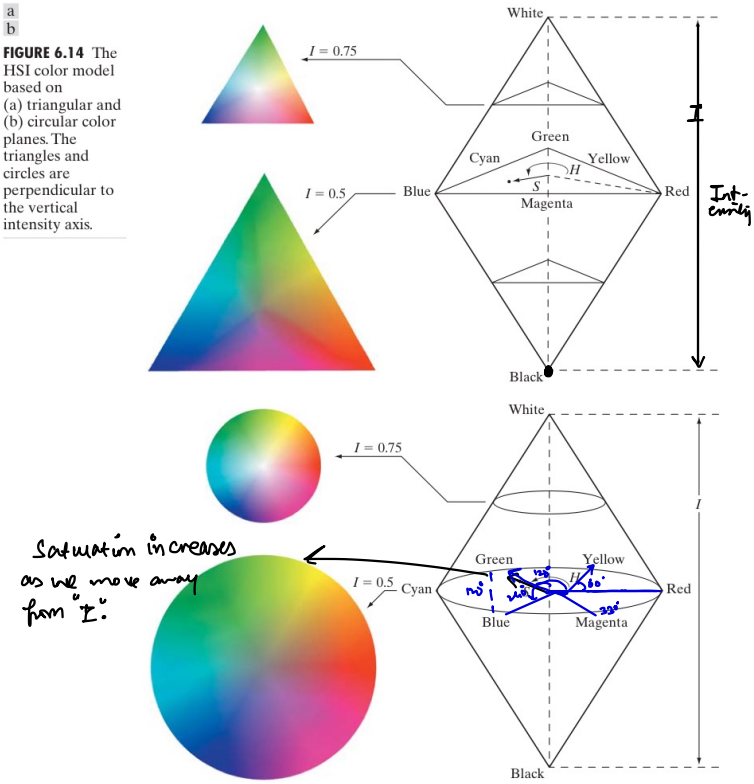
a b
FIGURE 6.12 Conceptual relationships between the RGB and HSI color models.



- Hue is always measured from "red".
→ From Red at 120° → we have green, and at 120° from green, we have blue from this blue at 120°, we have magenta.
→ From red we have yellow at 60°, and from yellow at 60°, we have green. at 60° from green we have cyan and at 60° from cyan, we have blue.

a
b

FIGURE 6.14 The HSI color model based on (a) triangular and (b) circular color planes. The triangles and circles are perpendicular to the vertical intensity axis.



Hue = θ ; if $B \le G$
$360^\circ - \theta$; if $B > G$

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

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

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

Converting color from RGB to HSI

1) Input RGB image.
2) Represent the RGB image in the range [0 1]
3) Find HSI components.

Example: Convert RGB to HSI
$R = 24$, $G = 98$, $B = 118$

Sol: $R = 24/255 = 0.09$ $G = 98/255 = 0.38$ $B = 118/255 = 0.46$

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

Hue is in degrees

Here $B = 118$ and $G = 98$, so $B > G$. We will use $360^\circ - \theta$

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

$$= \cos^{-1}\left(\frac{\frac{1}{2}(10.09 - 0.38) + 10.09 - 0.46))}{((0.09-0.38)^2 + (0.09-0.46)(0.38-0.46))^{1/2}} \right)$$

$$= \cos^{-1}\left(\frac{\frac{1}{2}((-0.29)+(-0.37))}{((-0.29)^2 + (-0.37)(-0.08))^{1/2}} \right)$$

$$= \cos^{-1}\left(\frac{-0.33}{\sqrt{0.1137}} \right)$$

$$\theta = \cos^{-1}\left(\frac{-0.33}{0.33} \right) = \cos^{-1}(-1) = 180^\circ$$

$$\theta = 180^\circ$$

$$H = 360^\circ - 180^\circ = \boxed{180^\circ}$$

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

$$= 1 - \frac{3}{0.09+0.38+0.46} * (\min(0.09, 0.38, 0.46))$$

$$= 1 - 3/0.93 * 0.09 = 1 - 0.29 = \boxed{0.71}$$

$$I = 1/3(R+G+B) = 1/3(0.09 + 0.38 + 0.46)$$

$$= 0.93/3 = \boxed{0.31}$$

Converting colors from HSI to RGB

- HSI is also in the range [0-1]
- Find the corresponding RGB values in the same range.

① : RG sector ($0° \le H \le 120°$)

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

& $G = 3I - (R+B)$

② GB sector: ($120° \le H \le 240°$)

$$H = H - 120°$$
$$R = I(1-S)$$
$$G = I\left[1 + \frac{S\cos H}{\cos(60°-H)}\right]$$

③ : BR sector ($240° \le H \le 360°$)

$$H = H - 240°$$
$$G = I(1-S)$$
$$B = I\left[1 + \frac{S\cos H}{\cos(60°-H)}\right]$$
$$R = 3I - (G+B).$$