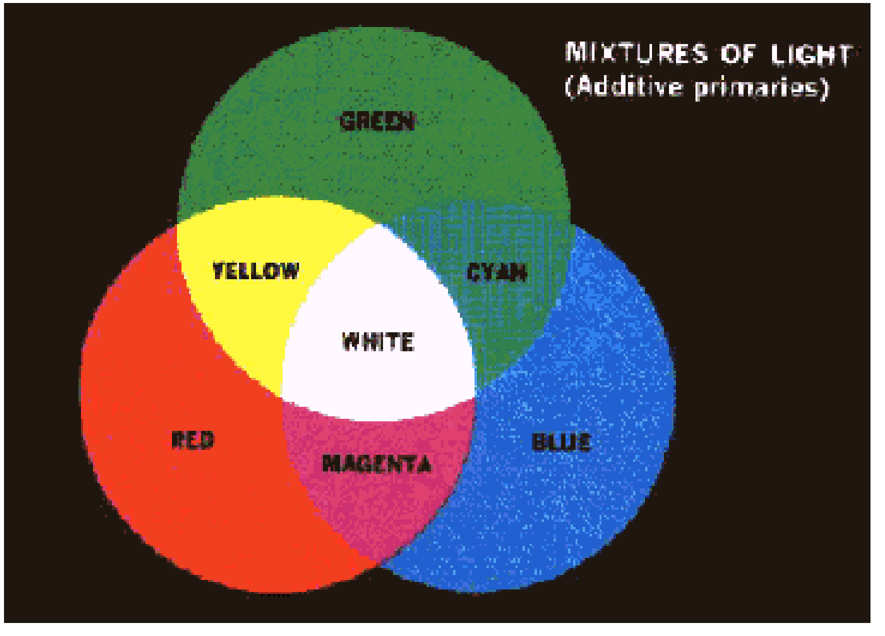
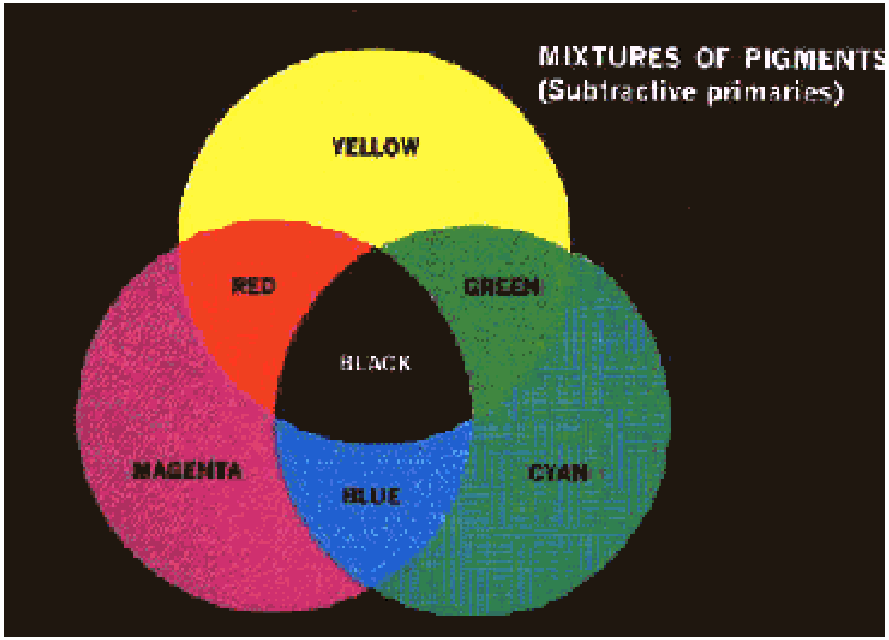
Color Formats

- *Additive color system*(*color of light*)
  - Primary colors- red (R), green (G), blue (B)
  - Secondary colors- magenta (R+B) 紫紅, cyan (G+B) 青藍, yellow (R+G)



Color Formats

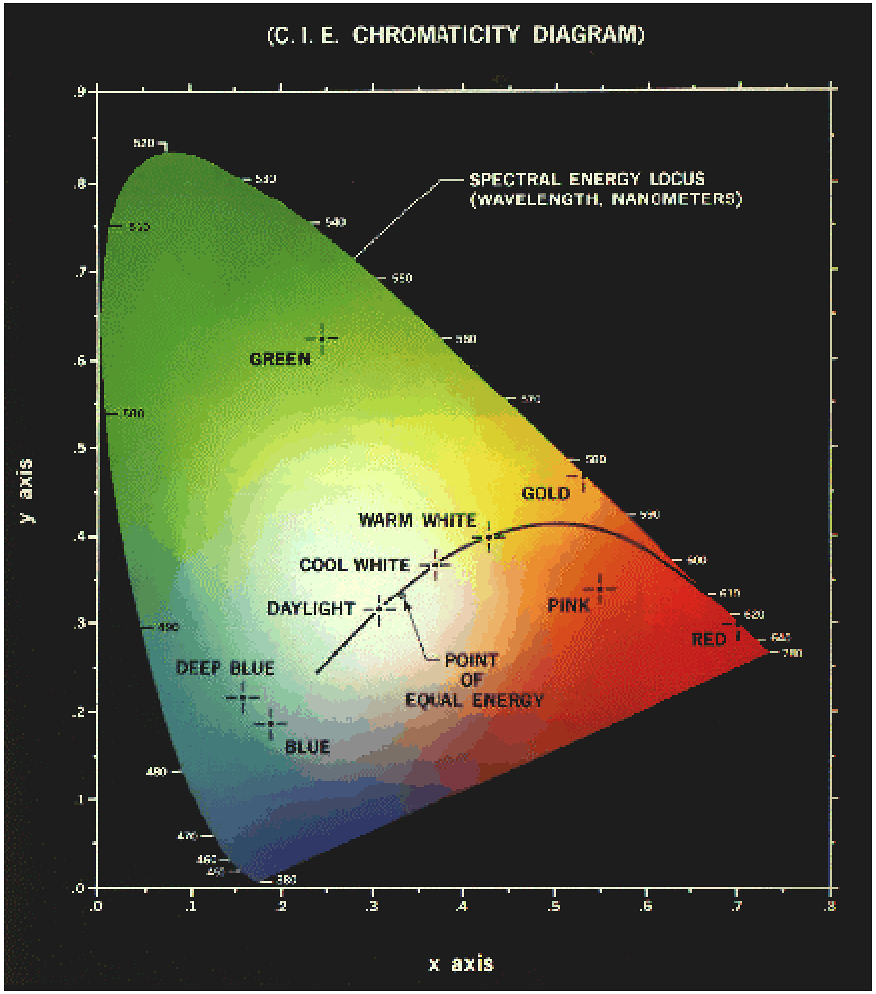
- *Subtractive color system*(*color of pigments, colorants*)
  - Primary colors- magenta, cyan, yellow
  - Secondary colors- red, green, blue



Characteristics of Color

- *brightness* - intensity
- *chromaticity* - hue and saturation
  - ***hue*** - dominant wavelength (color) perceived by human eyes
  - ***saturation*** - relative purity or the amount of white light mixed with a hue.
- *tristimulus values* - the amounts of red, green, blue (denoted as X, Y, and Z) needed to form any particular color.
- *trichromatic coefficients* - x, y, z with
  $x = X/(X + Y + Z)$, $y = Y/(X + Y + Z)$, $z = Z/(X + Y + Z)$.

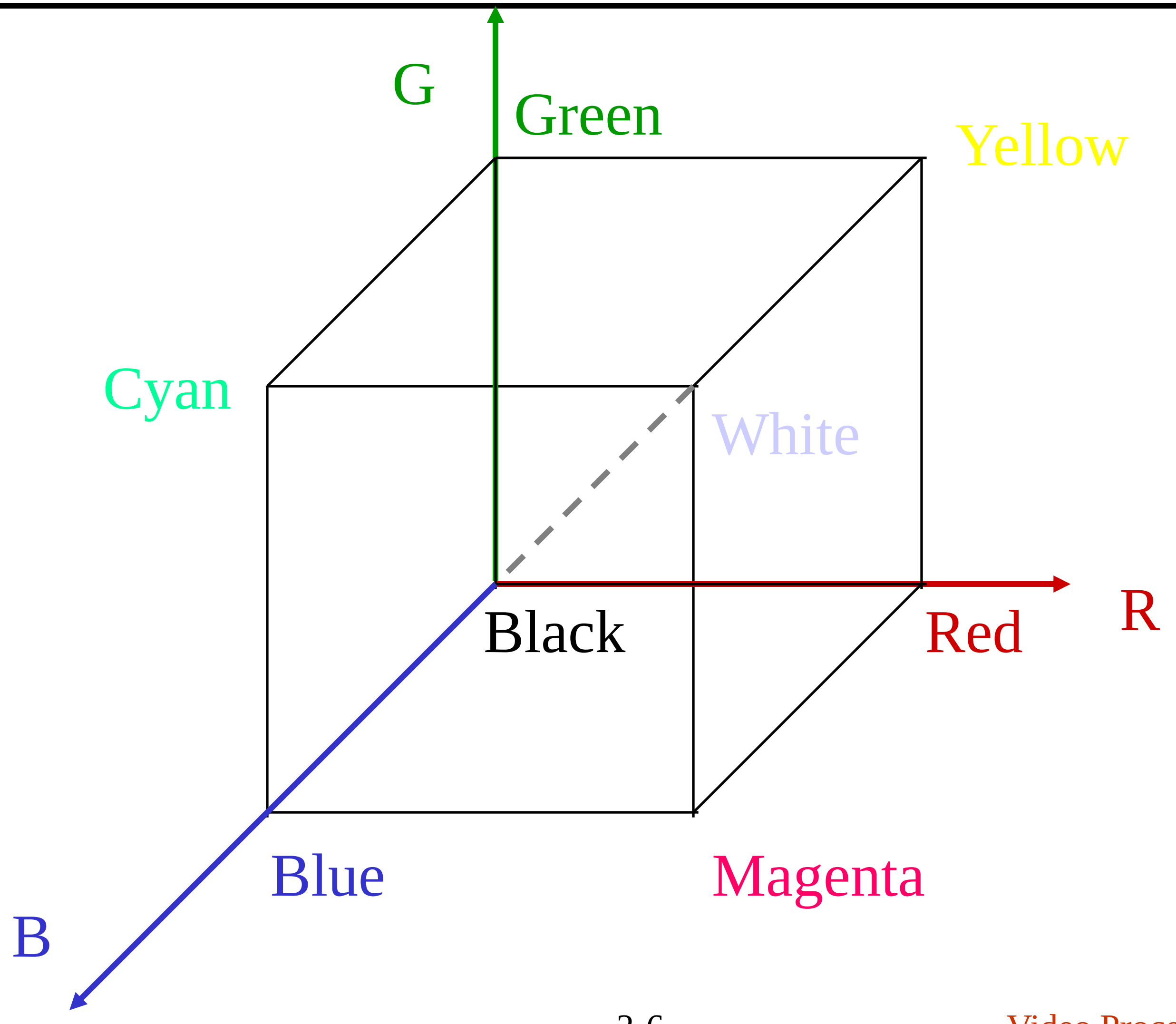
Chromaticity Diagram



Color Models

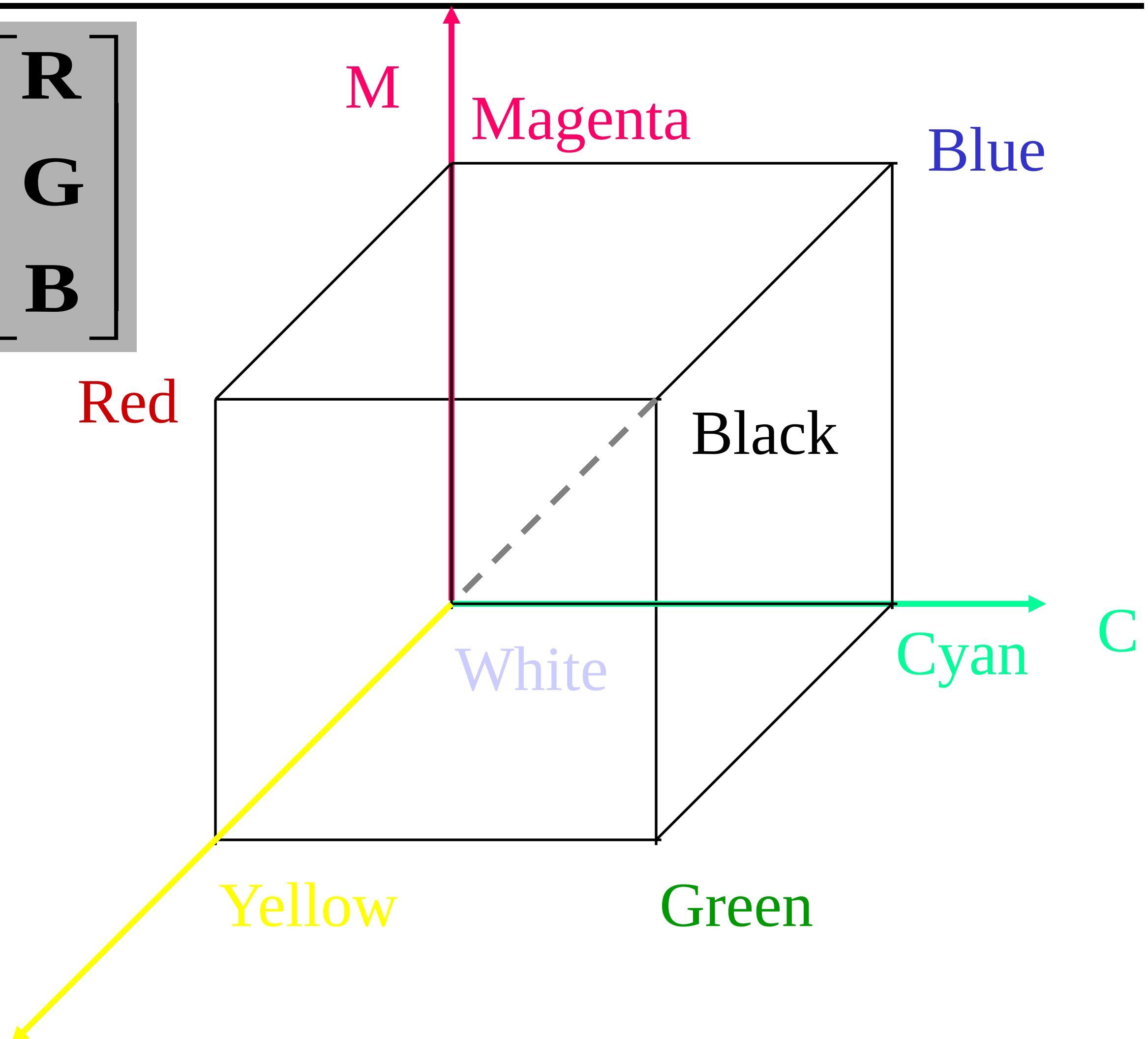
- *RGB* model - for hardware (e.g., color monitors, video cameras)
- *CMY* model- for color printers
- *YUV* (luminance, hue, saturation) – British PAL television standard
- *YIQ* (luminance, inphase, quadrature) – NTSC TV broadcasting
- YDrDb – French SECAM broadcast system
- YCrCb – CCIR-601 video standard
- *HSI* (hue, saturation, intensity) - color image manipulation
- *HSV* (hue, saturation, value) - color image manipulation

RGB Model



CMY Model

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



YUV Model

- Y – luminance or total illumination
- U, V – color difference values
- Y = 0.299R + 0.587G + 0.114B

  U = 0.493(B – Y)

  V = 0.877(R – Y)
- RGB → YUV   YUV → RGB

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0.0 & 1.140 \\ 1 & -0.395 & -0.581 \\ 1 & 2.032 & 0.0 \end{bmatrix} \begin{bmatrix} Y \\ U \\ V \end{bmatrix}$$

YIQ Model

- The luminance component (Y) and color information (I, Q) are decoupled.
- Useful in color TV broadcasting - for transmission efficiency and maintaining compatibility with monochrome TV.
- Human visual system is more sensitive to changes in luminance than to changes in hue or saturation.

YIQ Model (cont.)

- Y – luminance $Y = 0.299R + 0.587G + 0.114B$

  I – in-phase $I = V\cos 33^0 - U\sin 33^0$

  Q – quadrature $Q = V\sin 33^0 - U\cos 33^0$
- RGB → YIQ

$$\begin{bmatrix} \mathbf{Y} \\ \mathbf{I} \\ \mathbf{Q} \end{bmatrix} = \begin{bmatrix} \mathbf{0.299} & \mathbf{0.587} & \mathbf{0.114} \\ \mathbf{0.596} & \mathbf{-0.274} & \mathbf{-0.322} \\ \mathbf{0.211} & \mathbf{-0.522} & \mathbf{0.311} \end{bmatrix} \begin{bmatrix} \mathbf{R} \\ \mathbf{G} \\ \mathbf{B} \end{bmatrix}$$

- YIQ → RGB

$$\begin{bmatrix} \mathbf{R} \\ \mathbf{G} \\ \mathbf{B} \end{bmatrix} = \begin{bmatrix} \mathbf{1.0} & \mathbf{0.956} & \mathbf{0.621} \\ \mathbf{1.0} & \mathbf{-0.272} & \mathbf{-0.649} \\ \mathbf{1.0} & \mathbf{-1.106} & \mathbf{1.703} \end{bmatrix} \begin{bmatrix} \mathbf{Y} \\ \mathbf{I} \\ \mathbf{Q} \end{bmatrix}$$

YDrDb Model

- Y – luminance

  Dr – difference in red $\qquad Dr = -1.902(R - Y)$

  Db – difference in blue $\qquad Db = 1.505(B - Y)$

- RGB → YDrDb

$$\begin{bmatrix} \mathbf{Y} \\ \mathbf{Dr} \\ \mathbf{Db} \end{bmatrix} = \begin{bmatrix} \mathbf{0.299} & \mathbf{0.587} & \mathbf{0.114} \\ \mathbf{-1.333} & \mathbf{1.116} & \mathbf{-0.217} \\ \mathbf{-0.450} & \mathbf{-0.883} & \mathbf{1.333} \end{bmatrix} \begin{bmatrix} \mathbf{R} \\ \mathbf{G} \\ \mathbf{B} \end{bmatrix}$$

YCrCb Model

- Same as YUV without the coefficient for U and V plus a minor modification to allow integer math.
- $Y = 0.299R + 0.587G + 0.114B$

  $Cr = 0.713(R - Y)$

  $Cb = 0.564(B - Y)$
- RGB $\rightarrow$ YCrCb

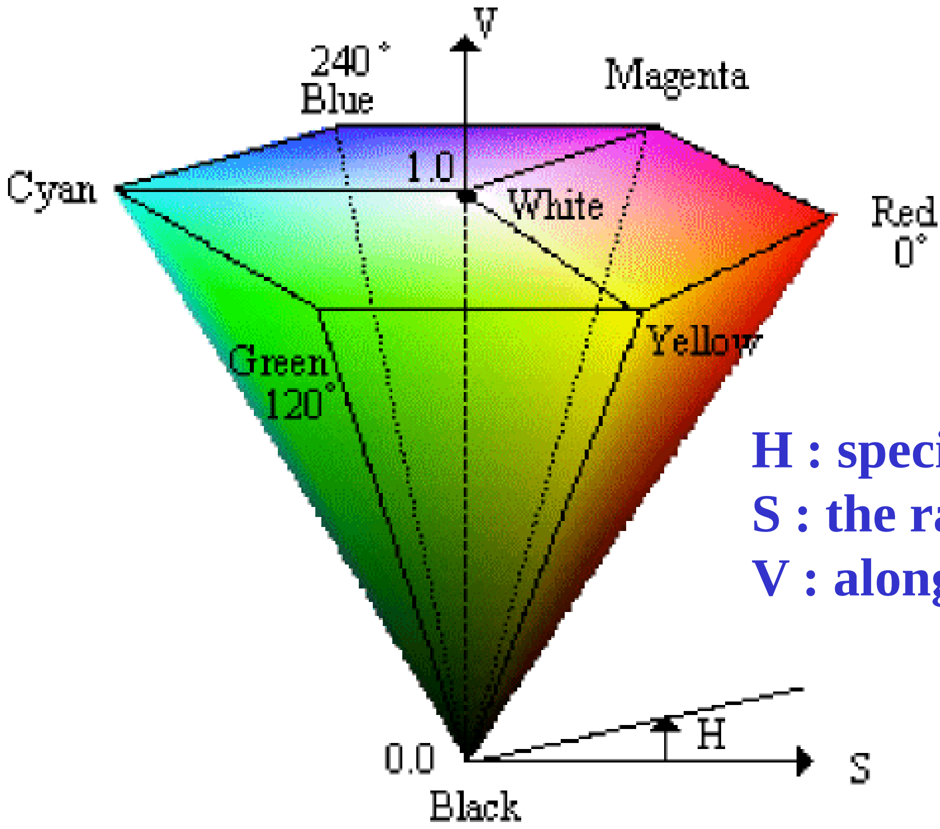
$$\begin{bmatrix} Y \\ Cr \\ Cb \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.500 & -0.419 & -0.081 \\ -0.169 & -0.331 & 0.500 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

YCrCb $\rightarrow$ RGB

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0.0 & 1.402 \\ 1 & 1.772 & 0.0 \\ 1 & -0.344 & -0.714 \end{bmatrix} \begin{bmatrix} Y \\ Cr \\ Cb \end{bmatrix}$$

HSV Model

- HSV - *hue*, *saturation*, and *value*



H : specific angles around the vertical axis
S : the radial distance from the vertical axis
V : along the central axis

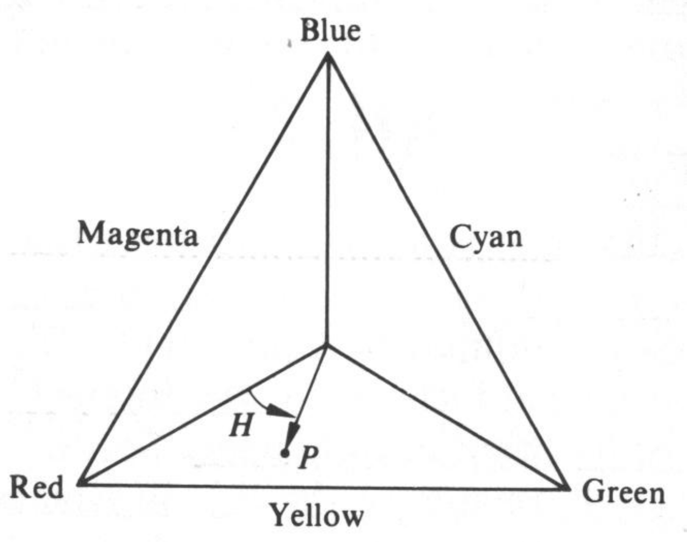
HSV Model (cont.)

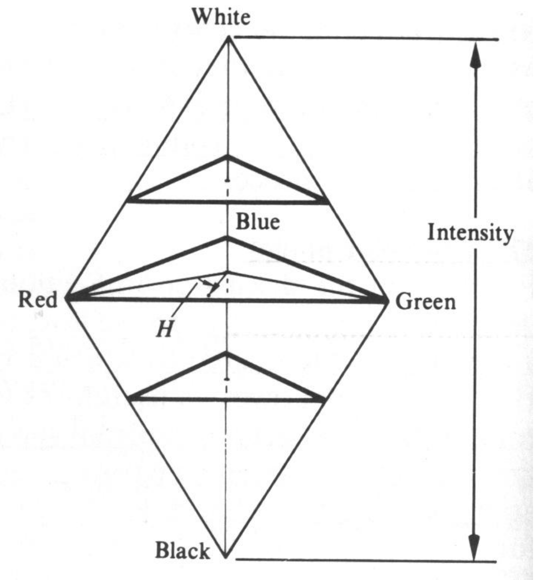
- V = Y/256

  S = $\sqrt{(Cr-128)^2+(Cb-128)^2}\,/128$

  H = $\sin^{-1}((Cr-128)/(128*s))$

HSI Model





- H : the *angle* of the vector w.r.t. the red axis

  S : the *distance* from *p* to the center of the triangle

  I : measured w.r.t. a line perpendicular to the triangle and passing through its center

HSI Model (cont.)

- RGB $\rightarrow$ HSI

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

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

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

Note: **1. if $B > G$ then $H = 360^\circ - H$, and let H = H/ 360°**

2. If $S = 0$, H undefined

3. S is undefined if I = 0

HSI Model (cont.)

- HSI $\longrightarrow$ RGB

(1)RG sector ($0^\circ < H \leqq 120^\circ$)

$$b = \frac{1}{3}(1 - S)$$

$$r = \frac{1}{3}\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right]$$

$$g = 1 - (r + b)$$

$R = 3Ir$, $G = 3Ig$, $\mathrm{B} = 3Ib$

HSI Model (cont.)

(2)*GB* sector ($120^\circ < H \leqq 240^\circ$)

$$H = H - 120^\circ$$
$$r = \frac{1}{3}(1 - S)$$
$$g = \frac{1}{3}\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right]$$
$$b = 1 - (r + g)$$

$R = 3Ir$, $G = 3Ig$, $B = 3Ib$

(3)*GB* sector ($240^\circ < H \leqq 360^\circ$)

$$H = H - 240^\circ$$
$$g = \frac{1}{3}(1 - S)$$
$$b = \frac{1}{3}\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right]$$
$$r = 1 - (g + b)$$

$R = 3Ir$, $G = 3Ig$, $B = 3Ib$