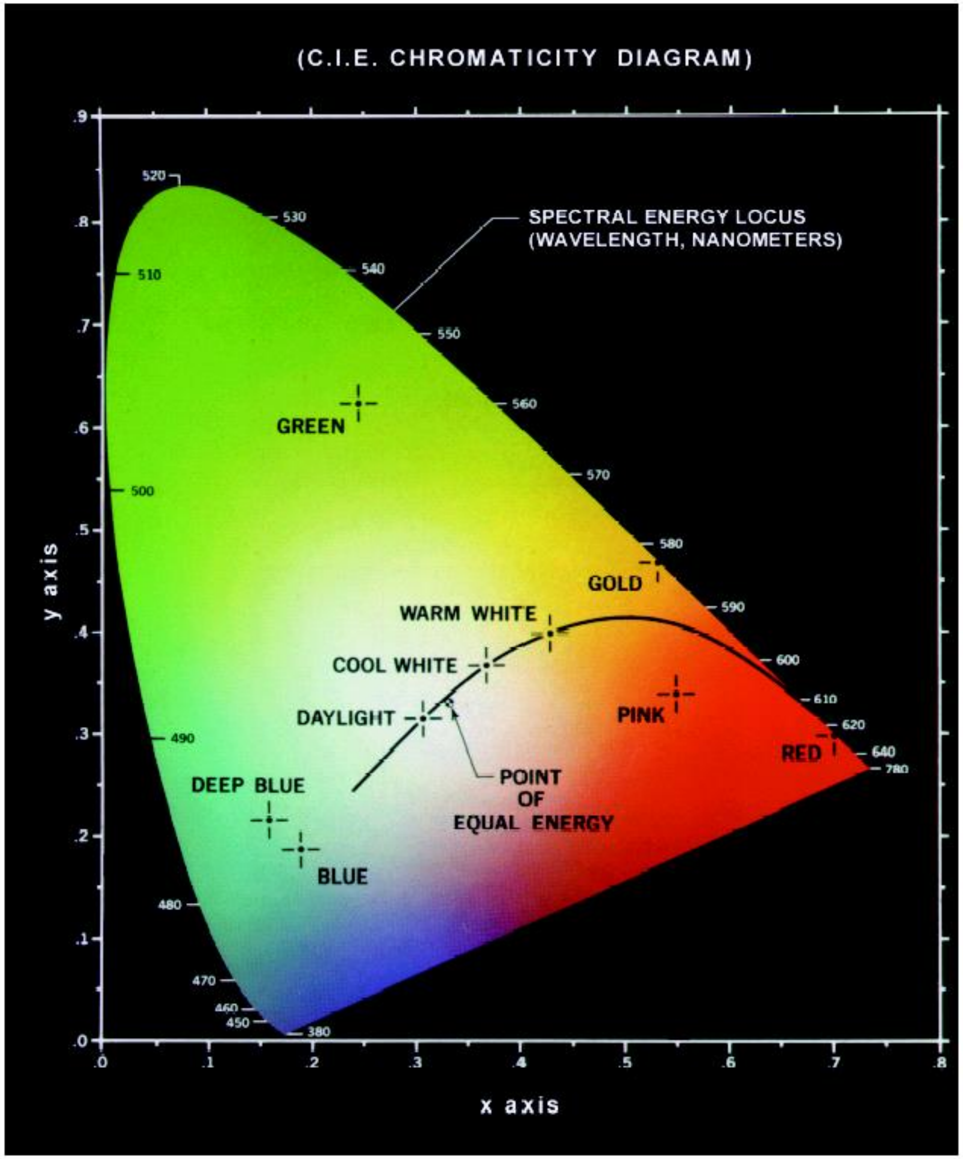
Colour Image Processing

Colour Fundamentals

- Human colour vision is achieved through 6 to 7 million cones in each eye
- Approximately 66% of these cones are sensitive to red light, 33% to green light and 6% to blue light

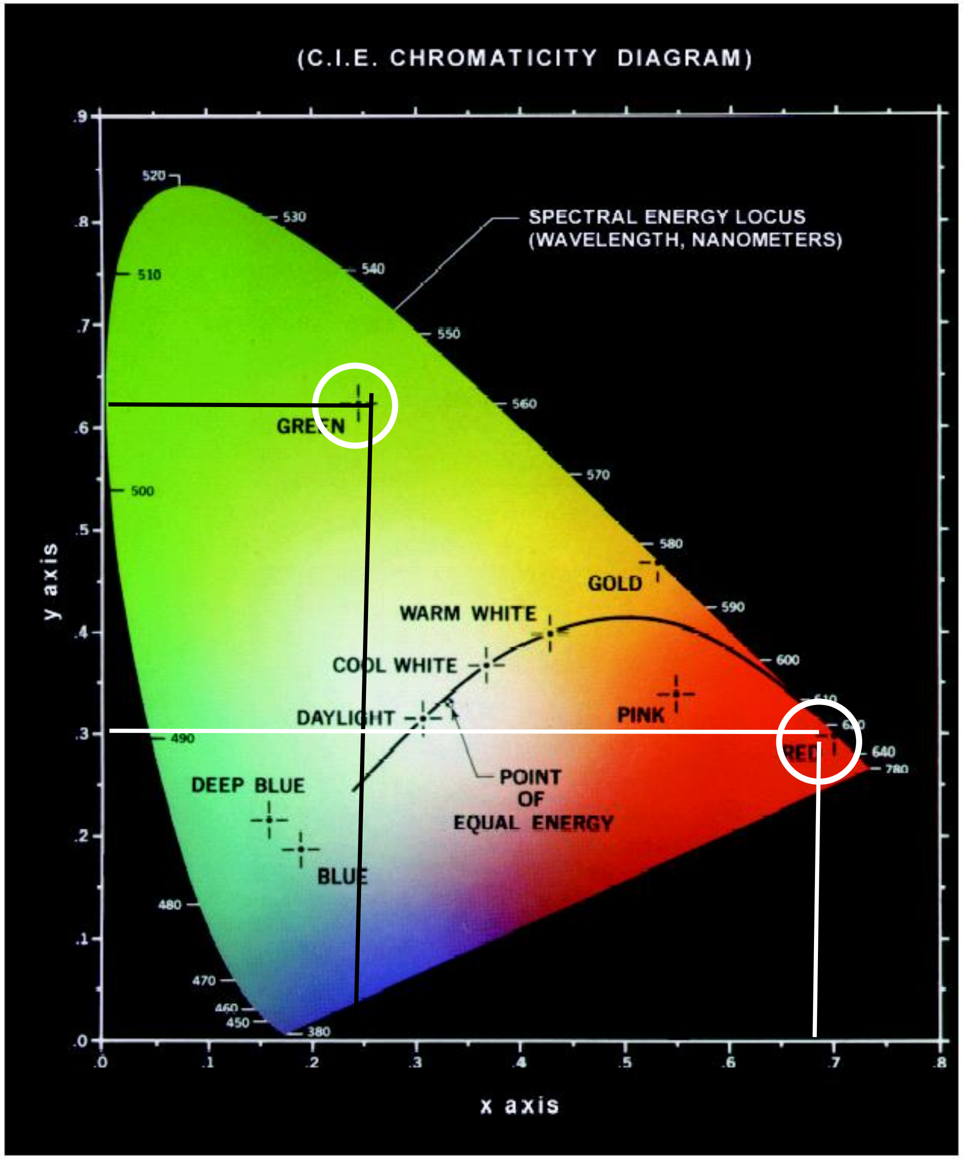
CIE Chromacity Diagram



- Specifies colours systematically
- x-axis represents the proportion of red
- y-axis represents the proportion of green
- The proportion of blue used in a colour is

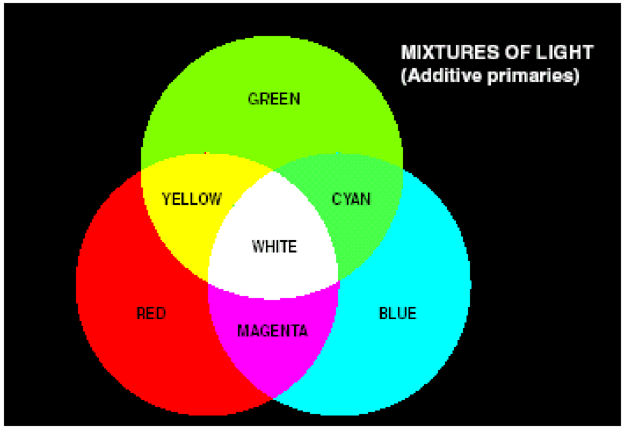
$$z = 1 - (x + y)$$

CIE Chromacity Diagram



- Greenish: 62% green, 25% red and 13% blue
- Redish: 32% green, 67% red and 1% blue
- Line joining 2 points defines different color variations that can be obtained by combining additively

Primary and secondary colors



Primary colors: Red, Green and Blue
Secondary colors: Cyan, Magenta and Yellow

Colour Models (Color Spaces)

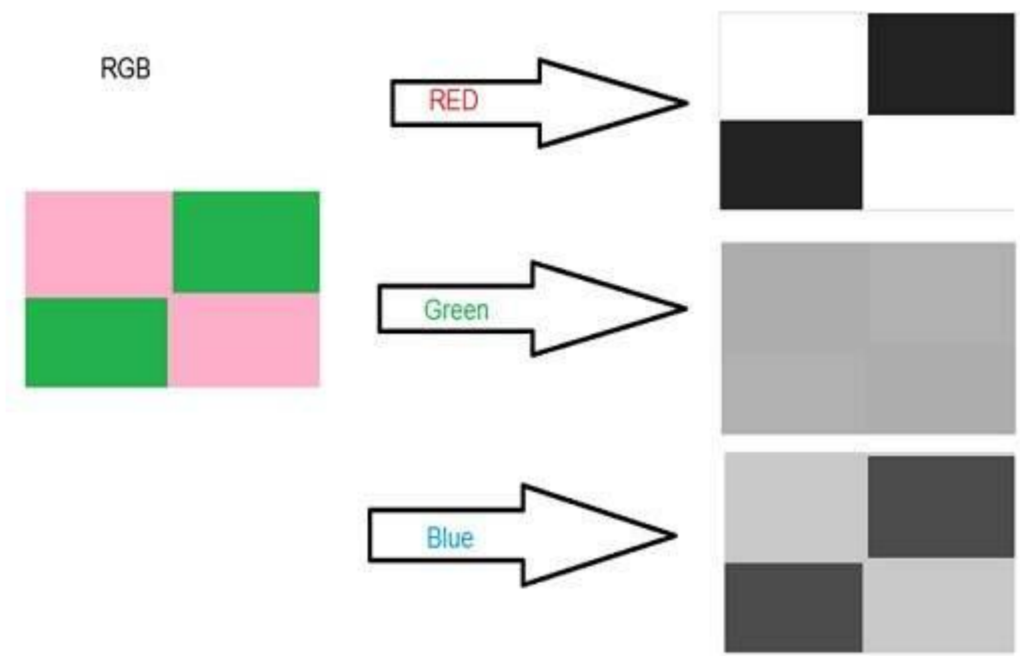
- RGB color space defines a color as the percentages of red, green, and blue hues mixed together
- Other color models describe colors by their hue (shade of color), saturation (amount of gray or pure color), and luminance (intensity, or overall brightness).
- Models are
  - RGB (Red Green Blue)
  - CMYK (Cyan Magenta Yellow K)
  - YC_bC_r
  - Lab
  - HSI (Hue Saturation Intensity)

Applications of RGB

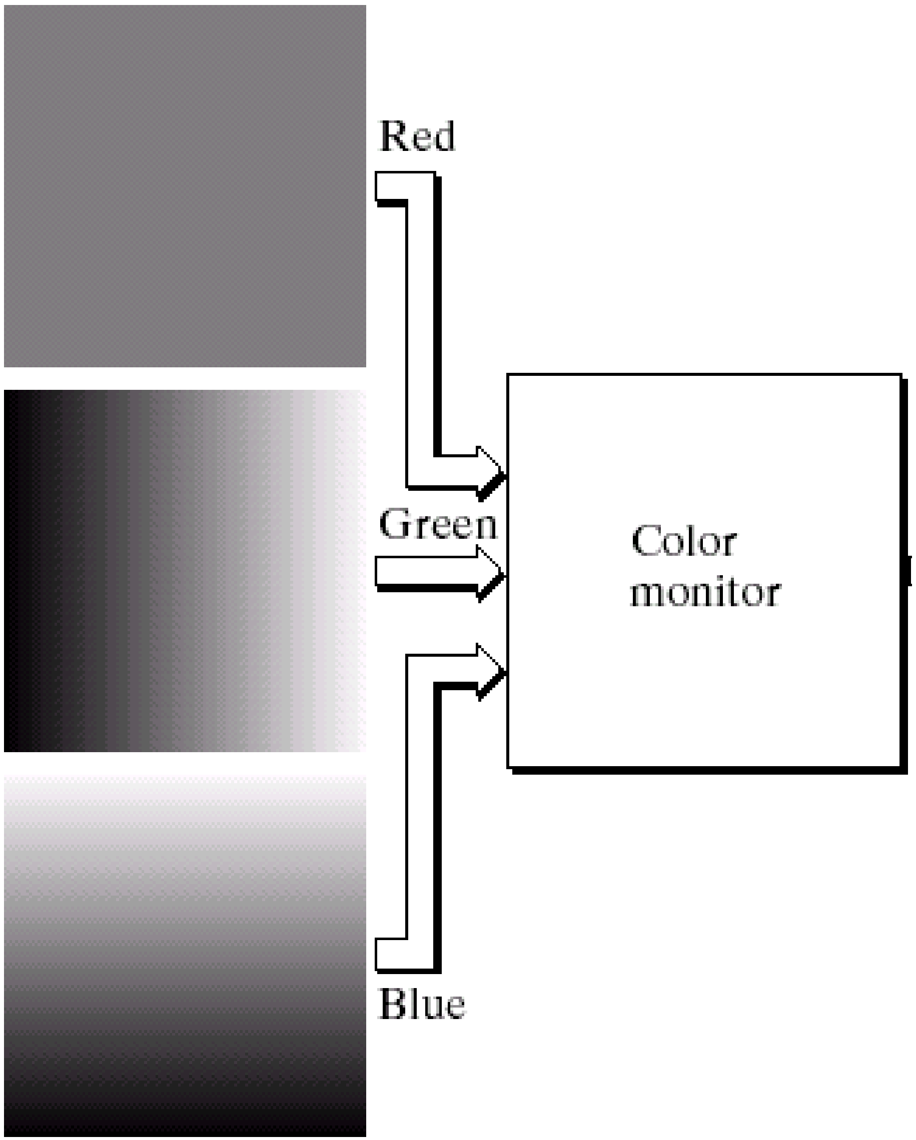
- Cathode ray tube (CRT)
- Liquid crystal display (LCD)
- Plasma Display or LED display such as a television
- A computer monitor or a large scale screen

RGB(R,G,B) color space

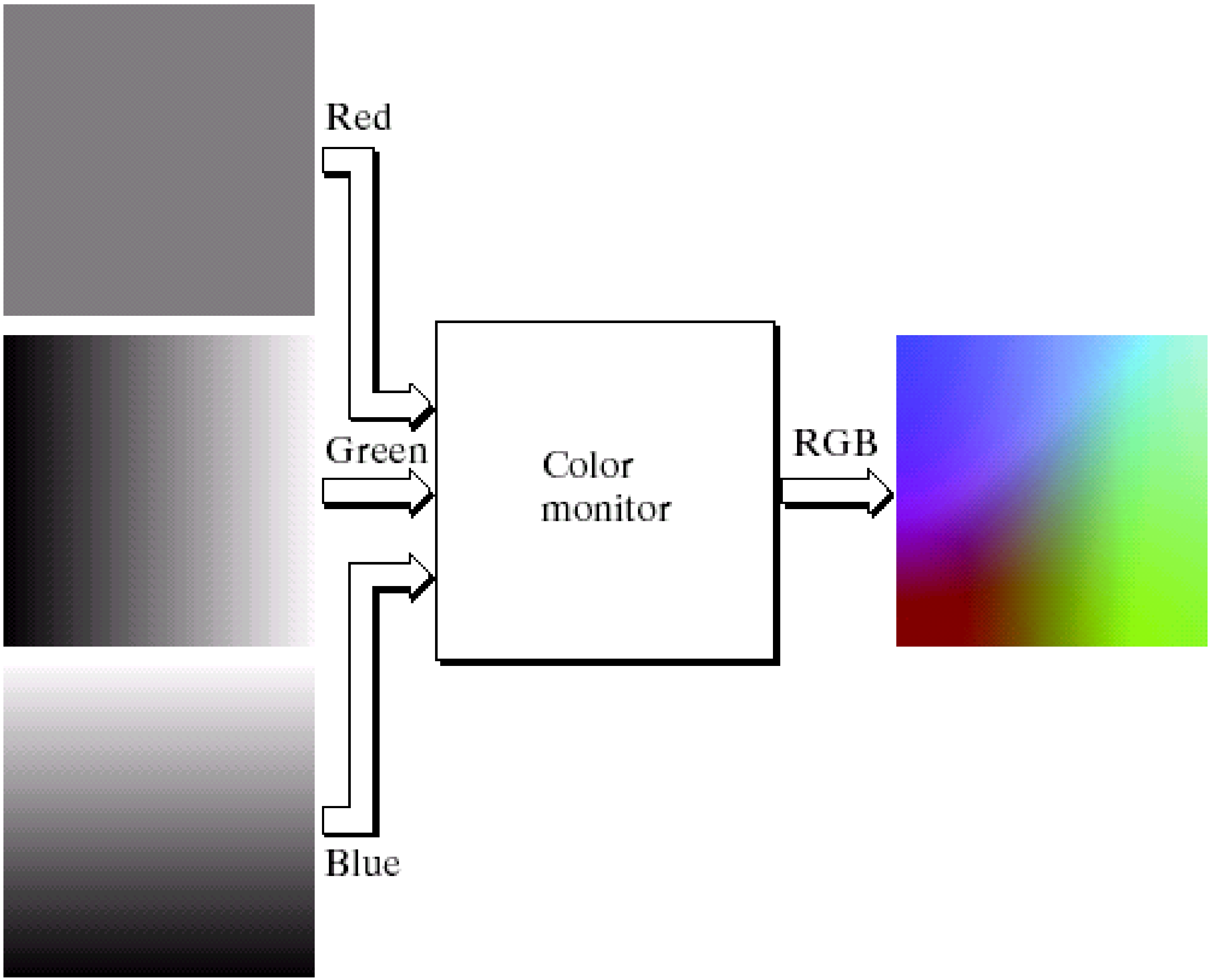
Intensity of pixels for R/G/B



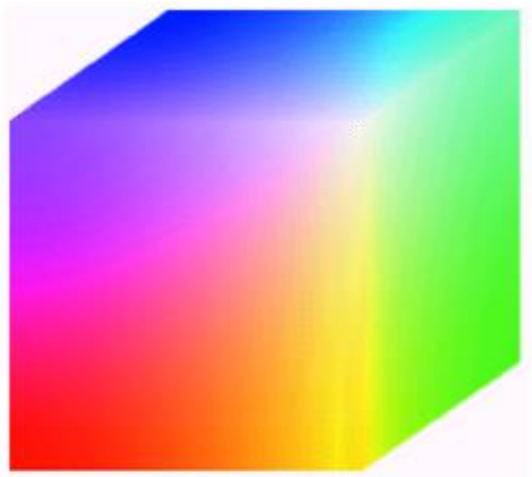
RGB(R,G,B) color space

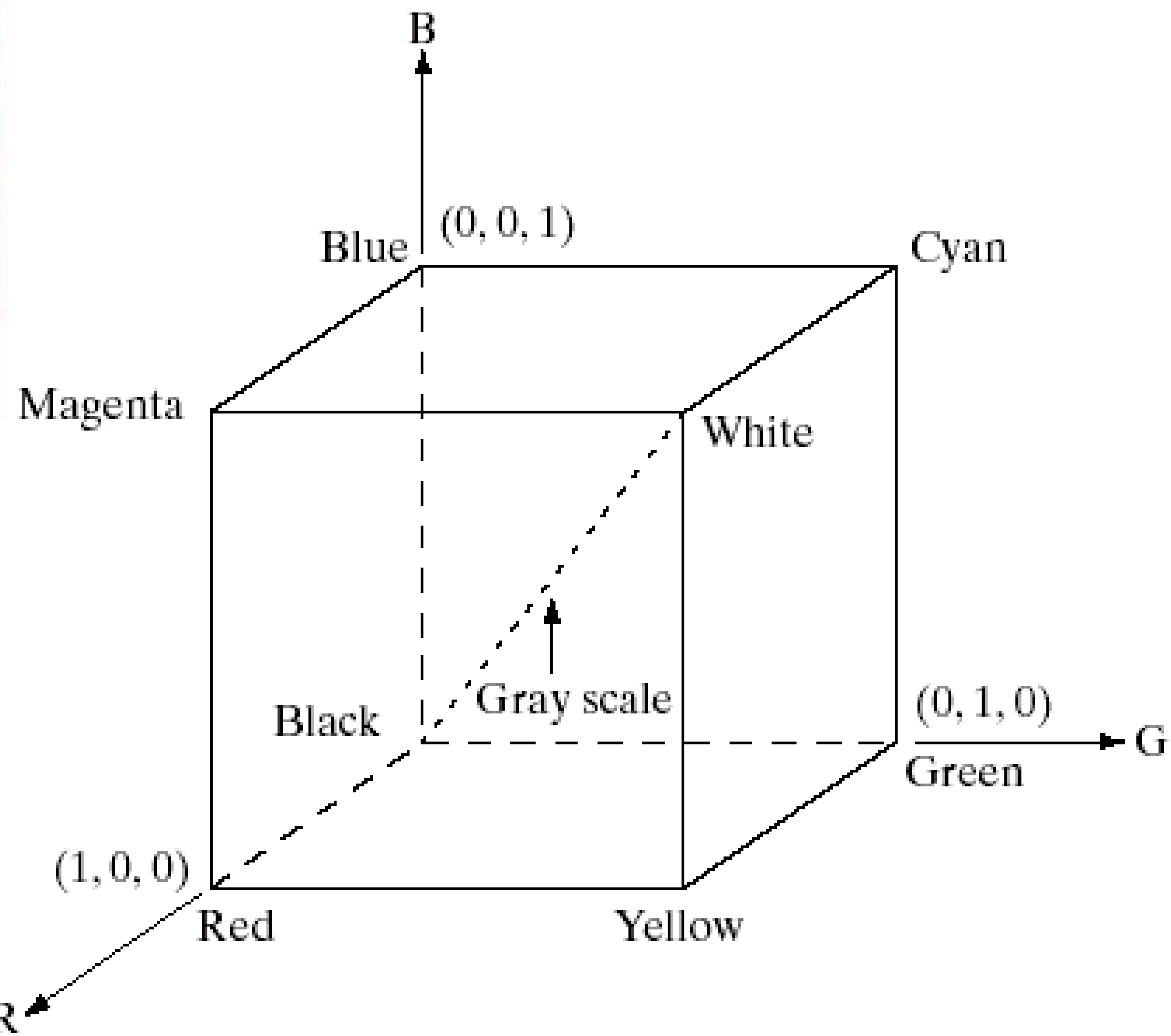


RGB(R,G,B)



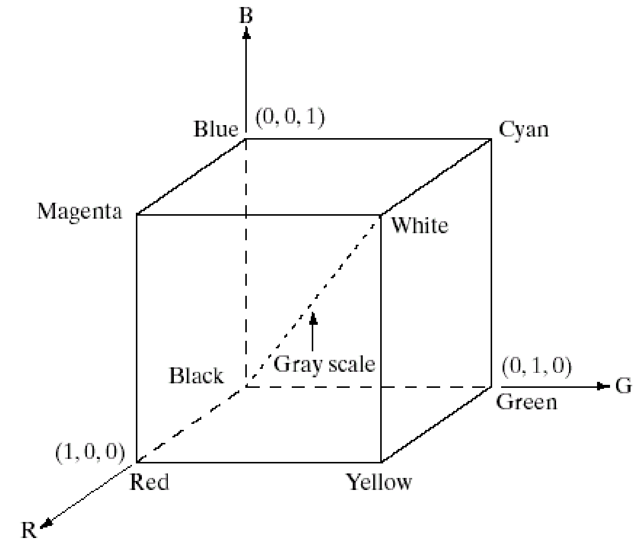
RGB (R,G,B)




B
Blue
(0, 0, 1)
Cyan
Magenta
White
Gray scale
Black
(0, 1, 0)
G
Green
(1, 0, 0)
Red
Yellow
R

RGB (R,G,B)

- Each colour appears in its primary spectral components of red, green and blue
- 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 also at the corner
  - Different colours are points on or inside the cube represented by RGB vectors



RGB (R,G,B)

- Number of bits used to represent each pixel is referred to as the colour depth
- A 24-bit image is referred to as a full-colour image

$(2^8)^3 = 16,777,216$ colours

CMY and CMYK color model

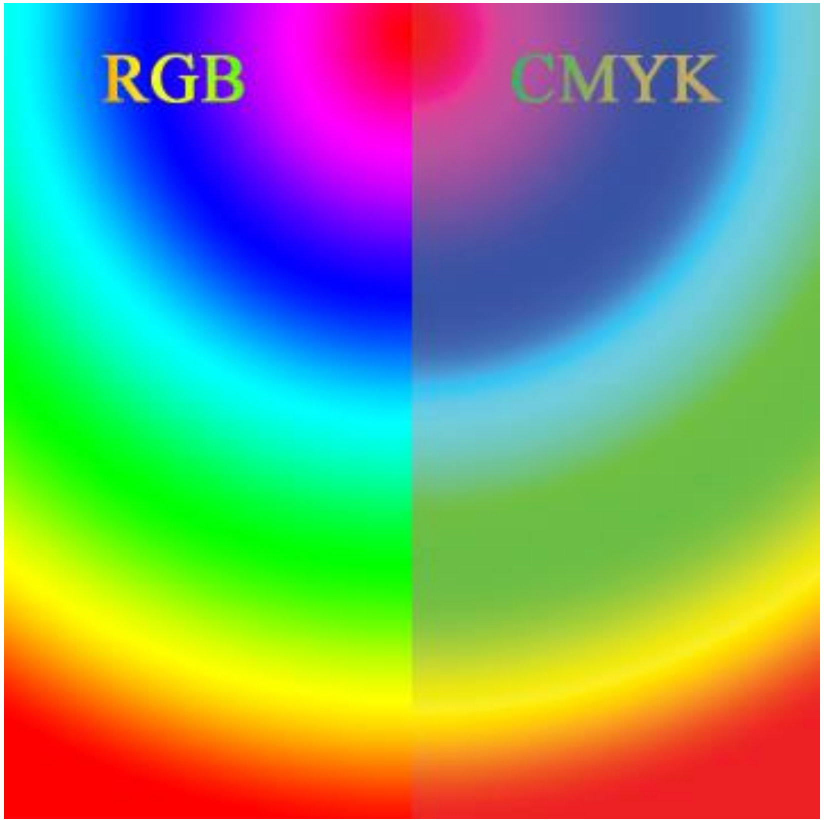
- Cyan, Magenta and Yellow are secondary colors
- Devices that deposit colored pigments on paper such as color printer and copier require CMY data input
- First RGB are normalized to the range [0,1]
- Then apply RGB to CMY conversion

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

- Equal amount of C, M and Y should produce black
- Black is commonly used by printers
- CMY model gives muddy black look
- To produce true black, fourth color, black (K) is added
- Therefore CMYK model is used

RGB and CMYK model

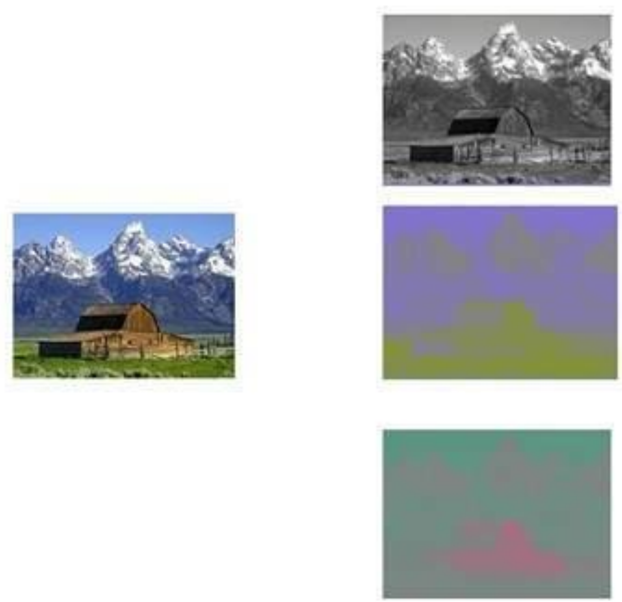
Colors seen on a computer monitor (RGB)



CMYK print

YCbCr color model

- Contains Y, the luma component and Cb and Cr are the blue-difference and red difference chroma components
- Widely used for digital video
- Other applications include JPEG and MPEG compression



YCbCr color model

- Y- Luminance or brightness of the image.

  Colors increase in brightness as *Y* increases
- Cb- Chrominance value that indicates the difference between the blue component and a reference value
- Cr- Chrominance value that indicates the difference between the red component and a reference value

Lab Color Model

- L- luminance Values are in the range [0, 100], where 0 specifies black and 100 specifies white
  - As *L* increases, colors become brighter
- a-Amount of red or green tones in the image.
  - A large positive ’*a*’ value corresponds to red/magenta
  - A large negative ’*a*’ value corresponds to green
- b - Amount of yellow or blue tones in the image
  - A large positive ’b’ value corresponds to yellow
  - A large negative ’b’ value corresponds to blue

The HSI Colour Model

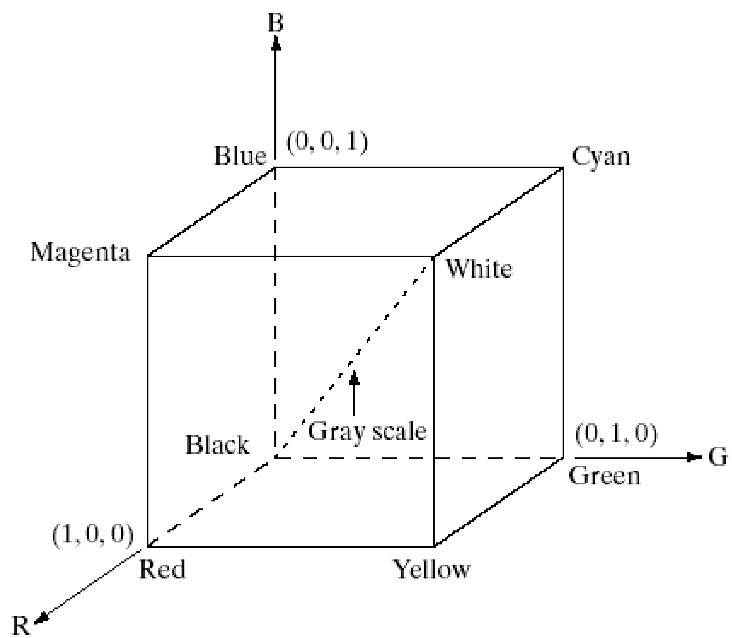
Useful for colour image processing

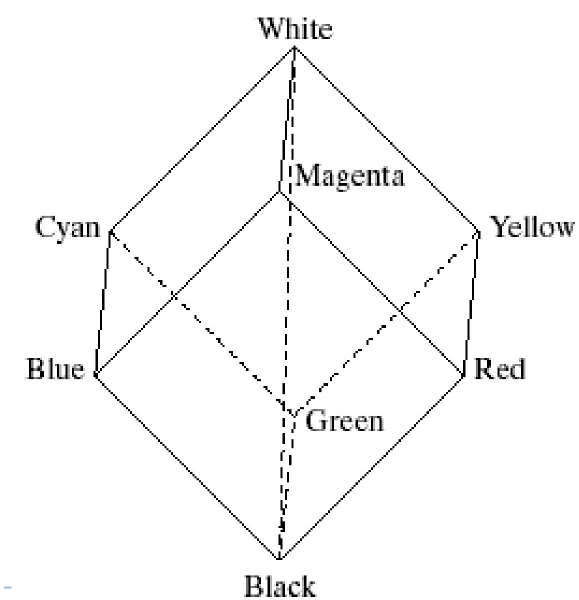
Three measures to describe colours:

- **Hue:** A colour attribute that describes a pure colour (pure yellow, orange or red)
- **Saturation:** Gives a measure of how much a pure colour is diluted with white
- **Intensity:** Similar to intensity for grey level images

HSI derived from RGB

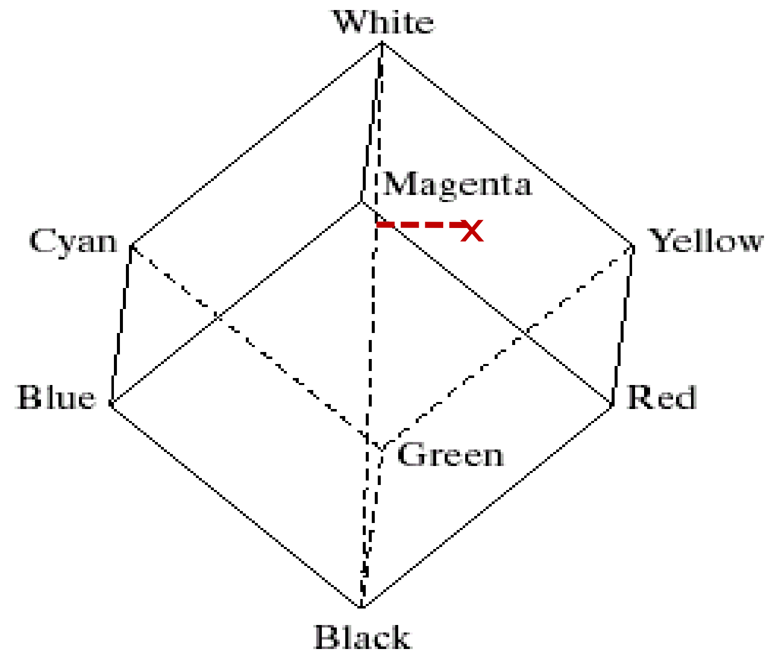
- Intensity can be extracted from RGB images
- Intensity is diagonal from black to white
- Rotate diagonal to make it vertical
- For HSI, rotate cube on the black vertex and position the white vertex directly above it

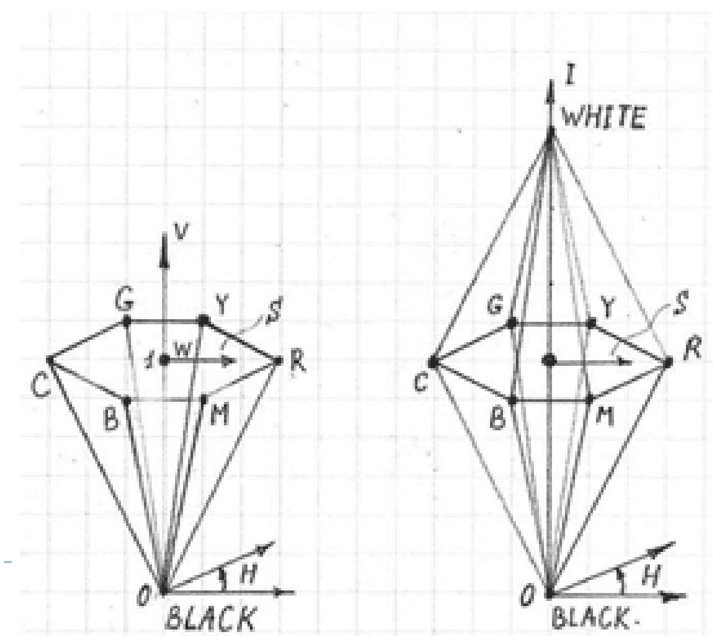




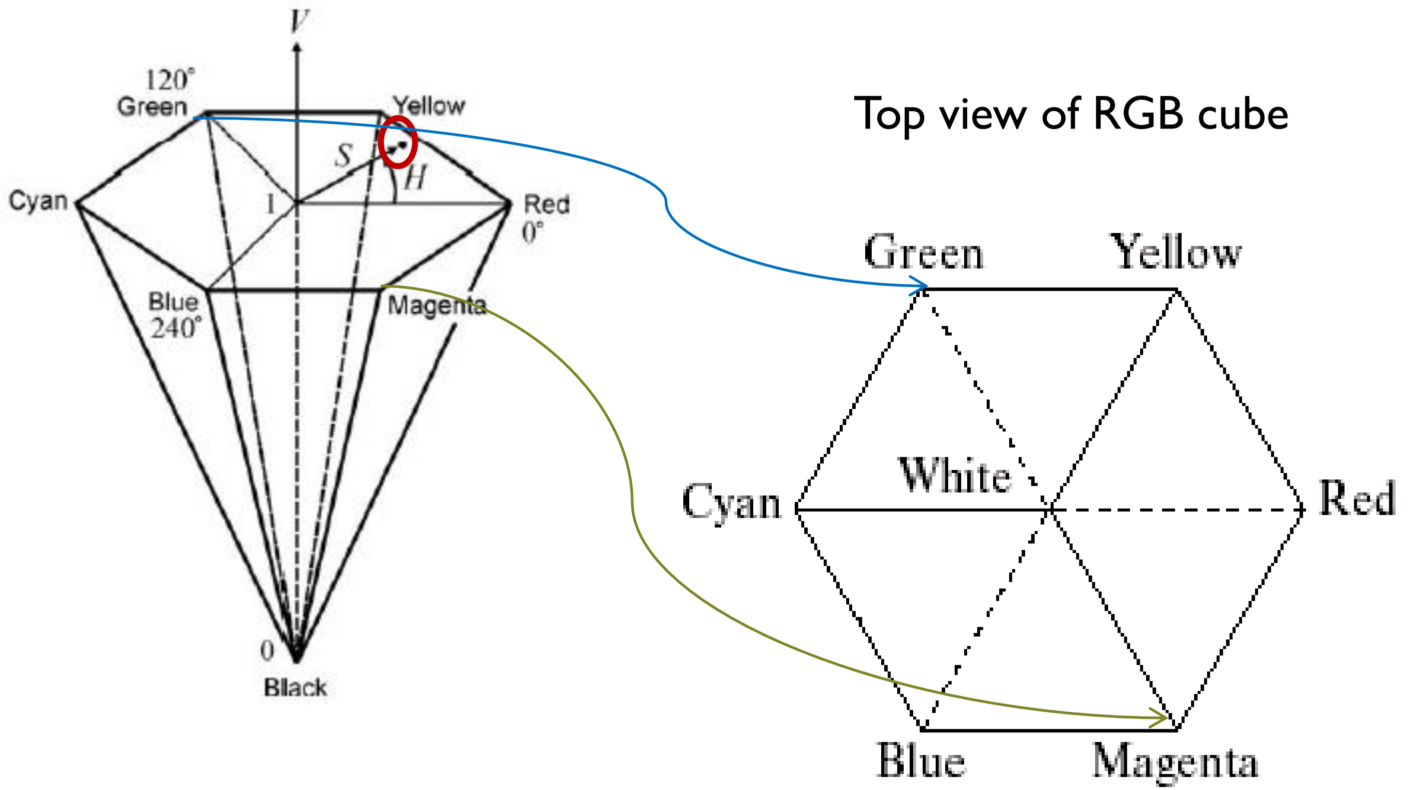
HSI derived from RGB

- Intensity component is determined by passing a plane *perpendicular* to the intensity axis and point
- The intersection of the plane with the intensity axis gives us the intensity component of the colour





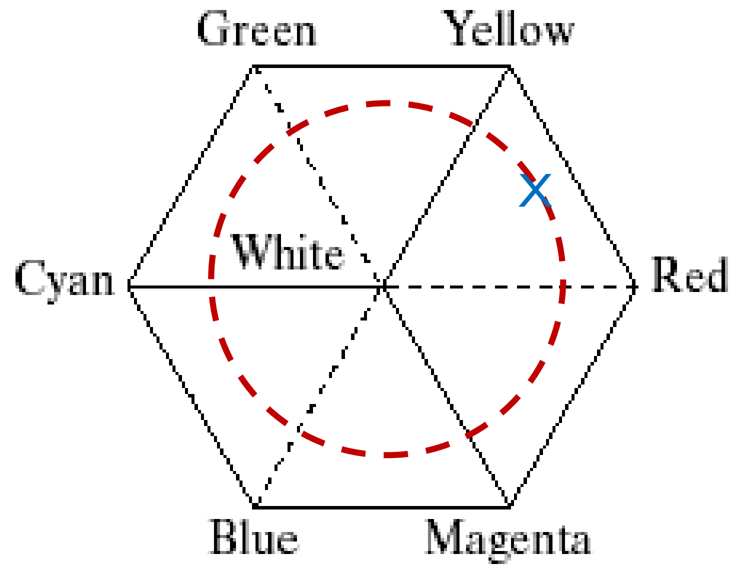
HSI derived from RGB

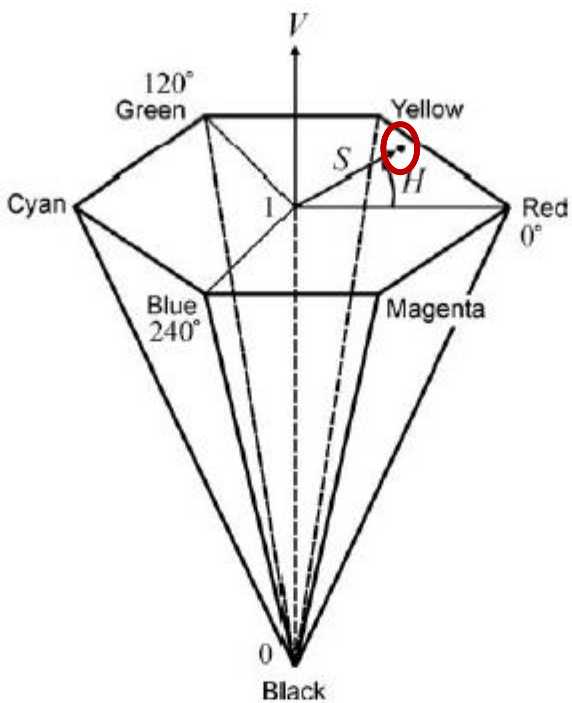


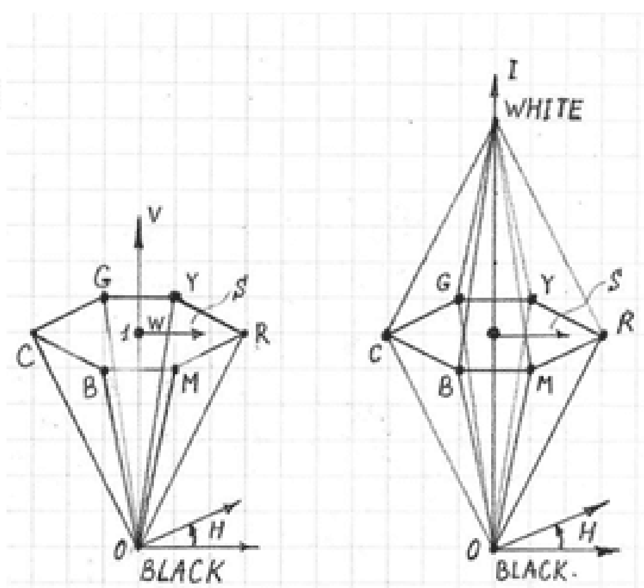
- Hexagonal shape with each primary colour separated by 120°
- Secondary colours are at 60° from the primaries

The HSI Colour Model

- HSI model is composed of a vertical intensity axis
- And locus of colour points that lie on planes perpendicular to that axis

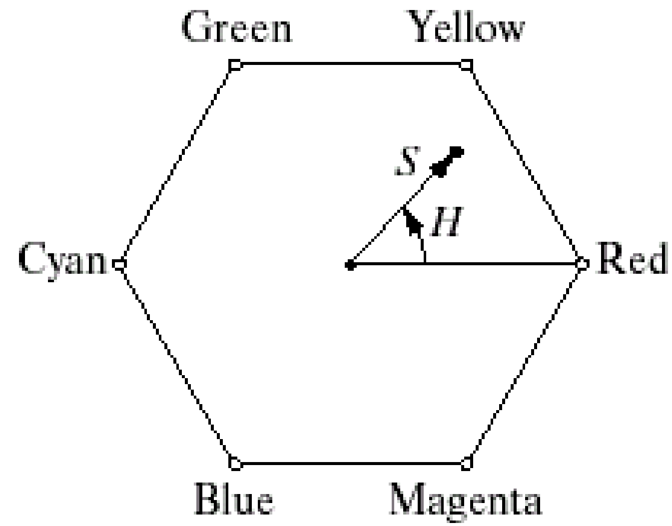


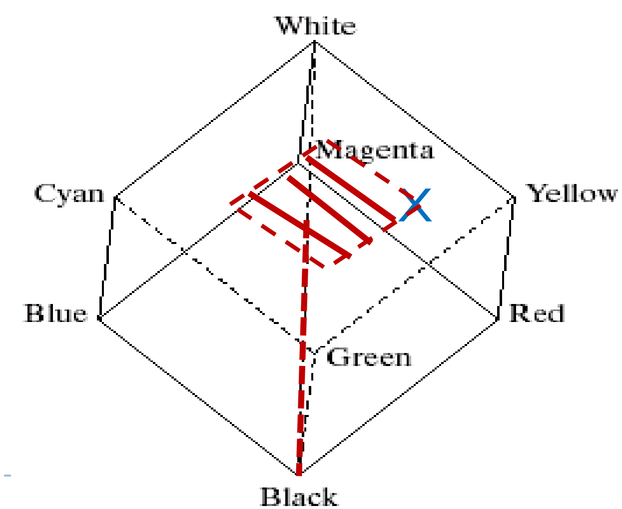




The HSI Colour Model

- For arbitrary colour point
  - The hue (H) is determined by an angle from a reference point, usually red
  - The saturation (S) is the distance from the origin to the point
  - H and S are called chromaticity components
  - The intensity is distance on vertical intensity axis





Converting From RGB To HSI

- Given R, G, and B of a color pixel
- H, S, and I values are

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

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

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

Converting From HSI To RGB

- Given H, S, and I of color pixel
- R, G, and B values are
  - RG sector ($0 <= H < 120°$)

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

  - GB sector ($120° <= H < 240°$)

$$R = I(1 - S) \quad G = I\left[1 + \frac{S\cos(H - 120)}{\cos(H - 60)}\right] \quad B = 3I - (R + G)$$

Converting From HSI To RGB

- BR sector (*240° <= H <= 360°*)

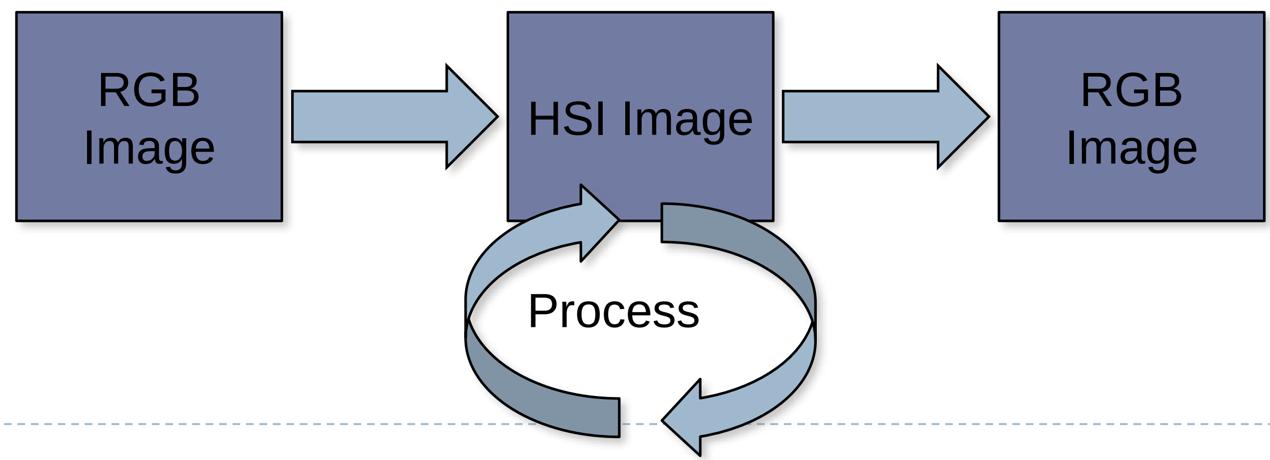
$$R = 3I - (G + B) \quad G = I(1 - S)$$

$$B = I\left[1 + \frac{S\cos(H - 240)}{\cos(H - 180)}\right]$$

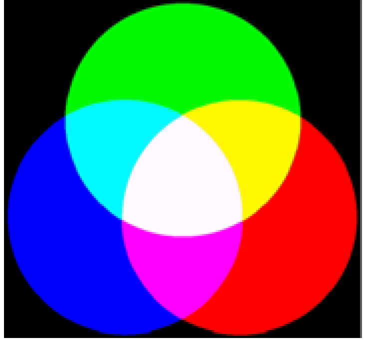
- Disadvantages
  - non linear value hue near red
  - computationally expensive conversion to/from RGB
  - hue is undefined for a saturation of 0

Process Images using HSI Model

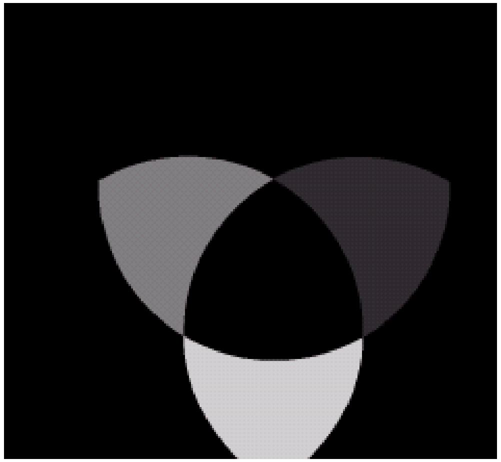
- First convert it from RGB to HSI
- Process HSI of image
- Finally convert the image back from HSI to RGB



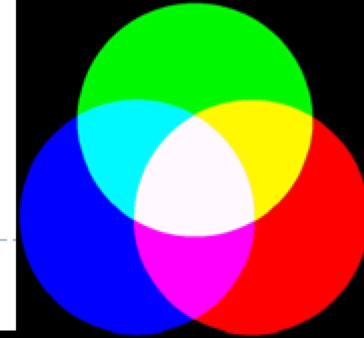
Modified HSI -> RGB



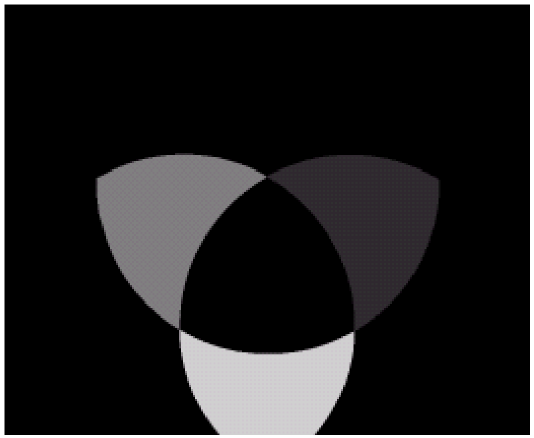
Hue if
R, G, B
regions are
made 0

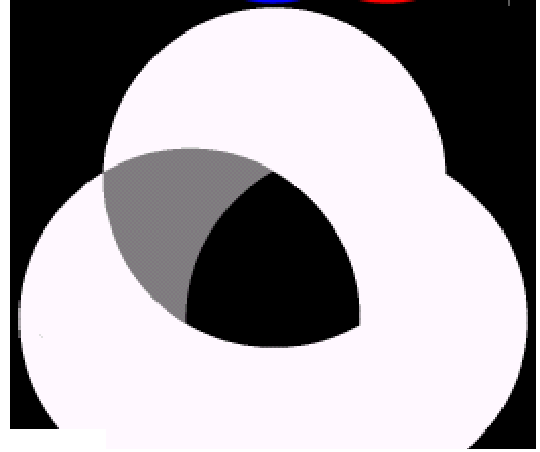


Modified HSI -> RGB



Hue if
R, G, B
regions are
made 0

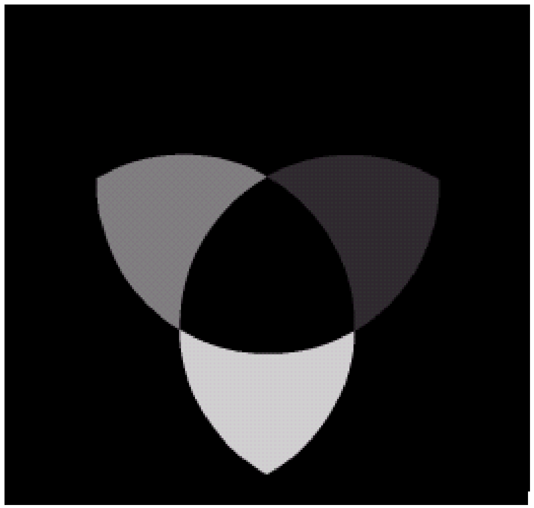


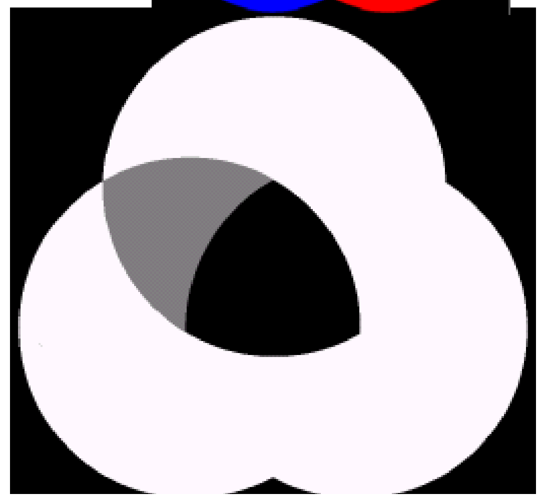


Saturation if
cyan is
reduced to
half

Modified HSI -> RGB

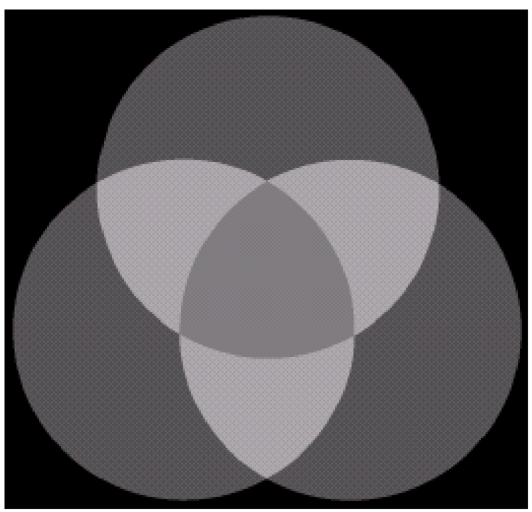
Hue if R, G, B regions are made 0



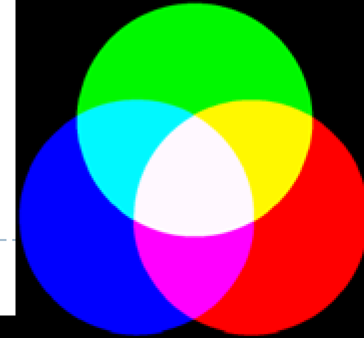


Saturation if cyan is reduced to half

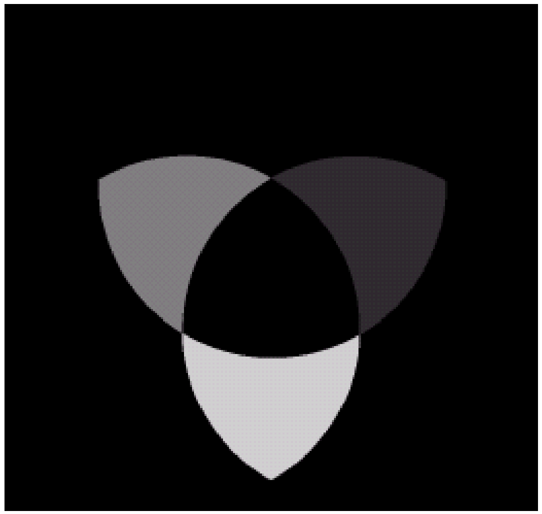
Intensity if central portion/2

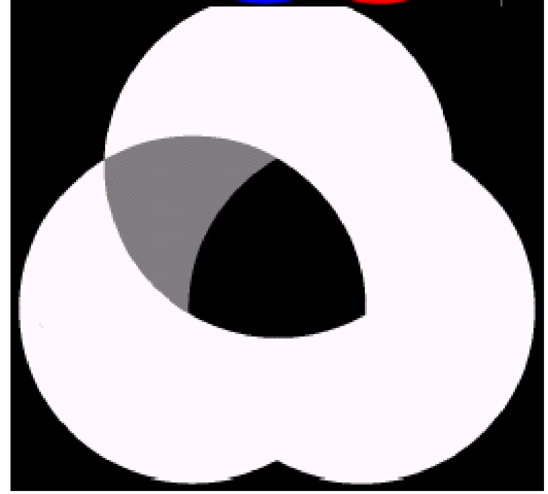


Modified HSI -> RGB



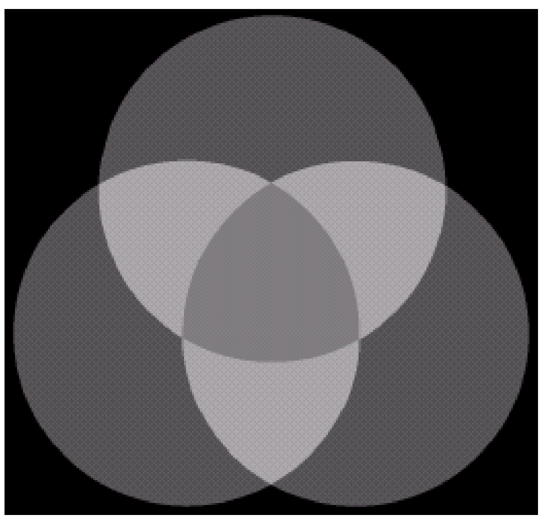
Hue if R, G, B regions are made 0

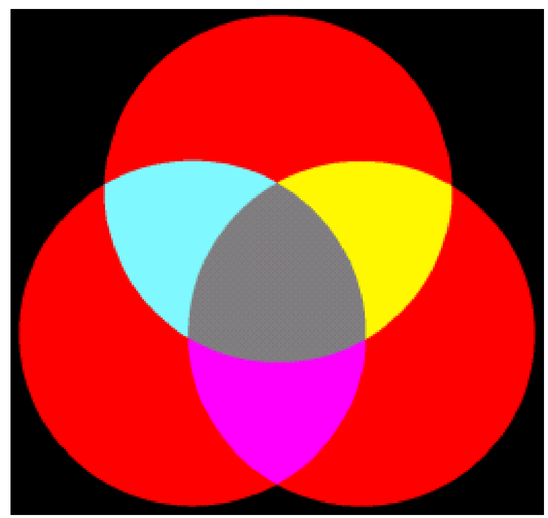




Saturation if cyan is reduced to half

Intensity if central portion/2





RGB Image

Allows independent control on H, S and I

YC_bC_r model

- The *YCbCr* color model is the most popular color representation for digital video
- One component represents luminance (*Y*)
- Other two are color difference signals: *Cb* (the difference between the blue component and a reference value)
- and *Cr* (the difference between the red component and a reference value)
- Conversion from *RGB* to *YCbCr* is possible using transformation matrix

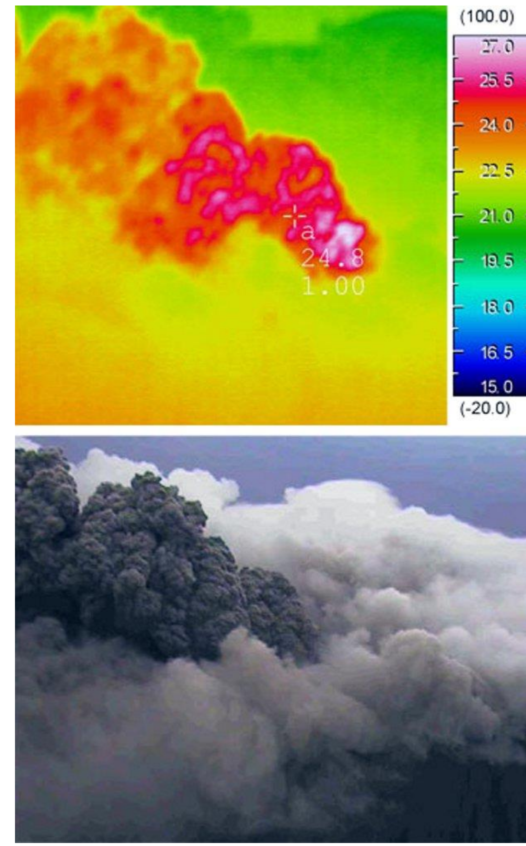
YC_bC_r model

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

Pseudocolour Image Processing

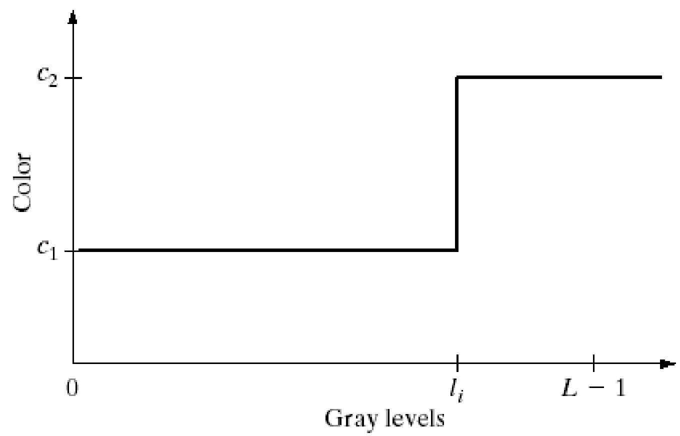
- Pseudocolour is also called false colour
- Image processing consists of assigning colours to grey values based on a specific criterion
- The principle use of pseudocolour image processing is for human visualization
- Human can distinguish between thousands of colour shades and intensities,

  compared to 256 shades of grey



Grey shades are given customized colors

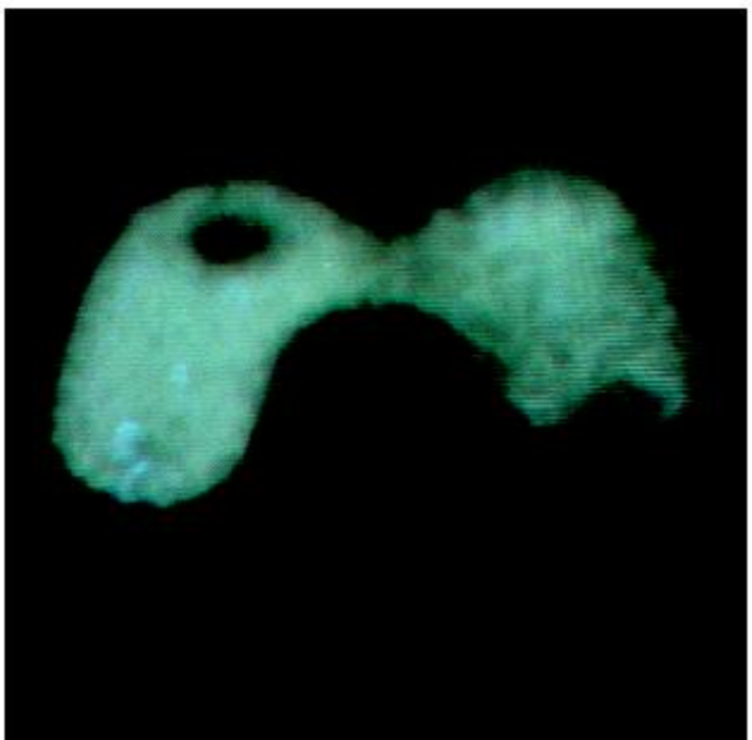
Pseudo Colour Image Processing – Intensity Slicing



- If intensity of a pixel in grey image < threshold
- Then corresponding pixel in output image has color, c_1
- else assign color, c_2

Pseudo Colour Image Processing – Intensity Slicing

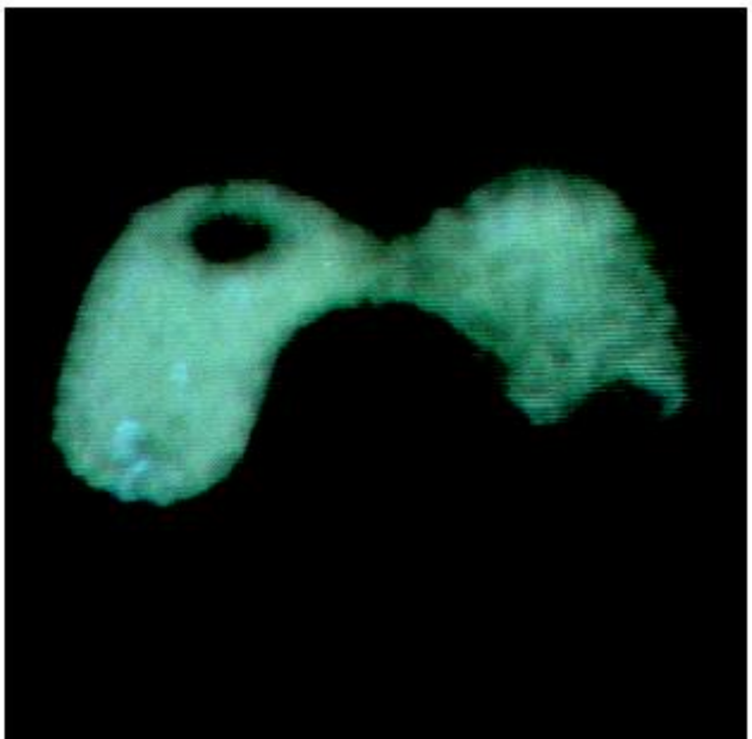
- Multiple colors can be assigned based on multiple thresholds



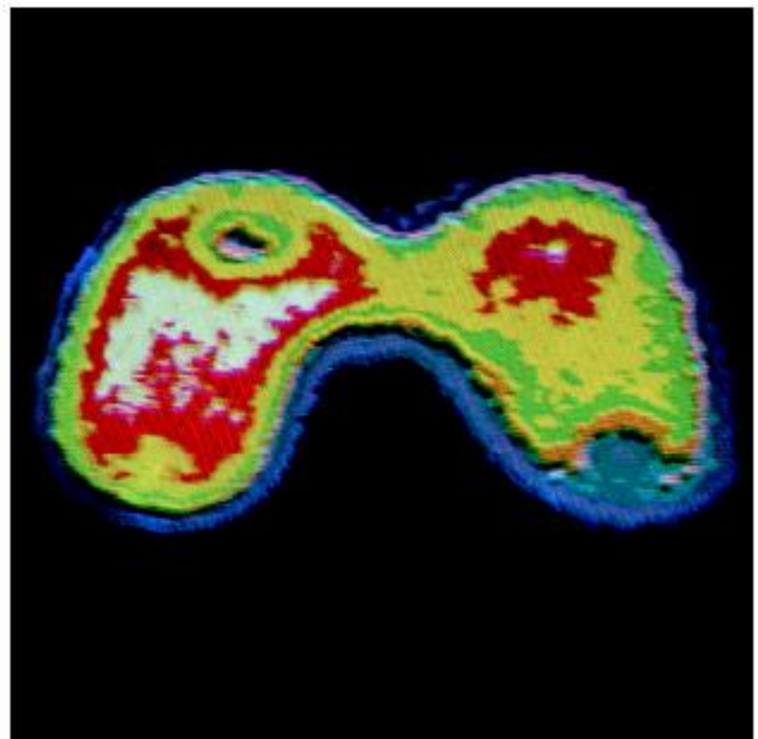
- two colors based on one threshold

Pseudo Colour Image Processing – Intensity Slicing

- Multiple colors can be assigned based on multiple thresholds

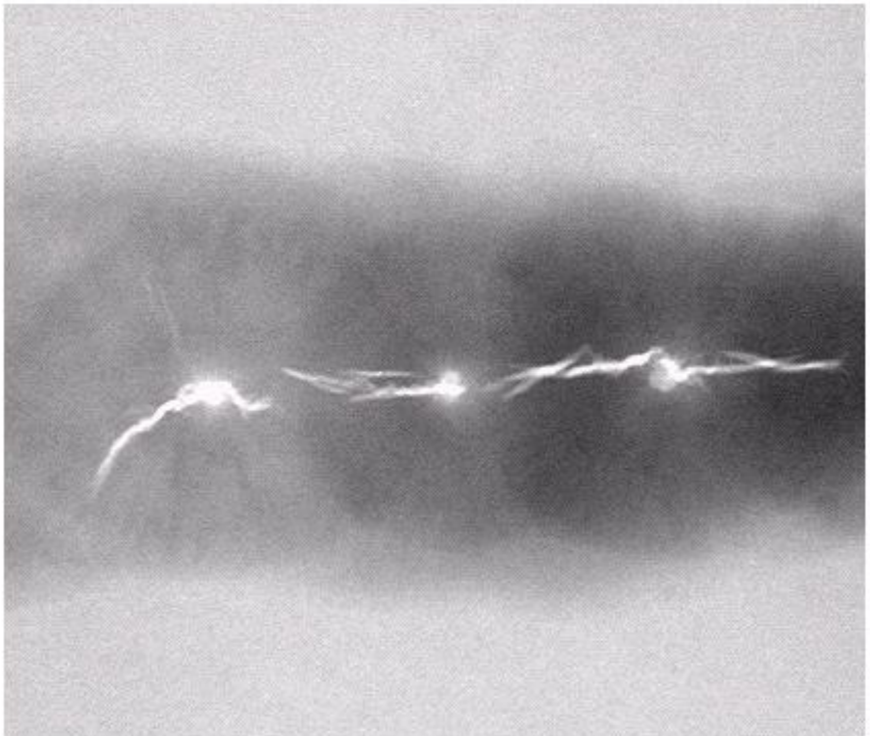


two colors based on one threshold



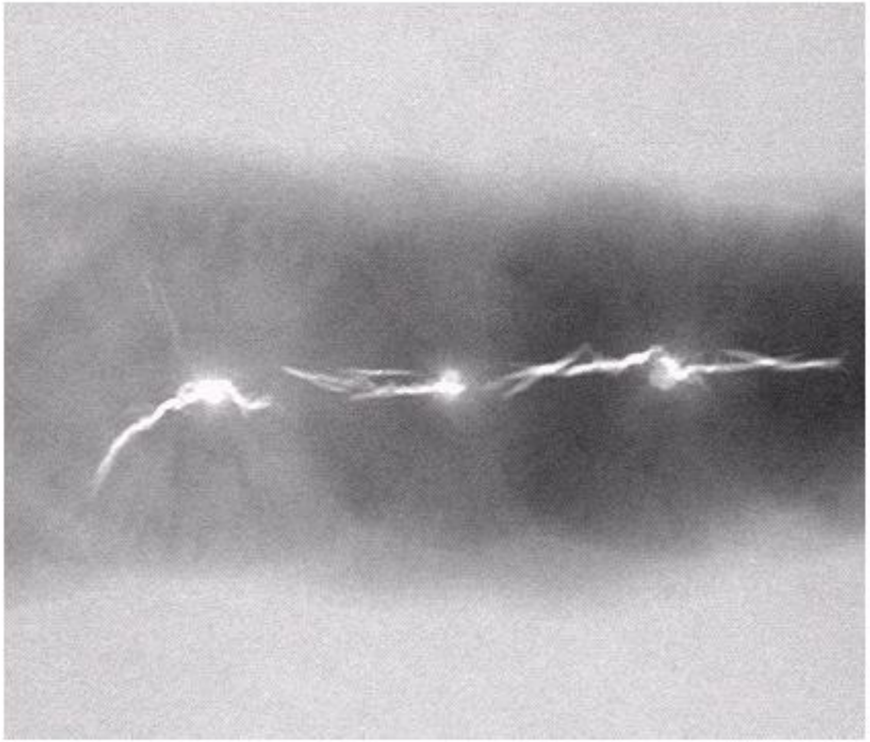
8 colors based on 7 threshold levels

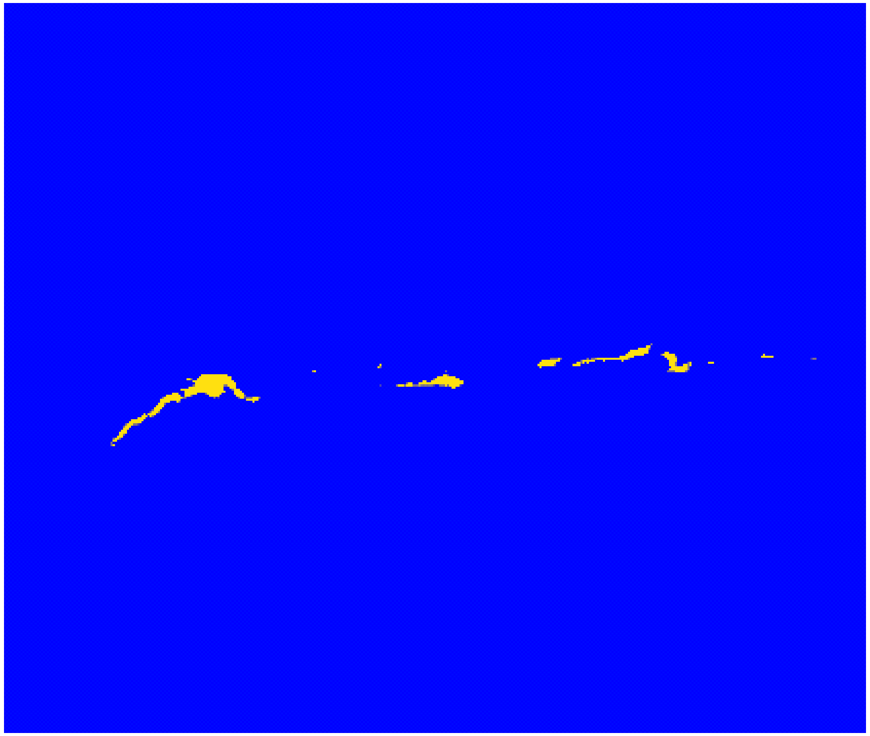
Intensity level slicing



Contains cracks and porosities

Intensity level slicing

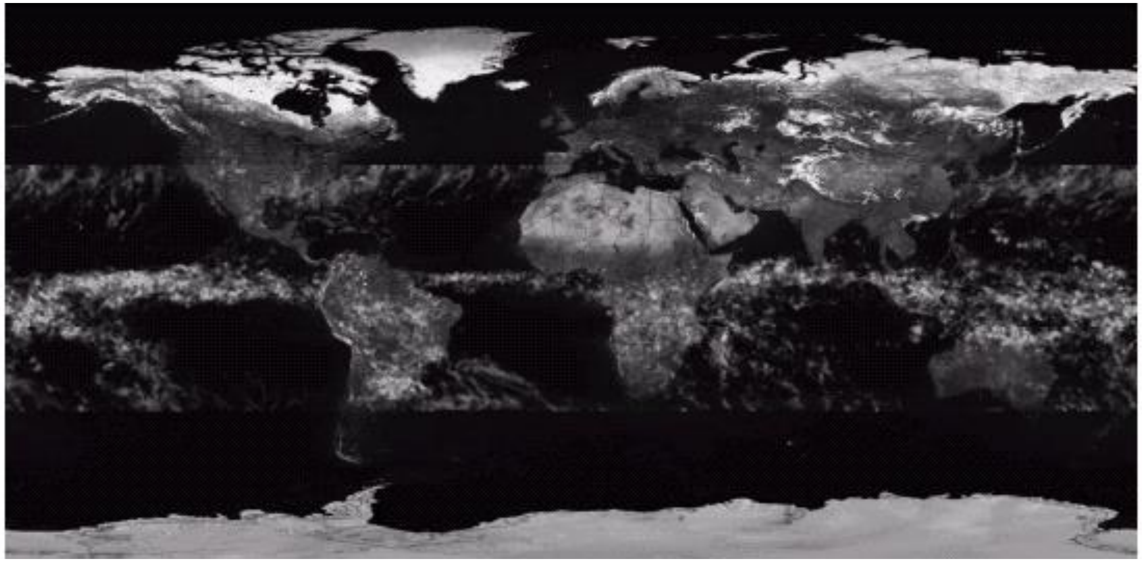




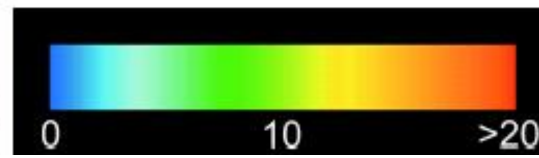
Contains cracks and porosities

2-level slicing

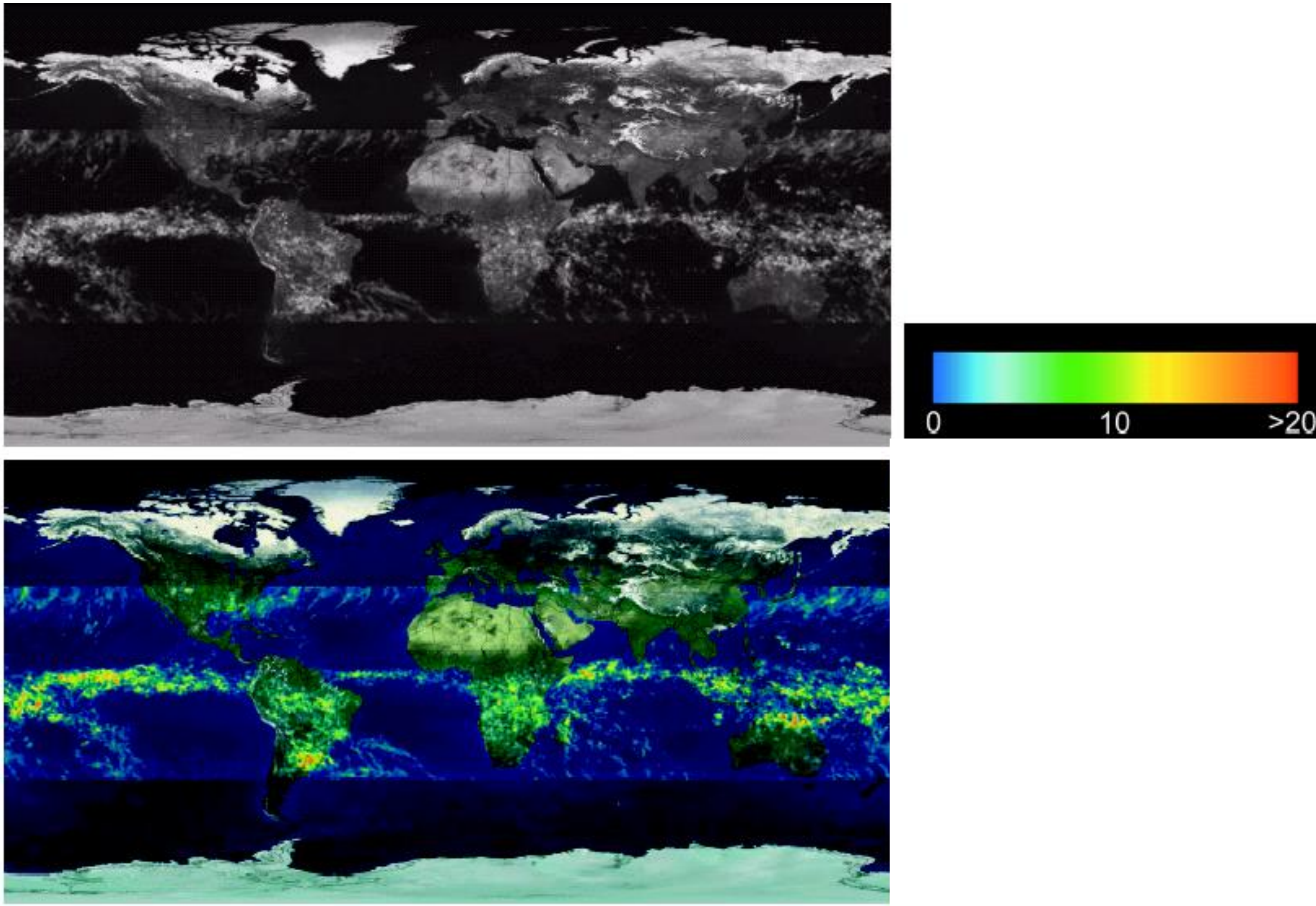
Intensity level slicing



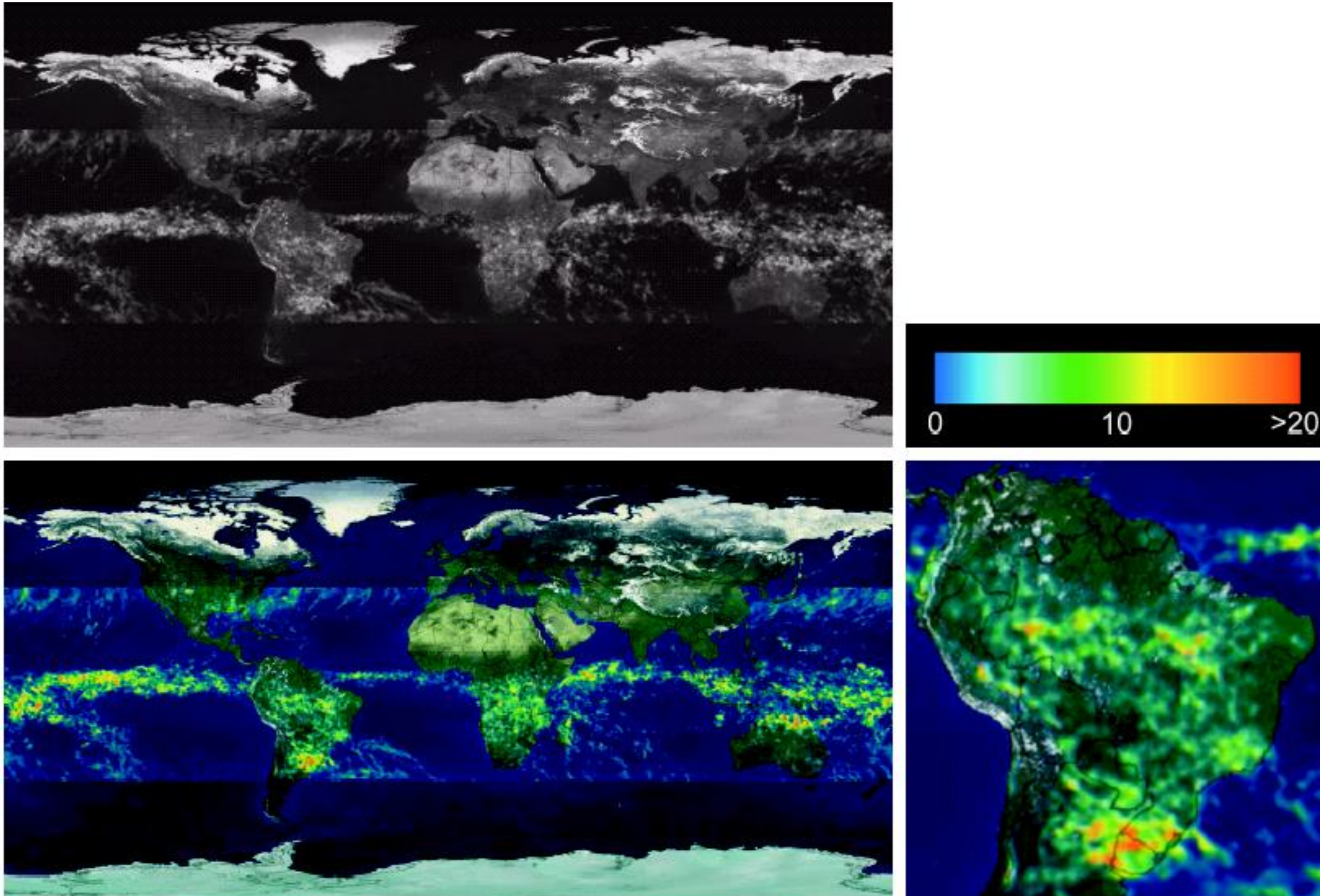
Color assignment



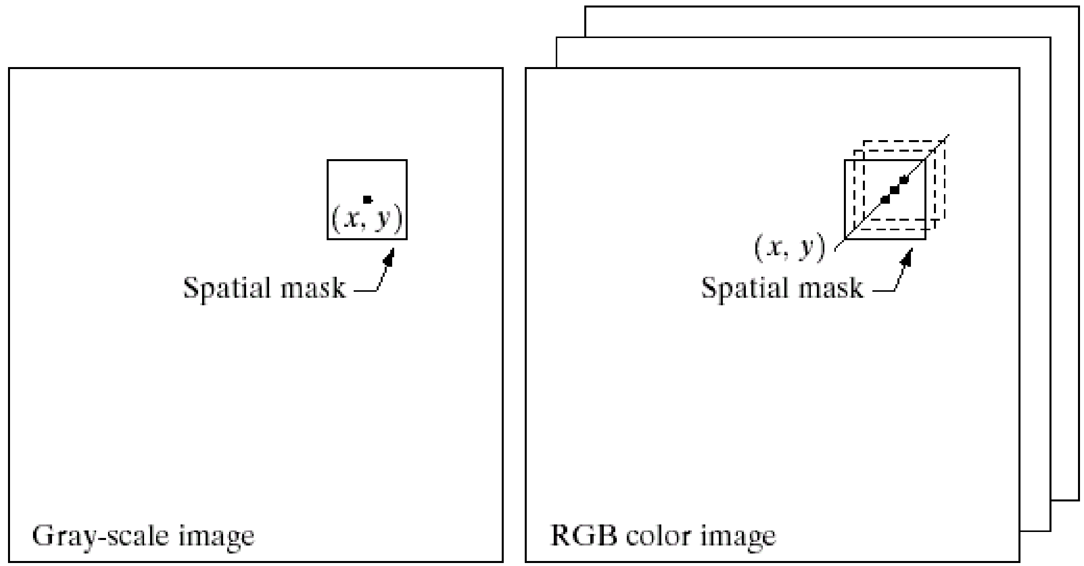
Intensity level slicing



Intensity level slicing



Full Colour Image Processing – Intensity Enhancement



- Apply mask/ transformation on all three channels
- Masks/ transformation can be different for each channel

Full Colour Image Processing – Intensity Enhancement

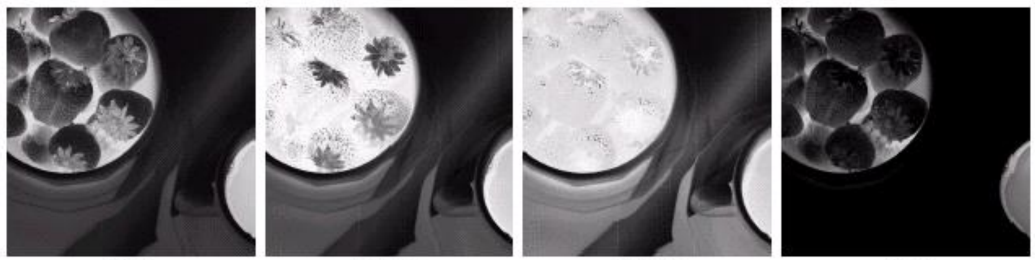
Full color

Convert to any color model

Full Colour Image Processing – Intensity Enhancement

Convert to any color model

Full color



Cyan Magenta Yellow Black

CMYK planes

Full Colour Image Processing – Intensity Enhancement

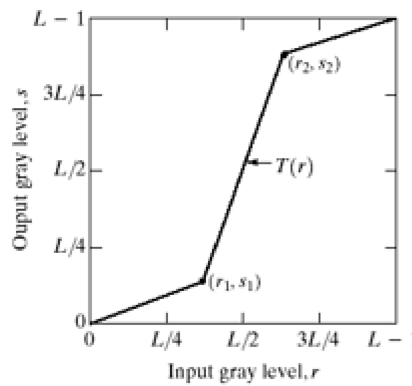
Convert to any color model

CMYK planes

RGB planes

HSI planes

Full Colour Image Processing – Intensity Enhancement



- Transformation characteristic for gray image
- Transformation characteristics can be applied to each of color planes

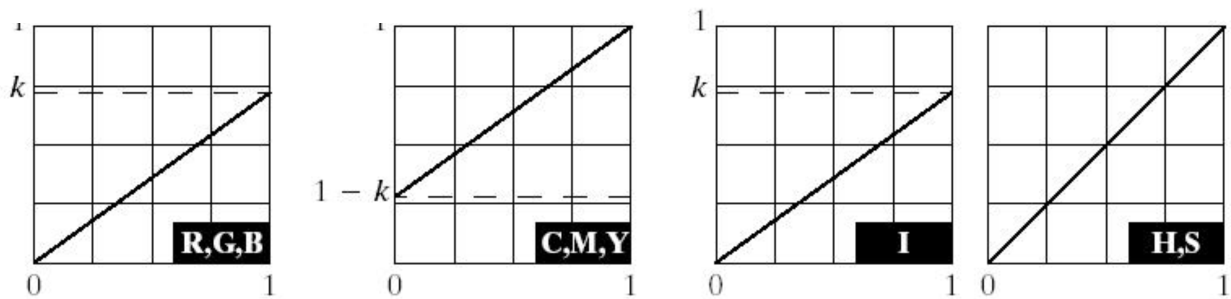
Full Colour Image Processing – Intensity Enhancement

Original Image

Full Colour Image Processing – Intensity Enhancement

- Apply Transformation characteristics to any of the color space
- Each of R, G and B planes have same transformation
- Each of R, G and B planes have same transformation
- H and S planes have same transformation and I is given different transformation

Original Image

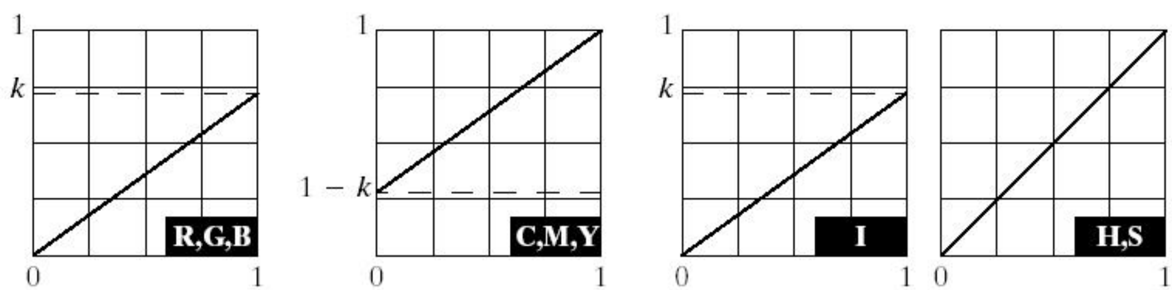


K=0.7

Full Colour Image Processing – Intensity Enhancement

Image after transformation

Original image

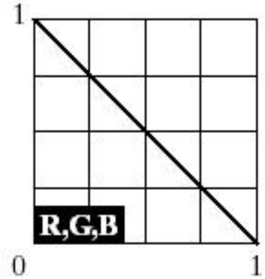


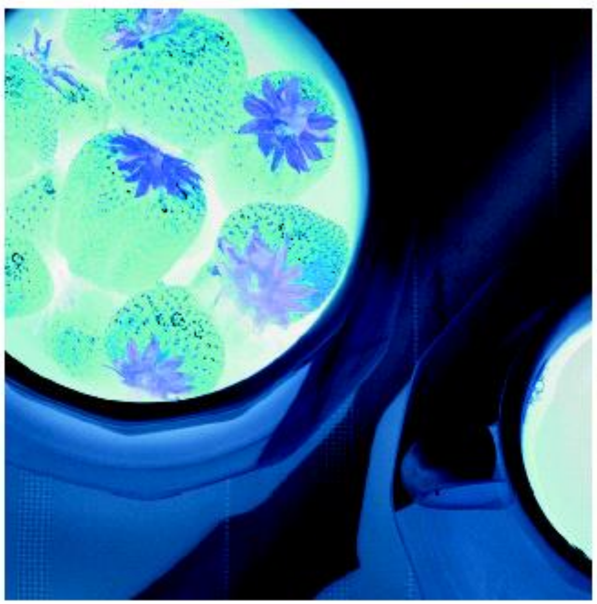
K=0.7

- Apply Transformation characteristics to any of the color space

Full Colour Image Processing – Intensity Enhancement(Complement)

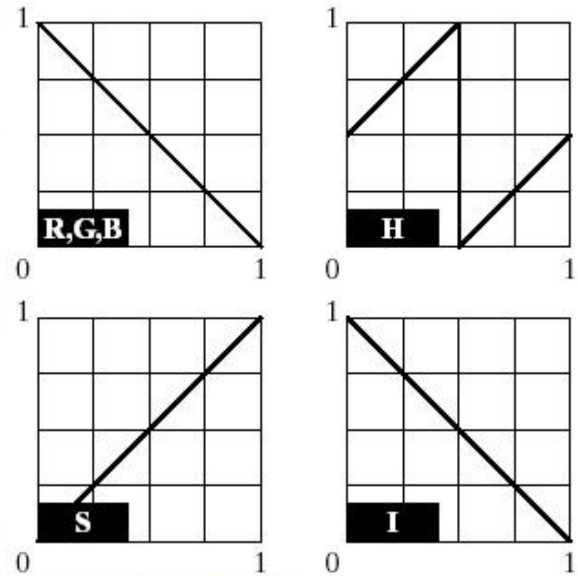
Full Colour Image Processing – Intensity Enhancement(Complement)



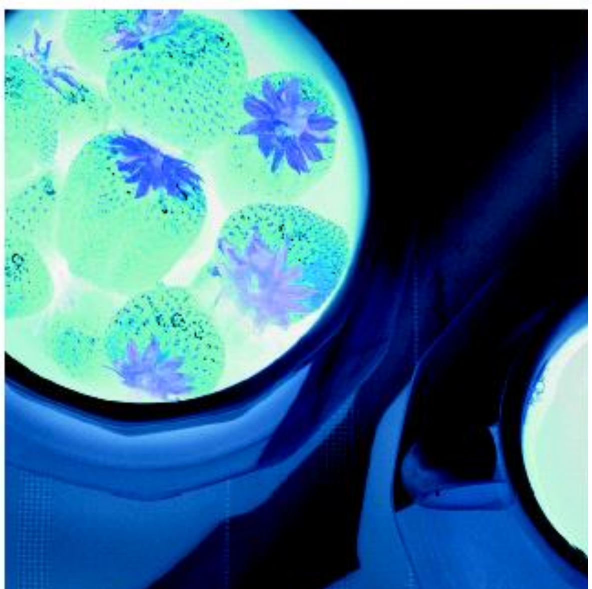


Transformation on RGB

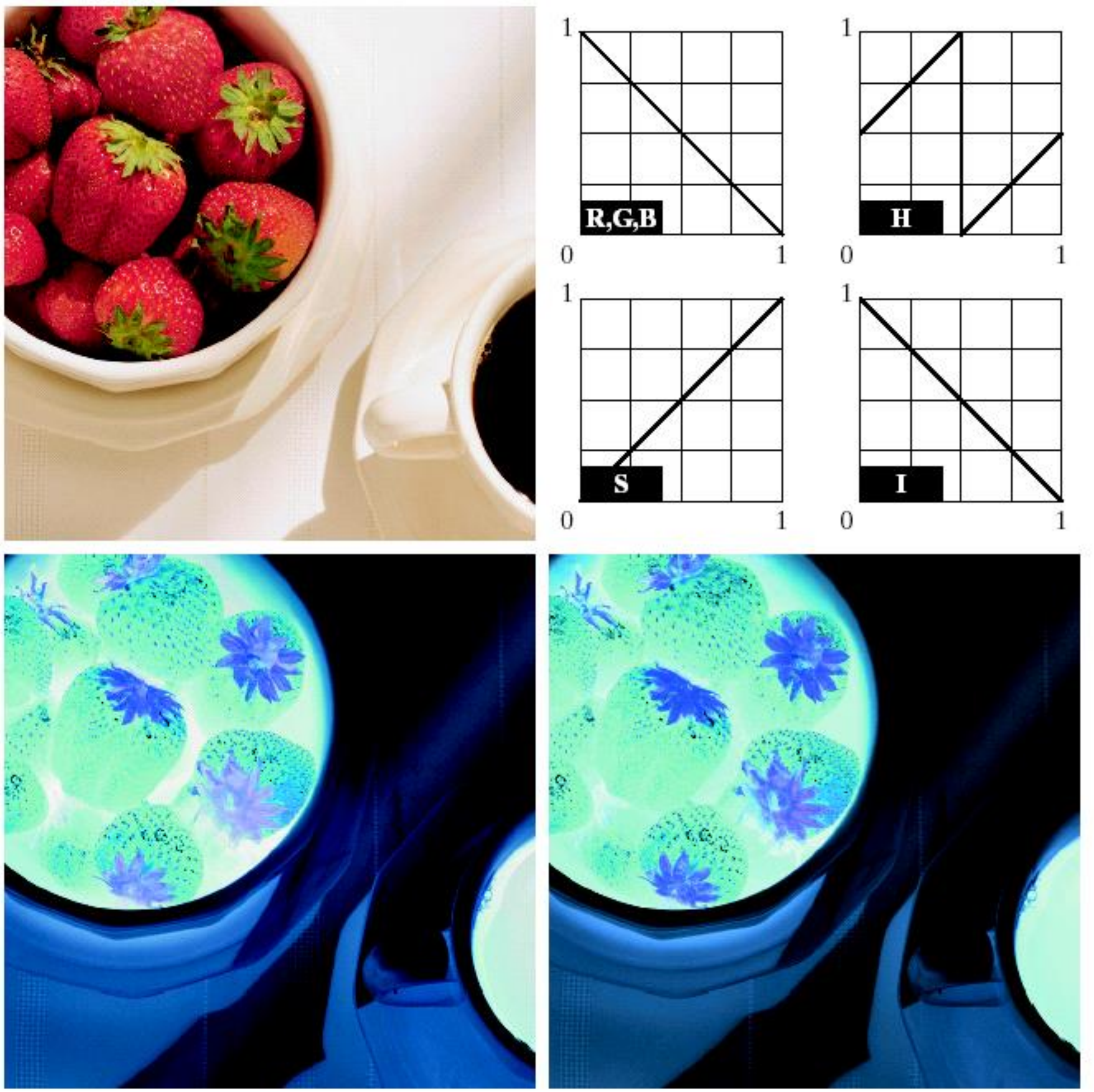
Full Colour Image Processing – Intensity Enhancement(Complement)



Transformation on RGB



Full Colour Image Processing – Intensity Enhancement(Complement)



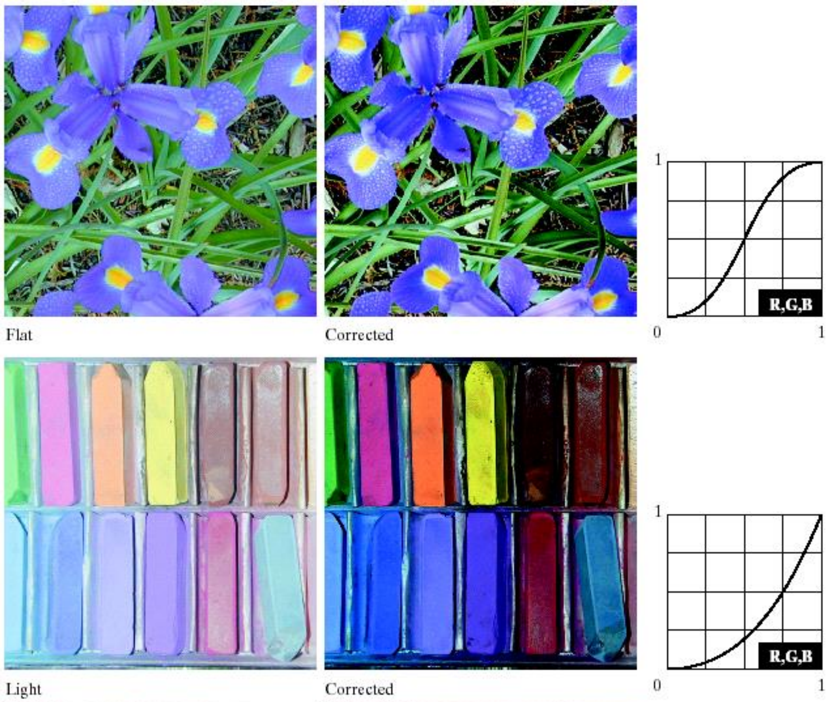
Transformation on RGB and HSI show the same results

Transformation on RGB

Transformation on HSI

Full Colour Image Processing – Intensity Enhancement

Full Colour Image Processing – Intensity Enhancement



Full Colour Image Processing – Intensity Enhancement