Marwadi
University

IMAGE PROCESSING
01CE0507

Unit 6
Color Image Fundamentals

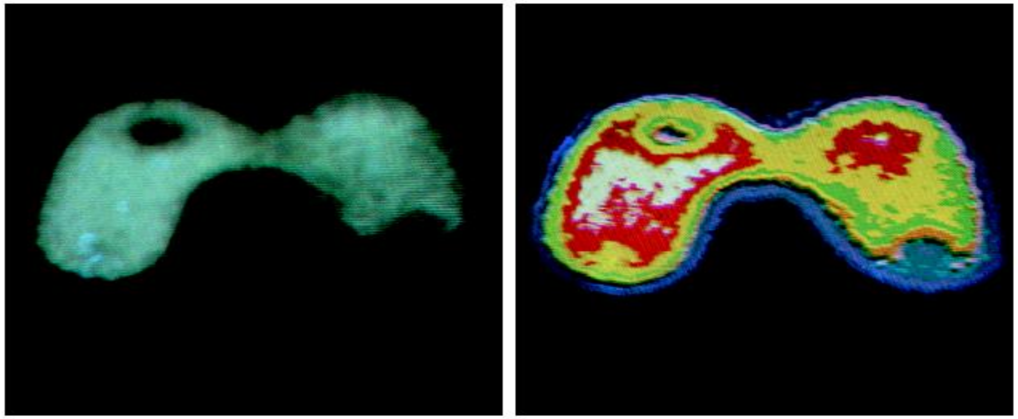
Prof. Urvi Y. Bhatt
Department of Computer Engineering

Outline

- Why use color in image processing?
- Category of Color Image Processing
- Color Fundamentals
- Primary Colors of Light VS Primary Colors of Pigment
- Color Models
- Pseudo-color Image Processing
  - Intensity Slicing / Density Slicing
  - Gray level to color transformations
- Color Image Smoothing & Sharpening

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



Category of Color Image Processing

Color Image Processing

Full – color processing

Pseudo – color processing

Input image acquired with full-color sensors
e.g.
Color TV / Color Scanner

Assigning color to monochrome intensity / Range of intensities

Color Fundamentals

- Color Spectrum seen by passing white light through a prism

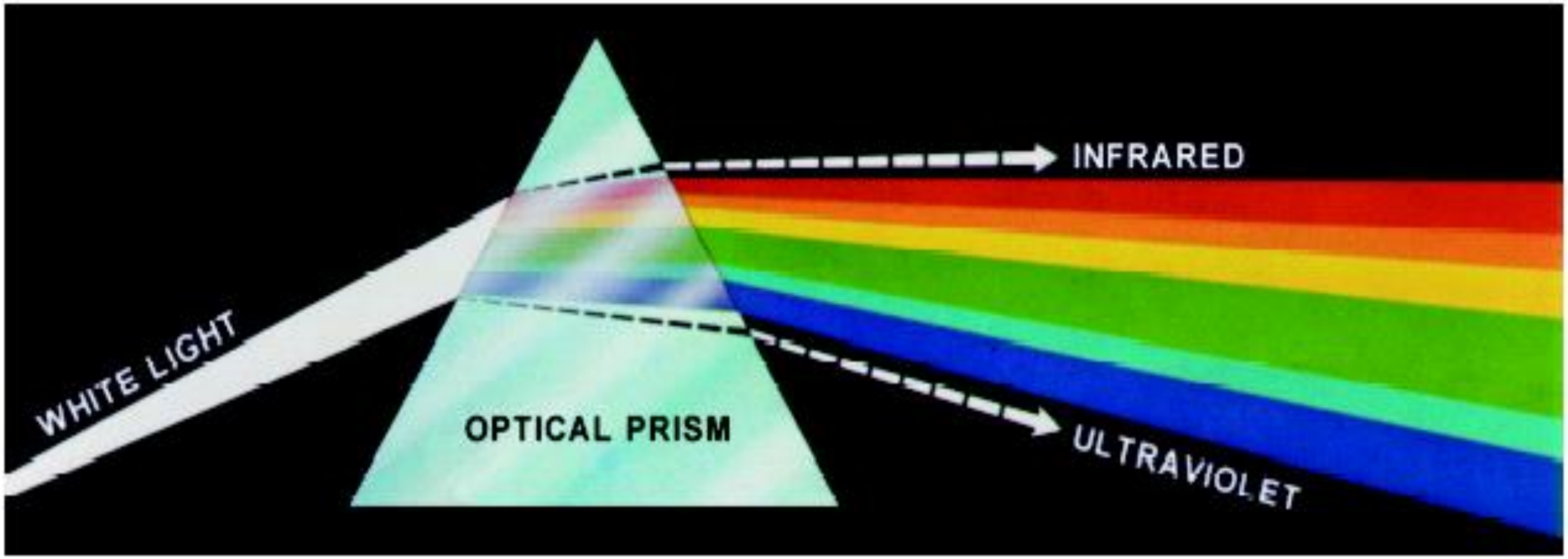


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

Color Fundamentals (Cont.)

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

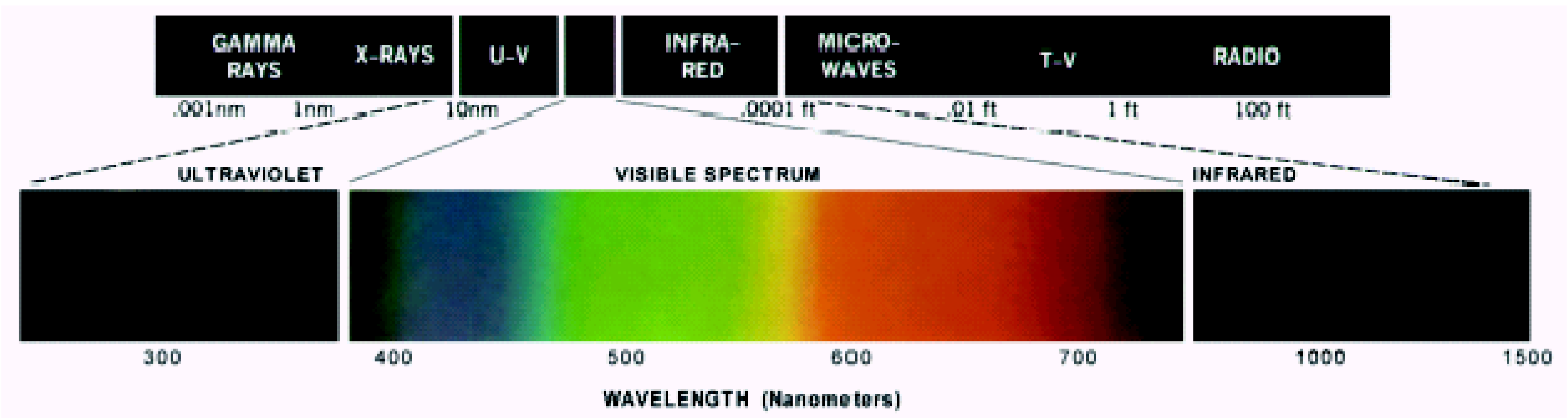
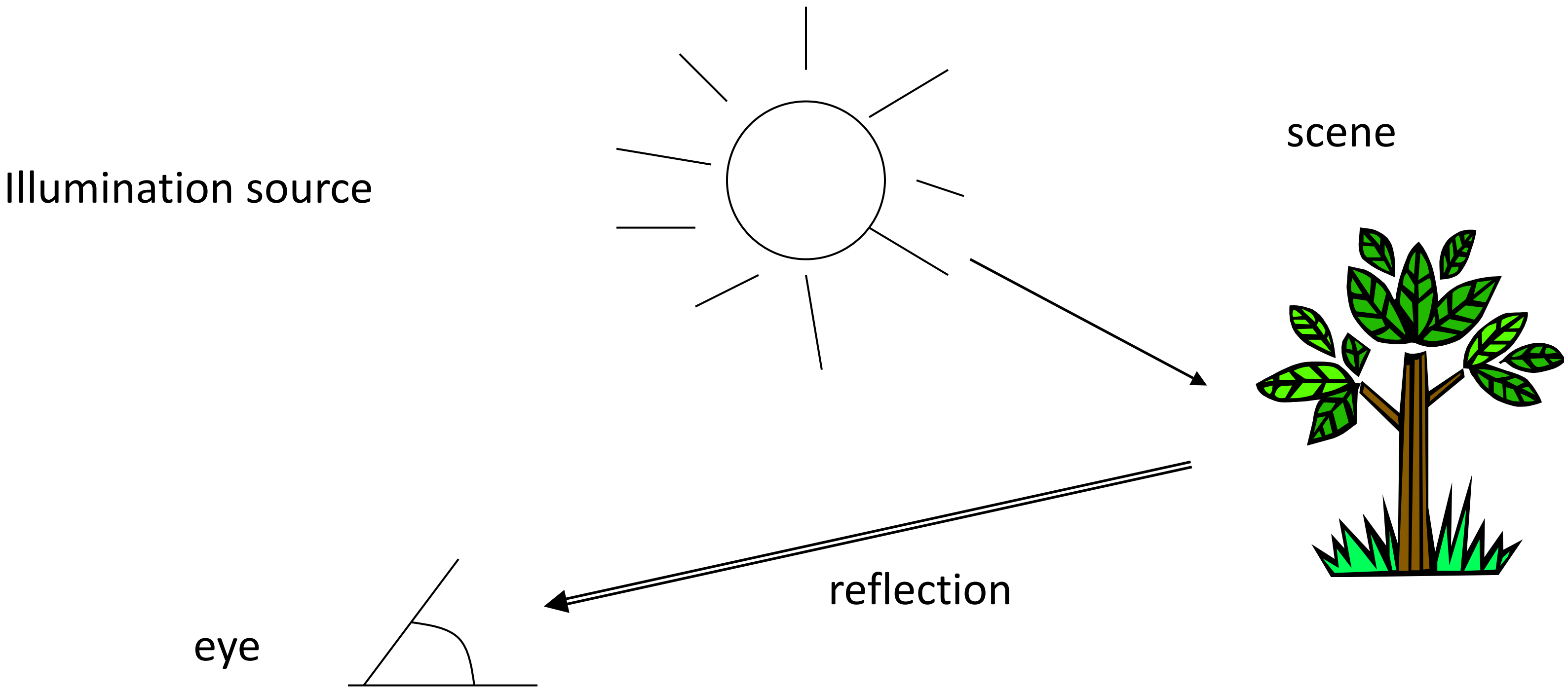


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

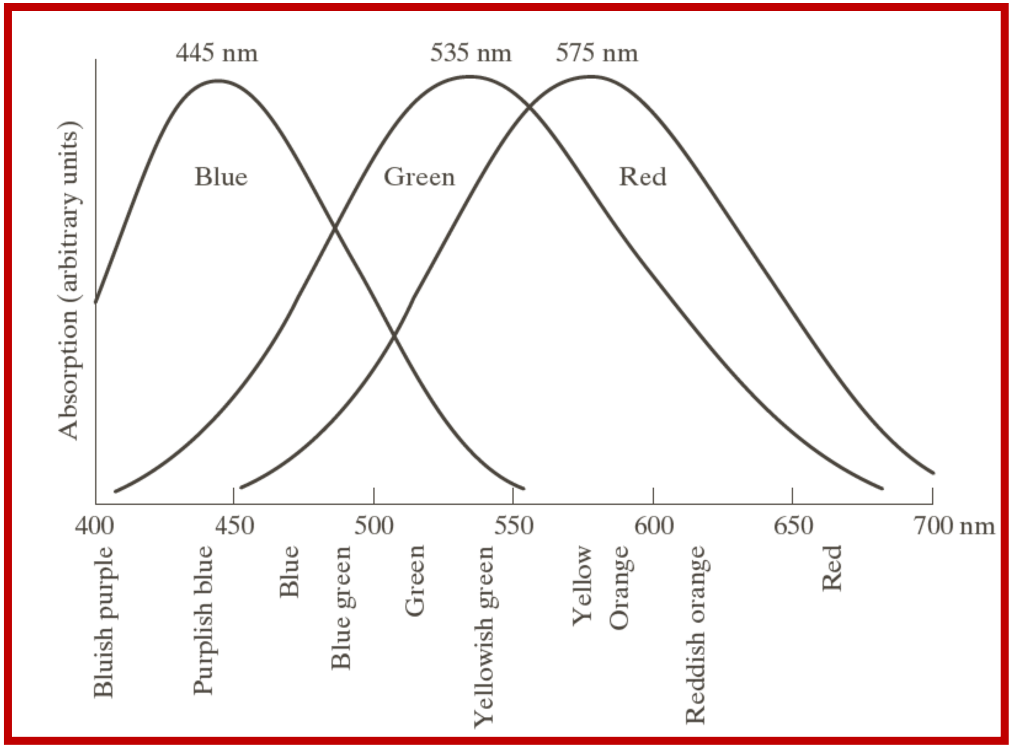
Color Fundamentals (Cont.)

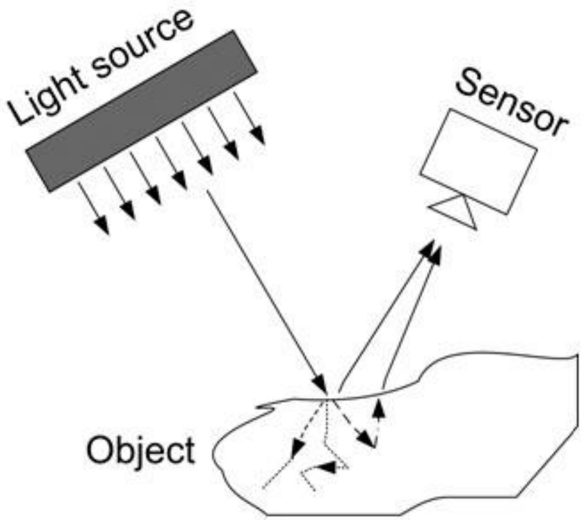
- The color that human perceive in an object = the light reflected from the object



Color Fundamentals (Cont.)

- Green objects reflect “green” light!.
- A body that reflects all wavelength in same proportion appears white





Human Eye Characteristics

- How Human eyes sense light?
  - Cones are the sensor in the eye responsible for color vision.
  - 6 to 7 million cones
    - 65 % cones : Sensitive to Red light (700 nm)
    - 33 % cones : Sensitive to Green light (446.1 nm)
    - 02 % cones : Sensitive to Blue light (435.8 nm)

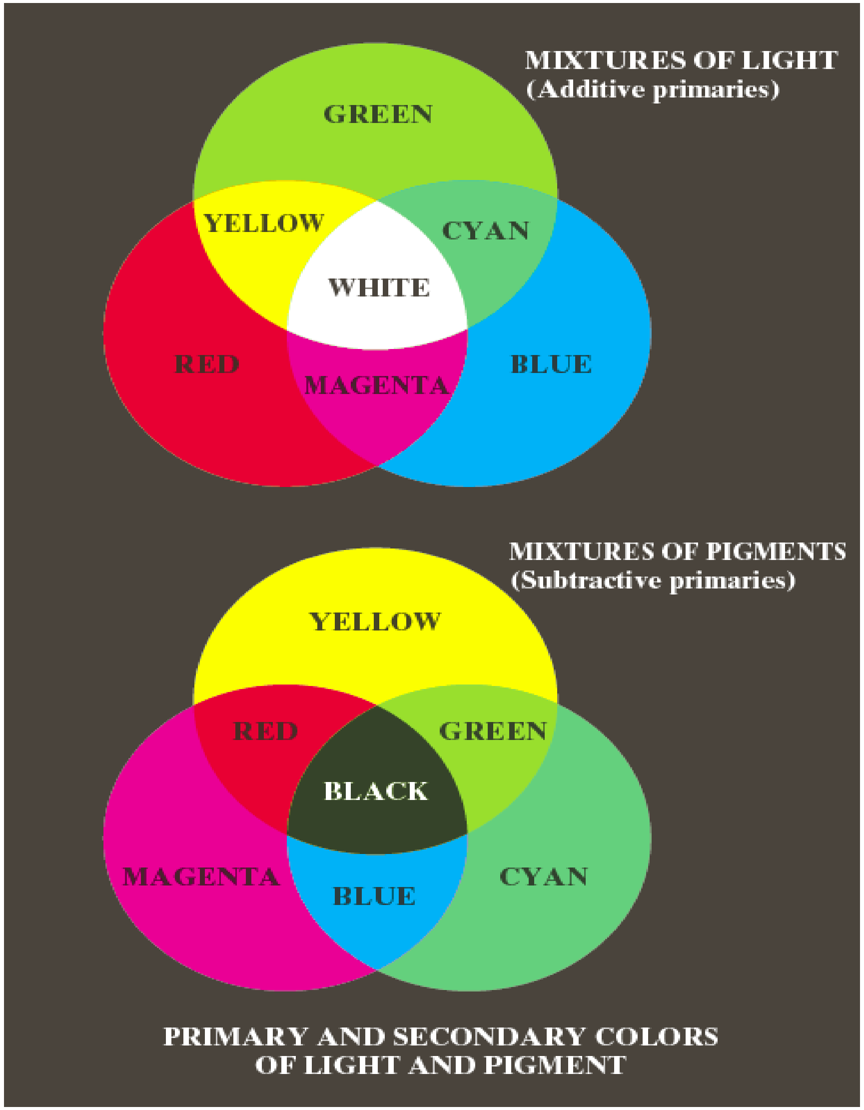
Achromatic Light

- Only intensities (amount of light)
- Gray levels as seen on black/white TV-monitor
- Ranges from black to white

Quantities to describe quality of chromatic light source

- Radiance
  - Total amount of energy that flows from light source Measured in watts (W)
- Luminance
  - Measure amount of energy an observer perceives Measured in lumens (lm)
- Brightness
  - Subjective descriptor
  - Practically not possible to measure

Primary Colors of Light

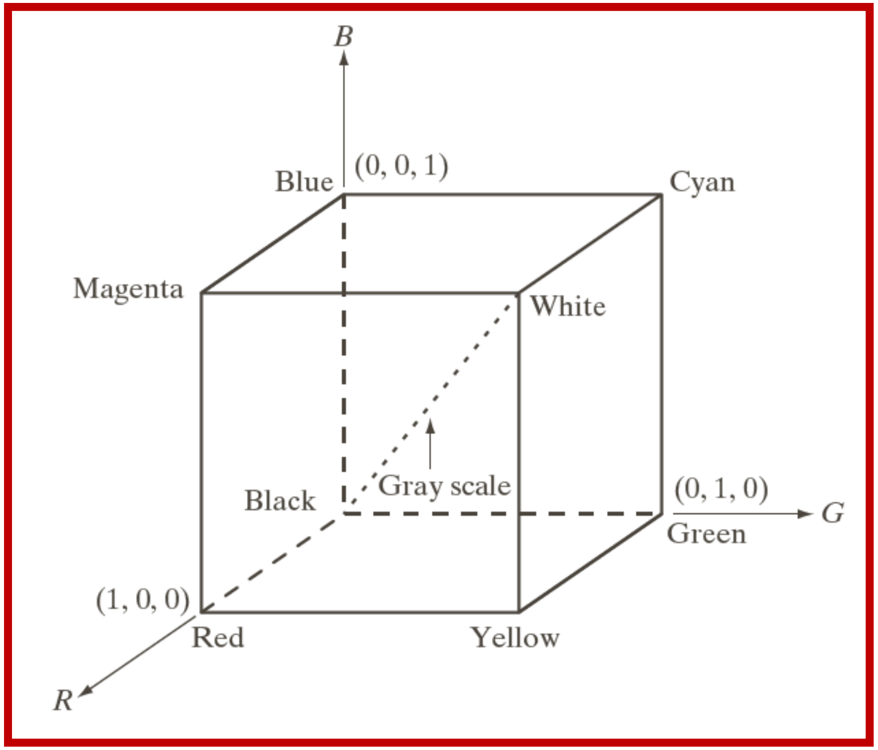


a
b

FIGURE 6.4 Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp Business Division.)

Primary Colors of Light (Cont.)

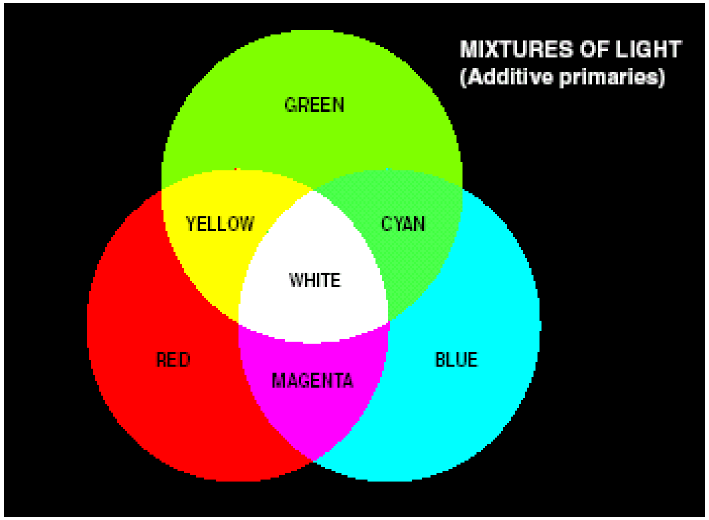
- Primary Colors are Red, Green and Blue.
- Secondary Color are Magenta, Cyan, and Yellow



Primary Colors of Pigment

- Primary color of pigments
  - Color that subtracts or absorbs a primary color of light and reflects or transmits the other two

Color of light:	R	G	B
Color of pigments:	absorb R Cyan	absorb G Magenta	absorb B Yellow



Primary Colors of Pigment (Cont.)

- Primary color of pigments are magenta, cyan, and yellow
- Secondary color of pigments are then red, green, and blue

Primary Colors of Light VS Primary Colors of Pigment

Primary Colors of Light	Primary Colors of Pigment
Primary Colors of light are Red, Green and Blue.	Primary color of pigments are Magenta, Cyan, and Yellow
Secondary Colors of Light are Magenta, Cyan, and Yellow	Secondary color of pigments are then Red, Green, and Blue

Additive VS Subtractive Color

Additive Color

- Involves light emitted directly from a source
- Mixes various amounts of red, green and blue light to produce other colors.
- Combining one of these additive primary colors with another produces the additive secondary colors cyan, magenta, yellow.
- Combining all three primary colors produces white.
- LED Dispalys

Subtractive Color

- Subtractive color starts with an object that reflects light and uses colorants to subtract portions of the white light illuminating an object to produce other colors. a
- If an object reflects all the white light back to the viewer, it appears white.
- If an object absorbs (subtracts) all the light illuminating it, it appears black.
- Painted Surfaces

Additive VS Subtractive Color

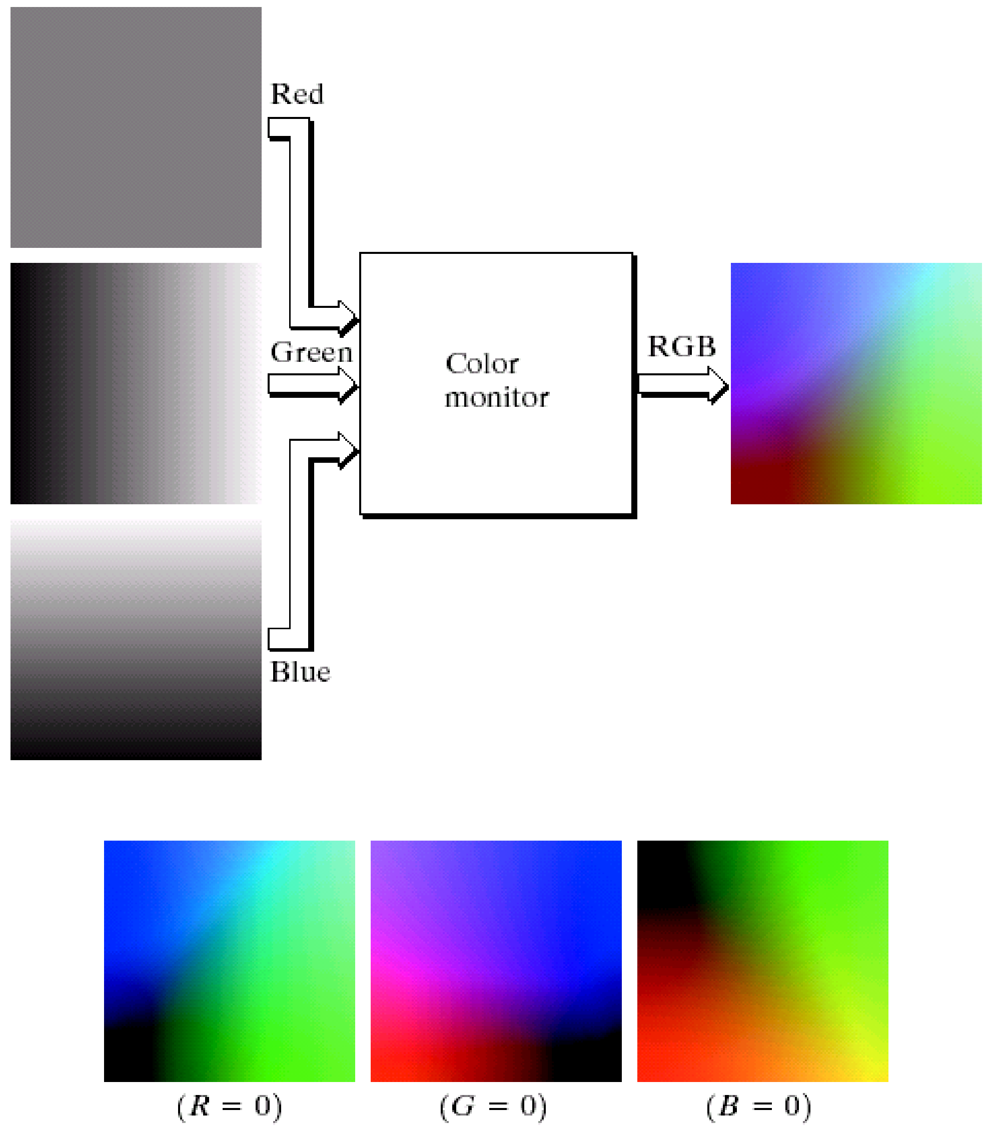
ADDITIVE COLORS
VERSUS
SUBTRACTIVE COLORS

Criterion	Additives	Subtractive
Definition	Occurs with the simultaneous action of various color 'irritants' on the eye.	Not mixing of color 'irritants', but creating color by subtraction
Basic colors	red, green, and blue	cyan, magenta and yellow
Color combinations	green + red = yellow, blue + red = magenta, blue + green = cyan	yellow + magenta = red, yellow + cyan = green, magenta + cyan = blue
Systems	RGB	CMYK

DifferenceBetween.net

Application of additive nature of light colors

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.



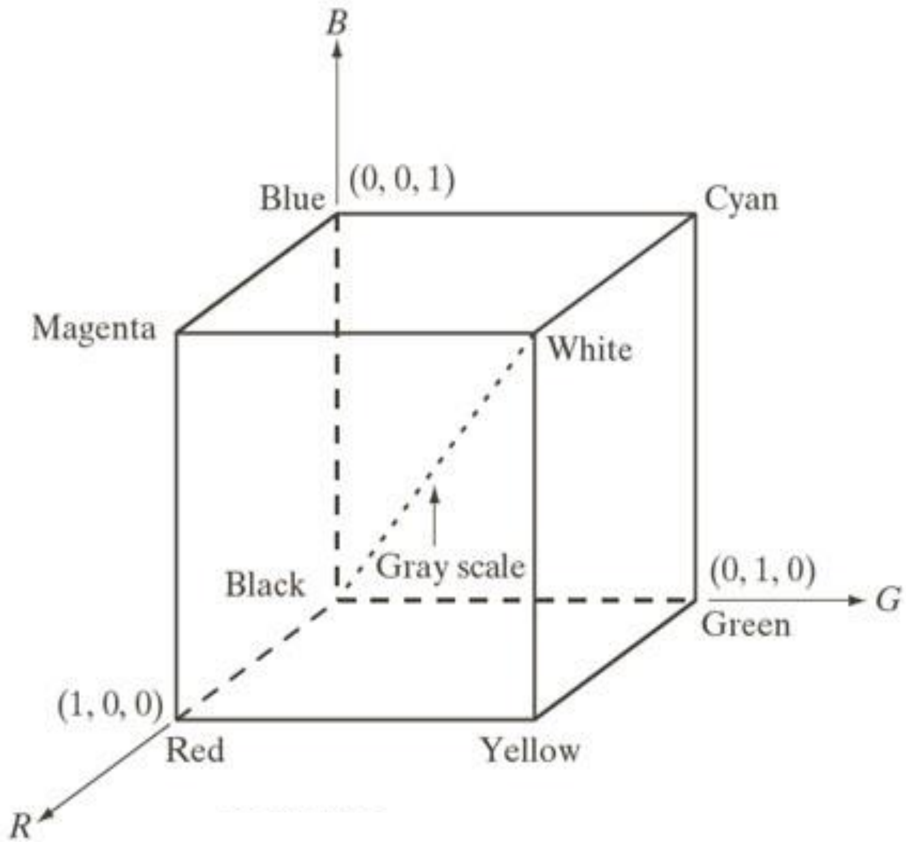
Color Models

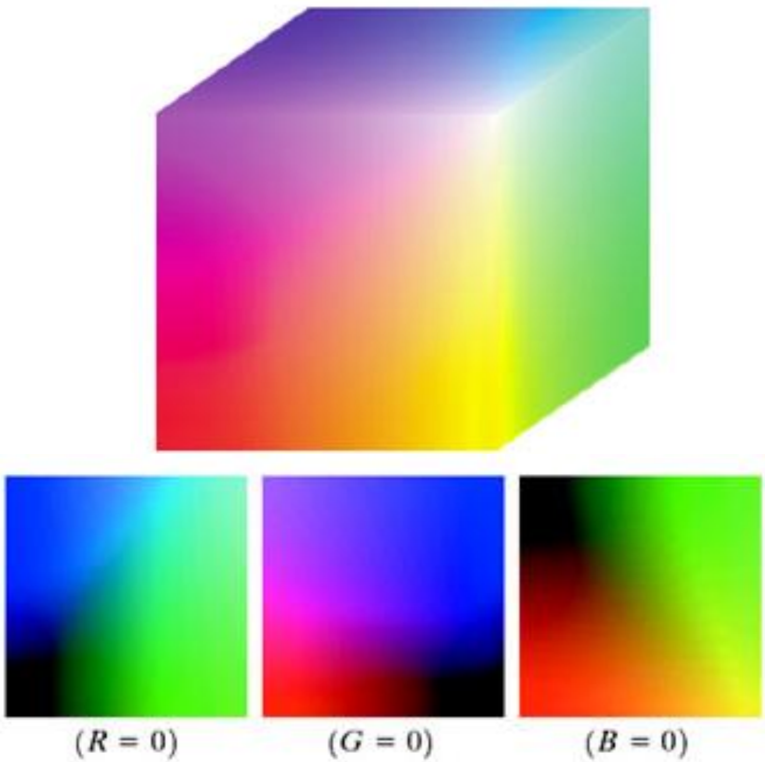
- RGB model
  - Color monitor, color video cameras
- CMY(K) model
  - Color printers
- HSI model
  - Color image manipulation

RGB Color Model

- Based on Cartesian coordinate system
- R, G, B were chosen due to the structure of the human eye
- Pixel depth: the number of bits used to represent each pixel in RGB space
- Example: Full-color image: 24-bit RGB color image -> (R, G, B) = (8 bits, 8 bits, 8 bits)

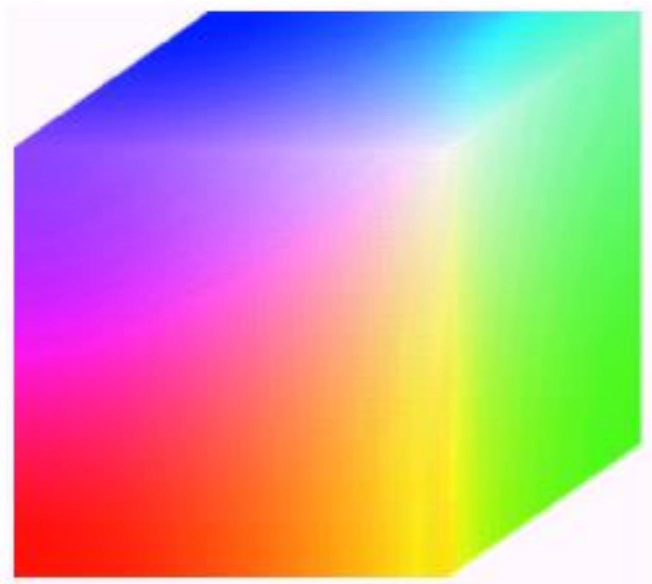
RGB Color Model (Cont.)



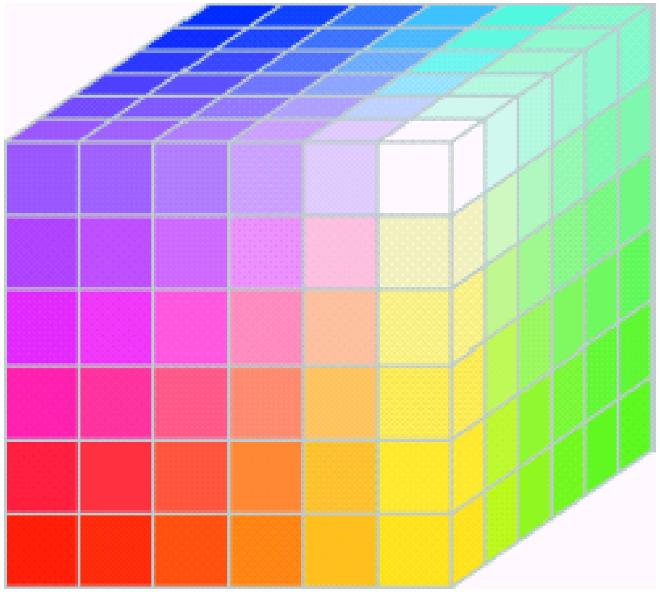


RGB Color Model (Cont.)

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



Full color cube



Safe color cube

RGB Color Model (Cont.)

RGB To Gray Scale

?

$$I = (R+G+B) / 3$$

( +  + ) / 3 =

$$I = a1*R + a2*G + a3*B \qquad a1+a2+a3=1$$

CMY Model (+Black = CMYK)

- Secondary color of light / Primary color of pigment
- Color printers and copiers

- Pure Cyan does not contain Red
- Pure Yellow does not contain Blue
- Pure Magenta does not contain green

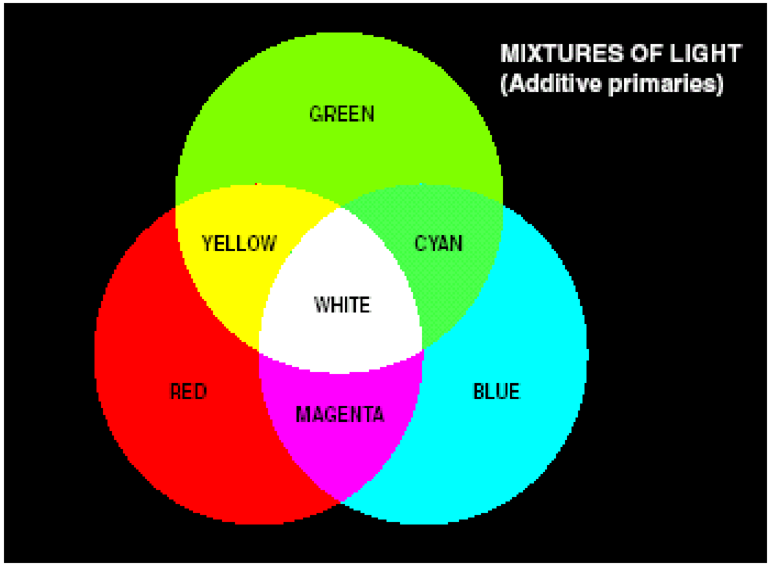
CMY Model (+Black = CMYK) (Cont.)

- Subtractive color system (Cyan subtract Red from white light)

  Example: White = (R,G,B) = (255,255,255)

  Subtract Red – Means red bit =0

  (0, 255,255) = Cyan



CMY Model (+Black = CMYK) (Cont.)

- CMY to RGB Conversion:

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

CMYK to RGB table

Color	Color name	(C,M,Y,K)	(R,G,B)	Hex
	Black	(0,0,0,1)	(0,0,0)	#000000
	White	(0,0,0,0)	(255,255,255)	#FFFFFF
	Red	(0,1,1,0)	(255,0,0)	#FF0000
	Green	(1,0,1,0)	(0,255,0)	#00FF00
	Blue	(1,1,0,0)	(0,0,255)	#0000FF
	Yellow	(0,0,1,0)	(255,255,0)	#FFFF00
	Cyan	(1,0,0,0)	(0,255,255)	#00FFFF
	Magenta	(0,1,0,0)	(255,0,255)	#FF00FF

RGB to CMY Conversion

C = B + G or White - R

M = R + B or White - G

G = G + B or White - B

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

RGB to CMY Conversion (Cont.)

Example: Conside (R,G,B) = (29, 98, 129). Convert RGB to CMY Model.

Note: Always map into [0 1], for that divide with 255

(R,G,B)=(29 / 255 , 98/255 , 129/255)

(R,G,B)=(0.113 , 0.384 , 0.501)

(C,M,Y) = (1-R , 1-G, 1-B) = (0.887,0.616,0.499)

So,

(R,G,B)=(29, 98, 129) ->(C,M,Y)=(0.887,0.616,0.499)

RGB to CMY Conversion (Cont.)

- Example: Conside (R,G,B) = (29, 98, 129). Convert RGB to CMY Model.

  (R,G,B)=(29, 98, 129)->(C,M,Y)=(0.887,0.616,0.499)

- Example: Conside (R,G,B) = (24, 149, 240). Convert RGB to CMY Model.

  (R,G,B)=(24, 149, 240)->(C,M,Y)=(0.905,0.415,0.058)

- Example: Conside (R,G,B) = (190, 48, 140). Convert RGB to CMY Model.

  (R,G,B)=(190, 48, 140)->(C,M,Y)=(0.254,0.811,0.450)

CMY to RGB Conversion

R = White - C

G = White - M

B = White - G

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

CMY to RGB Conversion (Cont.)

- Example: Conside (C,M,Y) = (231, 106, 15). Convert CMY to RGB Model.

Note: Always map into [0 1], for that divide with 255

(C,M,Y)=(231 / 255 , 106/255 , 15/255)

(C,M,Y)=(0.905,0.415,0.058)

(R,G,B) = (1-C , 1-M, 1-Y) = (0.095,0.585,0.942)

So,

(C,M,Y)=(29, 98, 129) ->(R,G,B)=(0.095,0.585,0.942)

RGB to CMY Conversion (Cont.)

Example: Conside (R,G,B) = (29, 98, 129). Convert RGB to CMY Model.

Note: Always map into [0 1], for that divide with 255

(R,G,B)=(29 / 255 , 98/255 , 129/255)

(R,G,B)=(0.113 , 0.384 , 0.501)

(C,M,Y) = (1-R , 1-G, 1-B) = (0.887,0.616,0.499)

So,

(R,G,B)=(29, 98, 129) ->(C,M,Y)=(0.887,0.616,0.499)

HSI Color Model

- Will you describe a color using its R, G, B components?
- Human describe a color by its Hue(H), Saturation(S), and brightness / Intensity(I)
- RGB is ideal for color image generation
- HSV is Ideal for developing image processing algorithms

HSI Color Model (Cont.)

- Chromaticity
  - H and S may characterize a color: Chromaticity
  - Chromaticity: hue + saturation

HSI Color Model (Cont.)

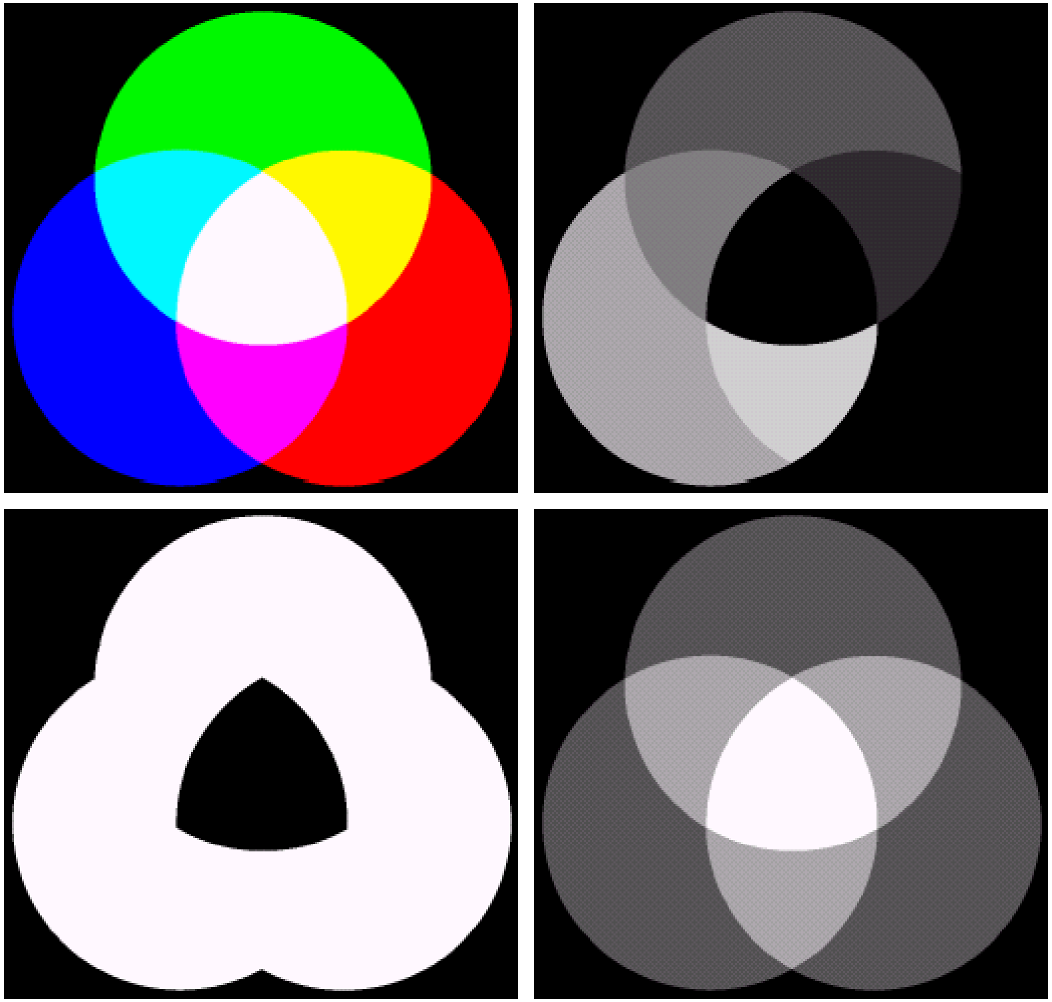
- Hue:
  - The **dominant wavelength** in the mixture of light waves, as perceived by an observer.
  - Hue is the color attribute that describes a pure color
- Saturation:
  - **relative purity**
  - Amount of white light added in Hue
- Brightness:
  - achromatic notion of **intensity**

Pure colors are fully saturated)
Not saturated are for example pink (Red + White)

Example: RED: fully saturated
PINK: Less saturated
(HUE is same in both the cases)

HSI Color Model (Cont.)

R,G,B

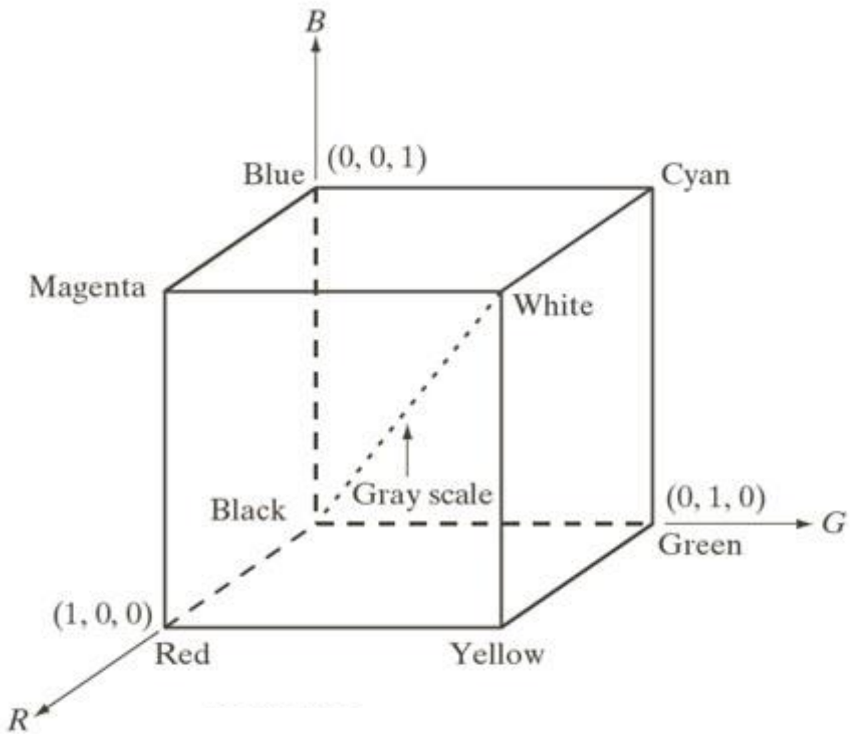


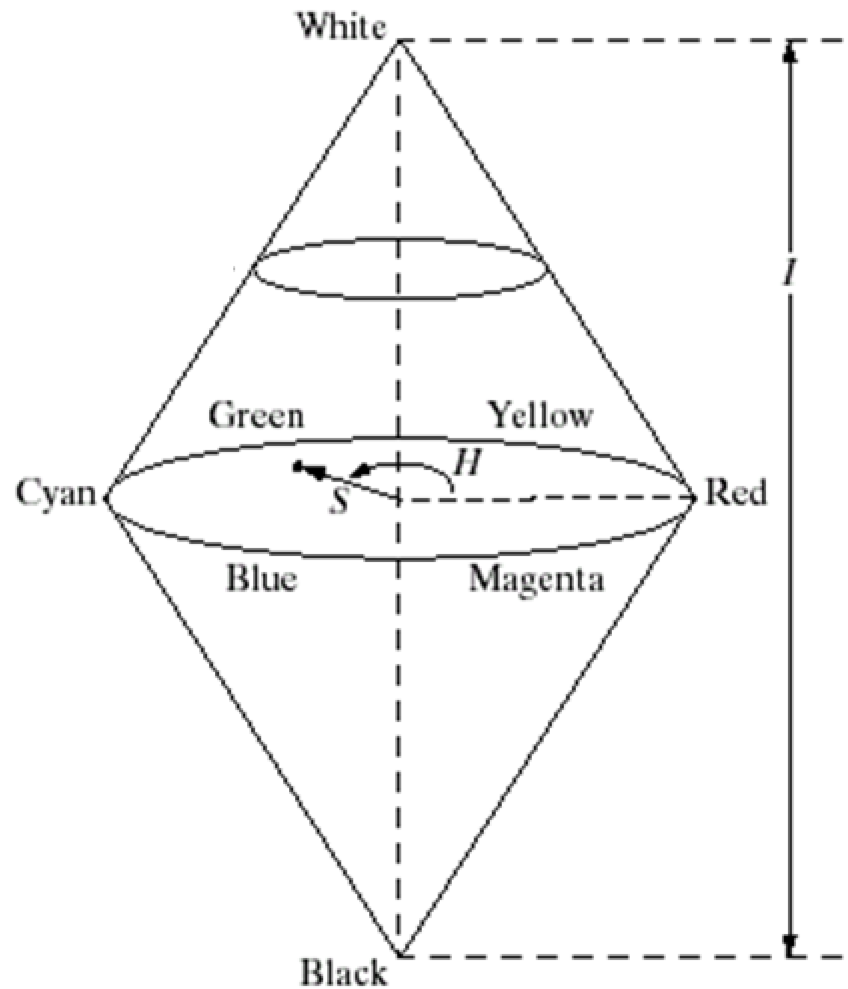
Hue

saturation

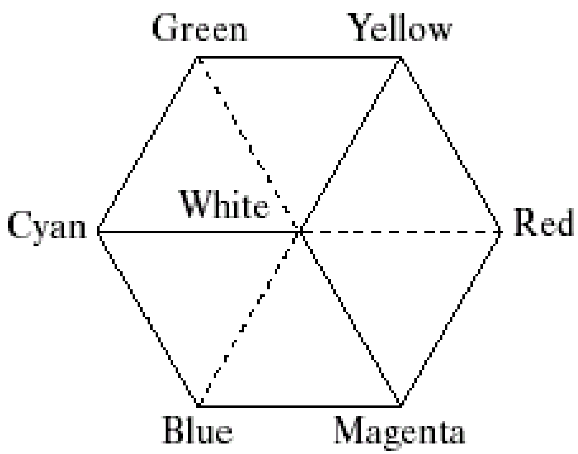
intensity

HSI Color Model (Cont.)

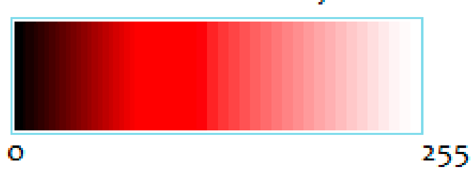




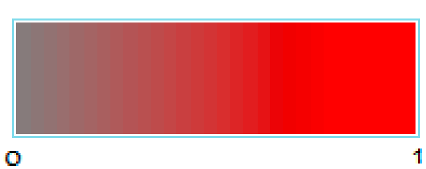
HSI Color Model (Cont.)

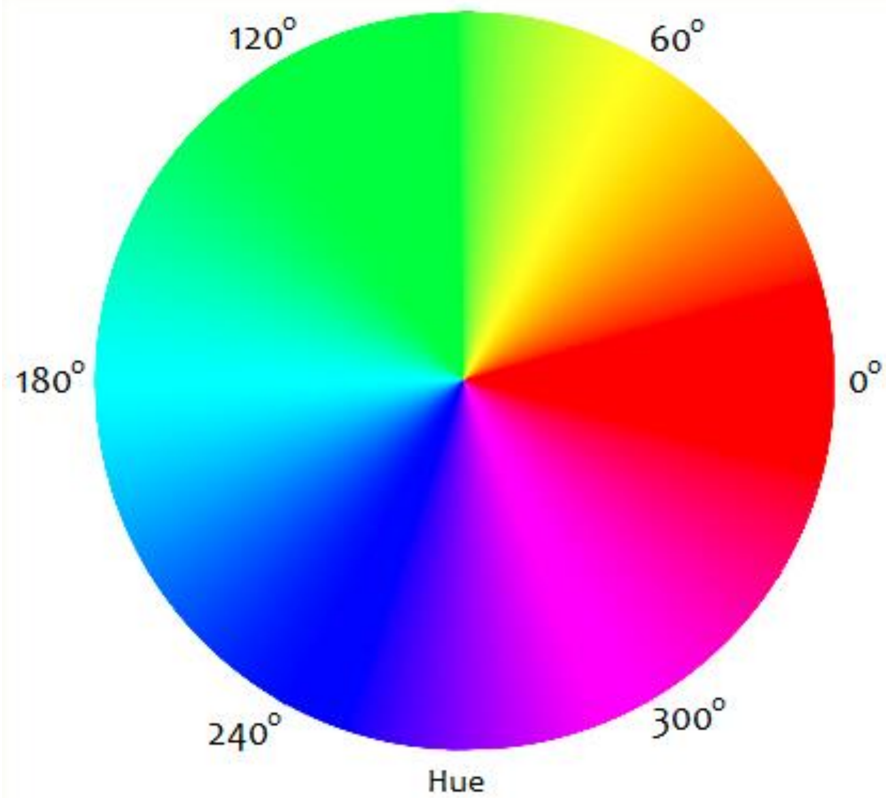


Color Intensity

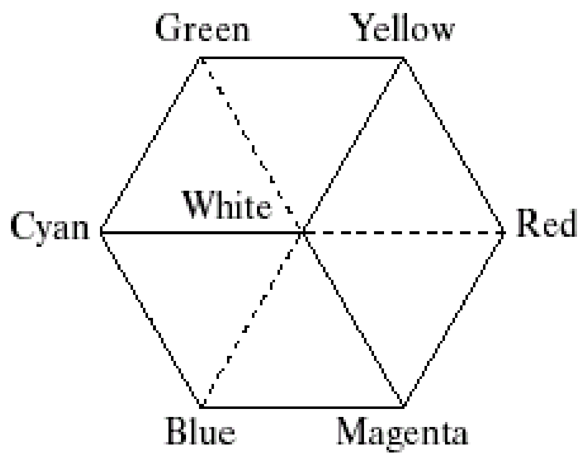


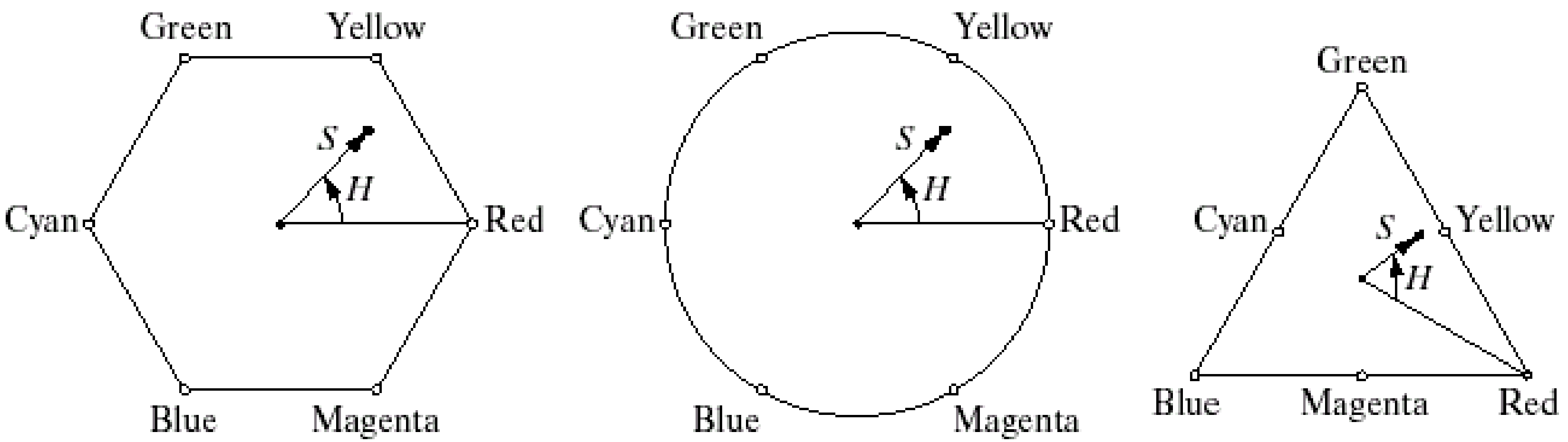
Color Saturation





HSI Color Model (Cont.)





RGB to HSI Conversion

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

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

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

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

RGB to HSI Conversion

Exmaple: Consider (R,G,B) = (24,98,118).

Convert RGB to HSI

Note: Always map into [0 1], for that divide with 255

(R,G,B) = (24/255,98/255,118/255)

(R,G,B) = (0.09,0.38,0.46)

I = 0.31

S = 0.71

Θ = 180 degree

H = 180 Degree

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

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

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

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

Note: Just for information

HSI to RGB Conversion

Marwadi University

For $0^o <= H < 120^o$

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

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

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

For $120^o <= H < 240^o$

$$H = H - 120^\circ$$

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

$$G = I\left[1 + \frac{S\cos(H - 120^\circ)}{\cos(180^\circ - H)}\right]$$

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

For $240^o <= H < 360^o$

$$H = H - 240^\circ$$

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

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

$$B = I\left[1 + \frac{S\cos(H - 240^\circ)}{\cos(300^\circ - H)}\right]$$

Comparison Between HSI,RGB & CMY

HSI
- Advantage:
  - This model humans perceive
  - Application Oriented
- Disadvantage:
  - Complex calculation

RGB
- Advantages:
  - Used in LCDs
  - Calculations are cheap
- Disadvantage:
  - This model is not humans perceive

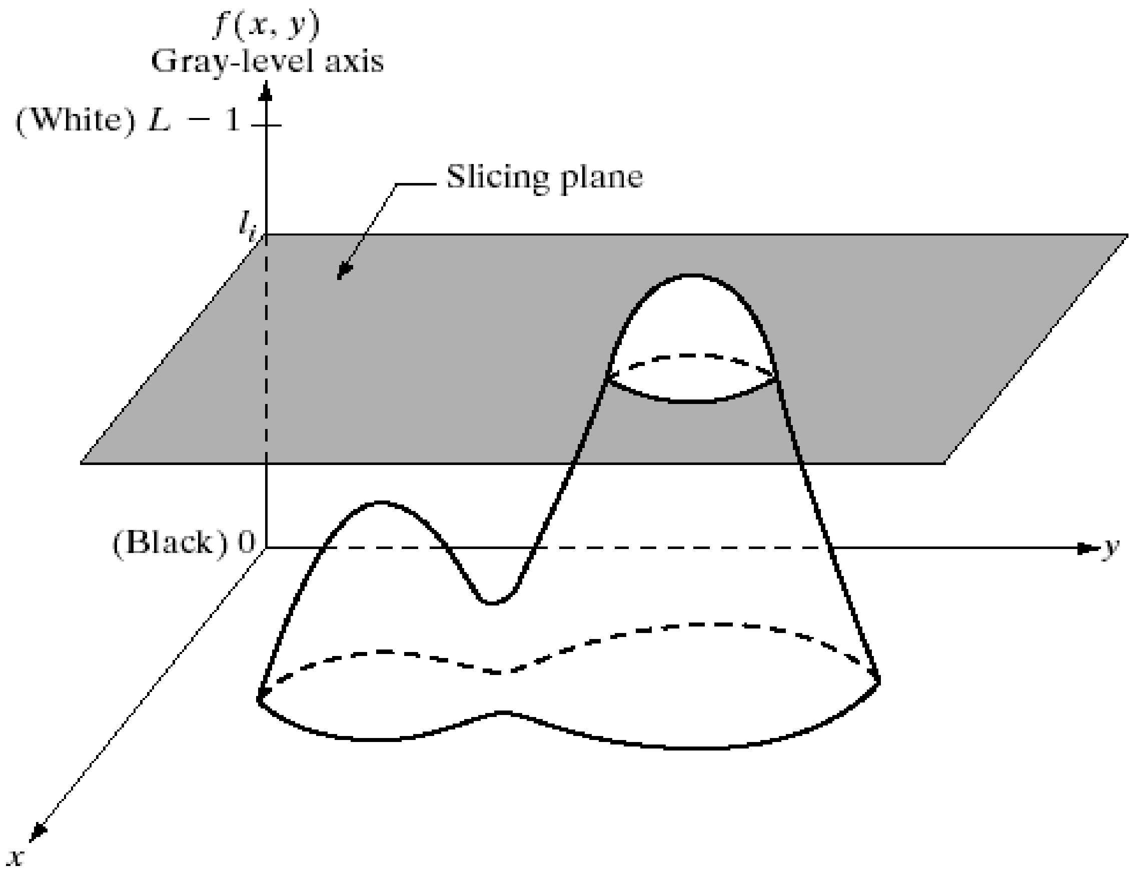
CMY:
- Advantages
  - Calculations are simple
  - Used in printers
- Disadvantage:
  - It does not produce complete black color

Pseudo-color Image Processing

- Pseudocolor (also called false color) image processing consists of assigning colors to gray values based on a specified criterion.
- Assign colors to gray values based on a specified criterion
- For human visualization and interpretation of gray-scale events
  - Intensity Slicing / Density Slicing
  - Gray level to color transformations

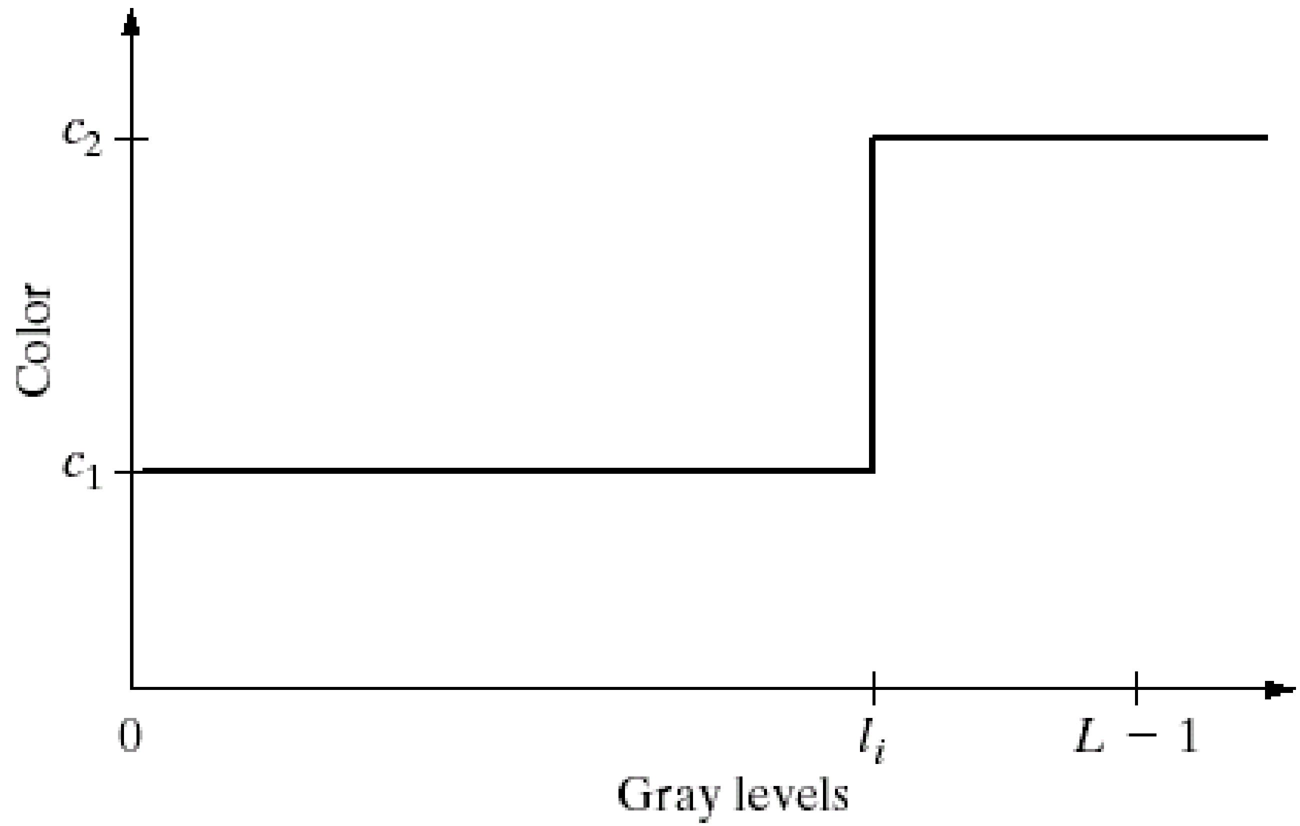
Intensity Slicing / Density Slicing

- 3-D view of intensity image



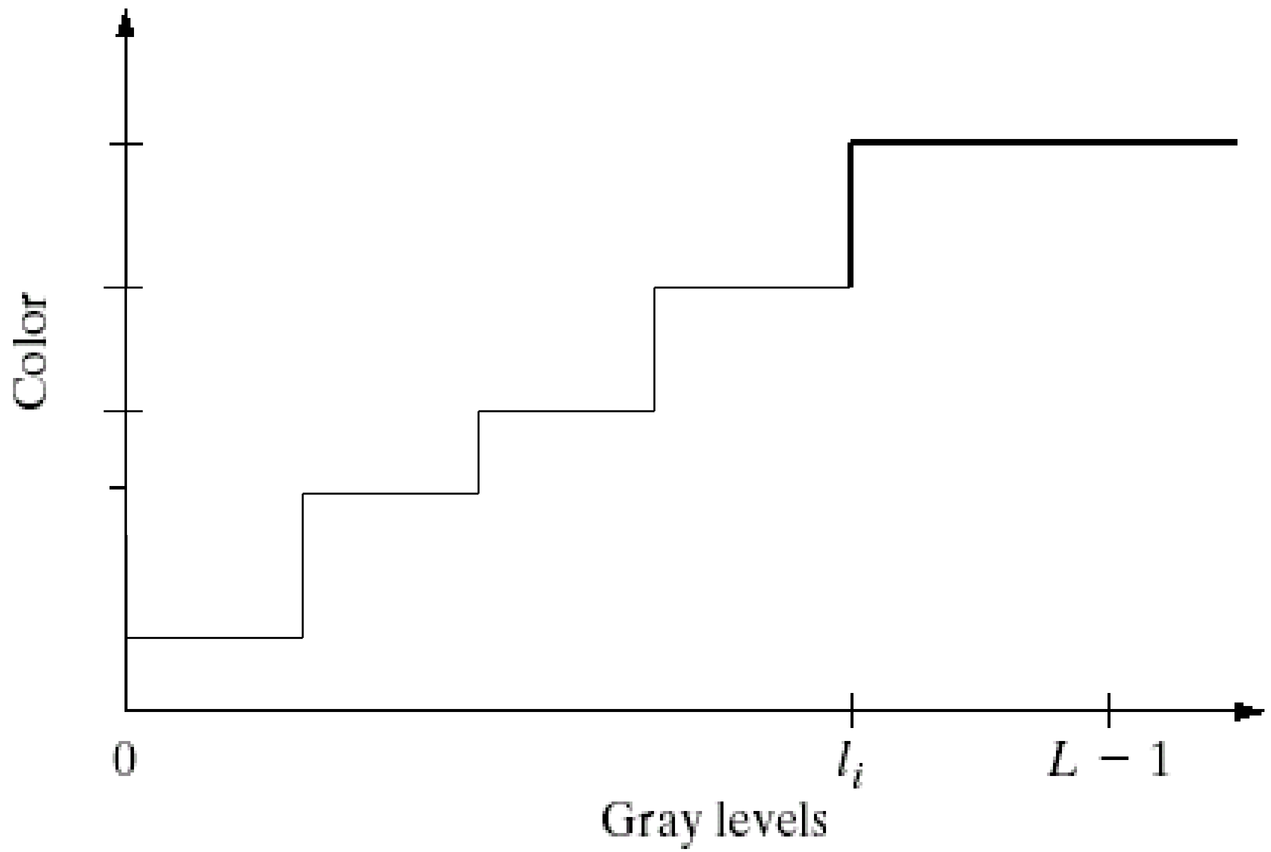
Intensity Slicing / Density Slicing (Cont.)

- Alternative representation of intensity slicing



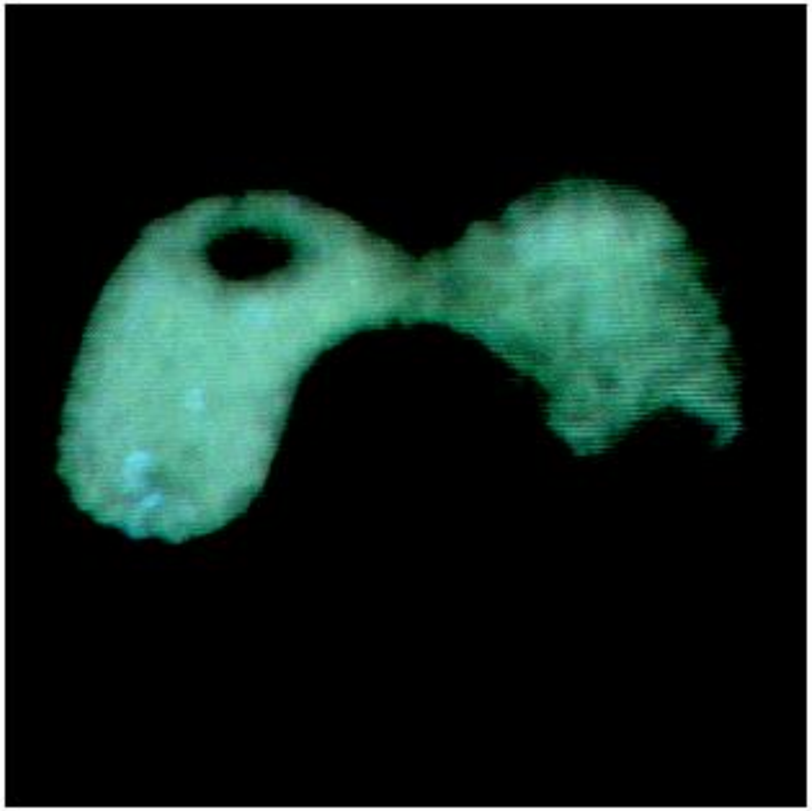
Intensity Slicing / Density Slicing (Cont.)

- More slicing plane, more Colors

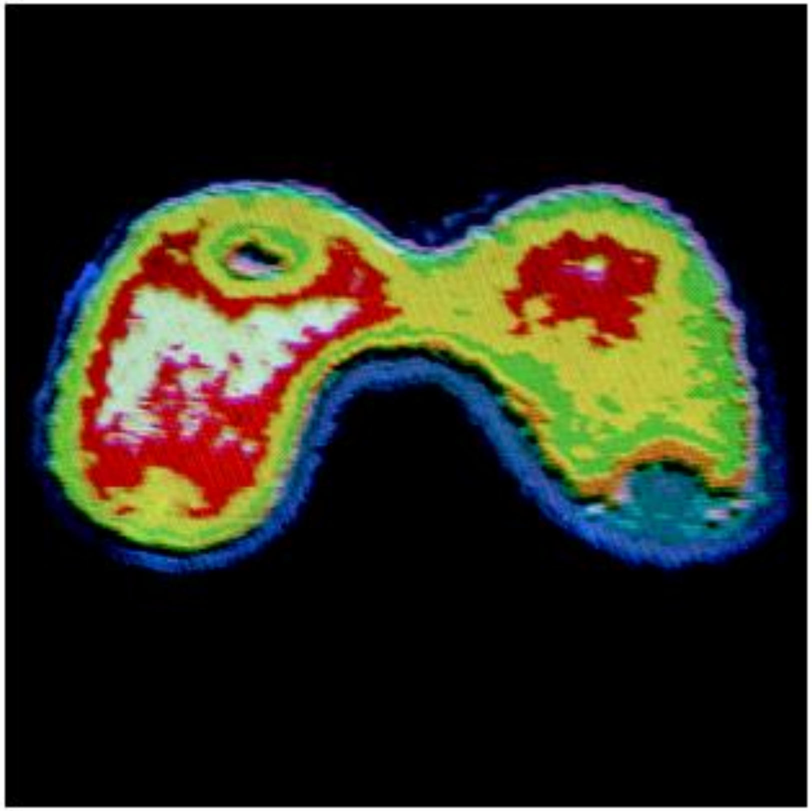


Intensity Slicing / Density Slicing (Cont.)

- Application: 1



Radiation test pattern

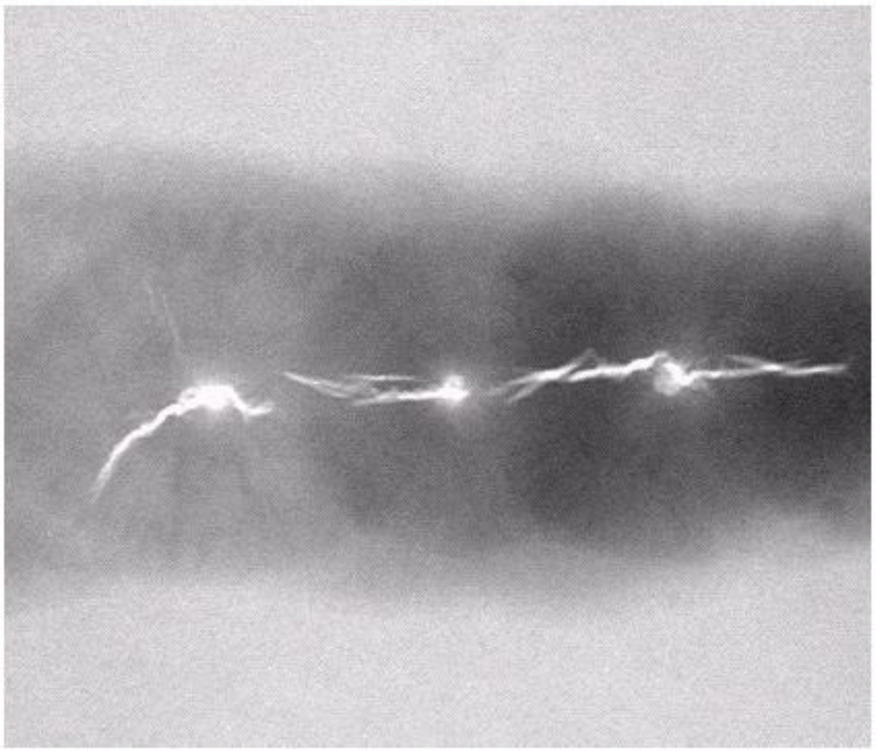


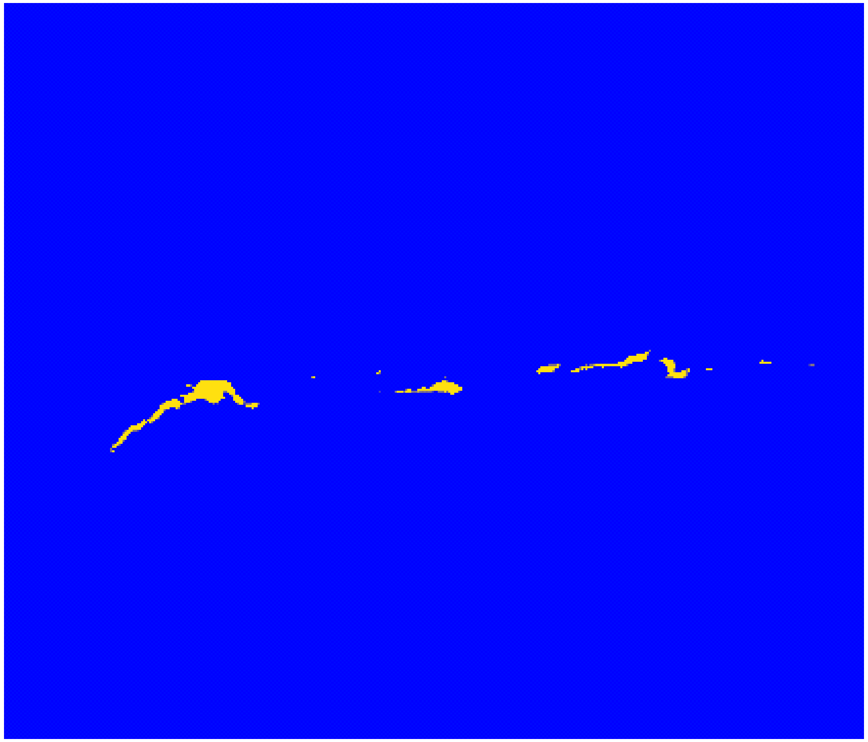
8 color regions

* See the gradual gray-level changes

Intensity Slicing / Density Slicing (Cont.)

- Application: 2

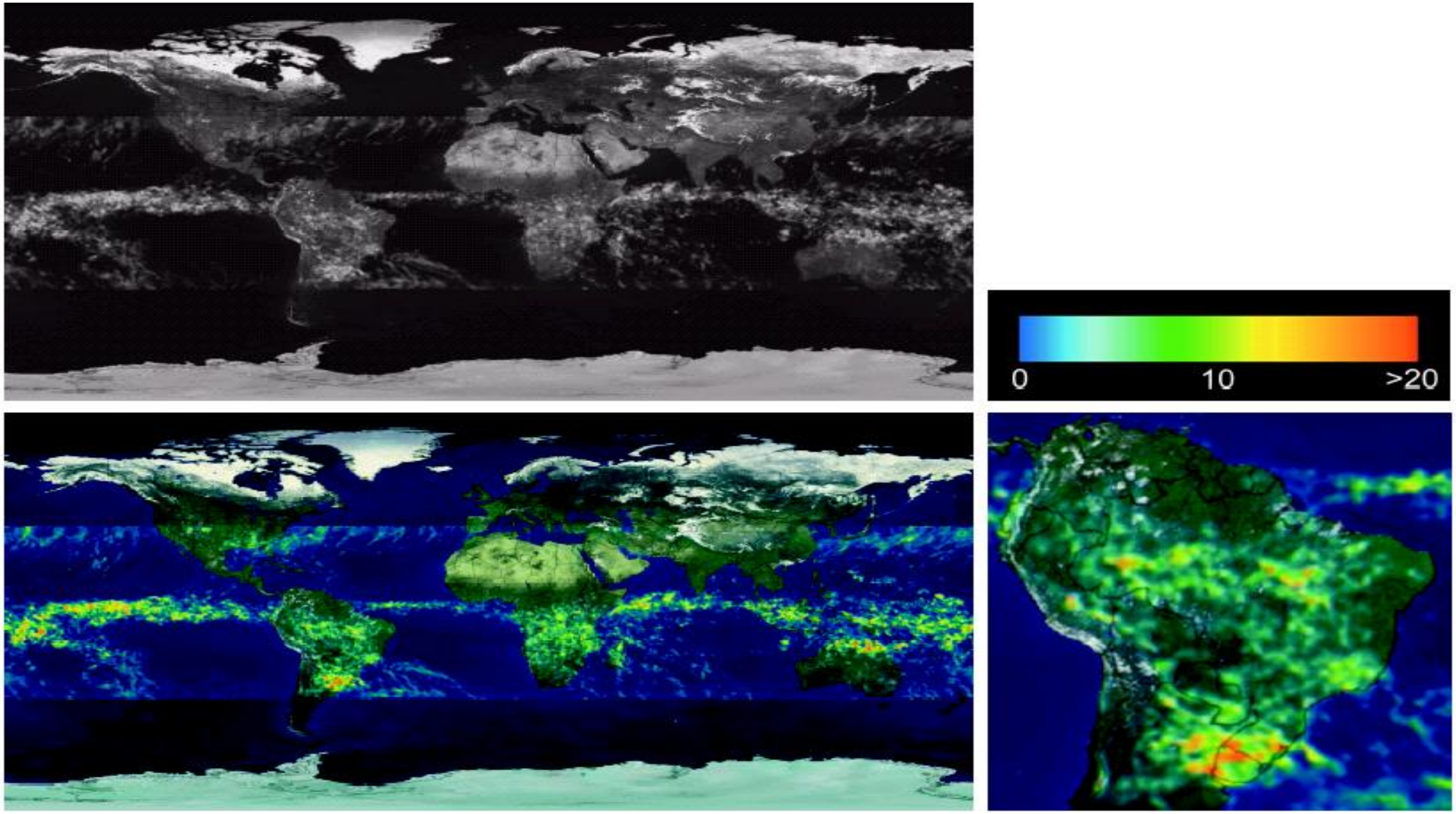




X-ray image of a weld

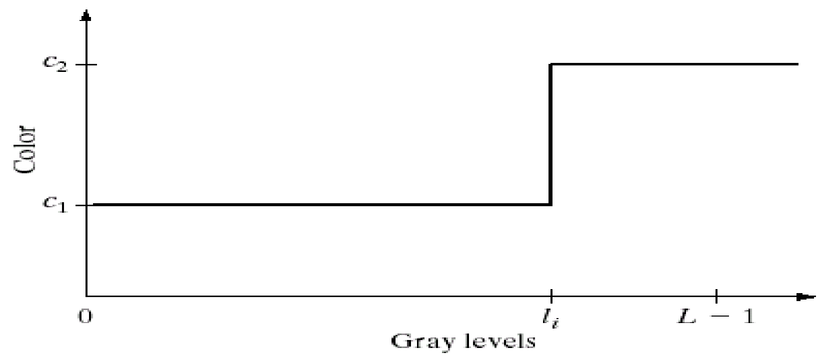
Intensity Slicing / Density Slicing (Cont.)

- Application: 3

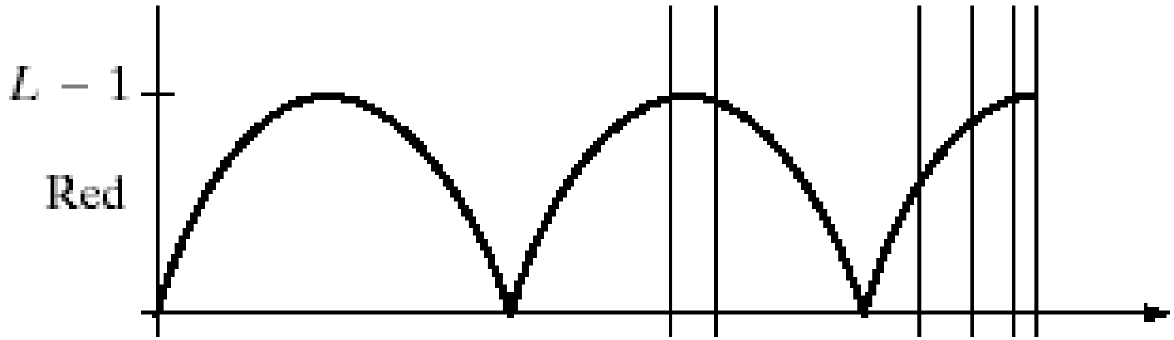


Gray Level To Color Transformation

- Intensity slicing: piecewise linear transformation



- General Gray level to color transformation



Gray Level To Color Transformation (Cont.)

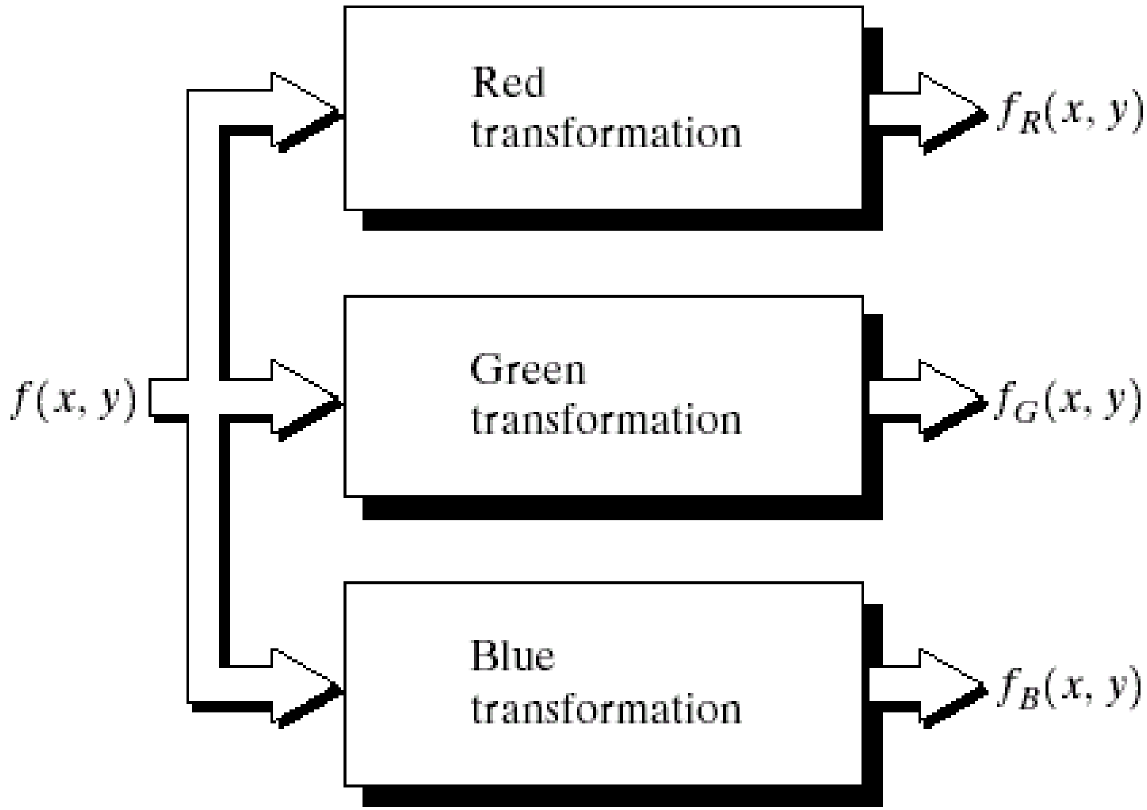
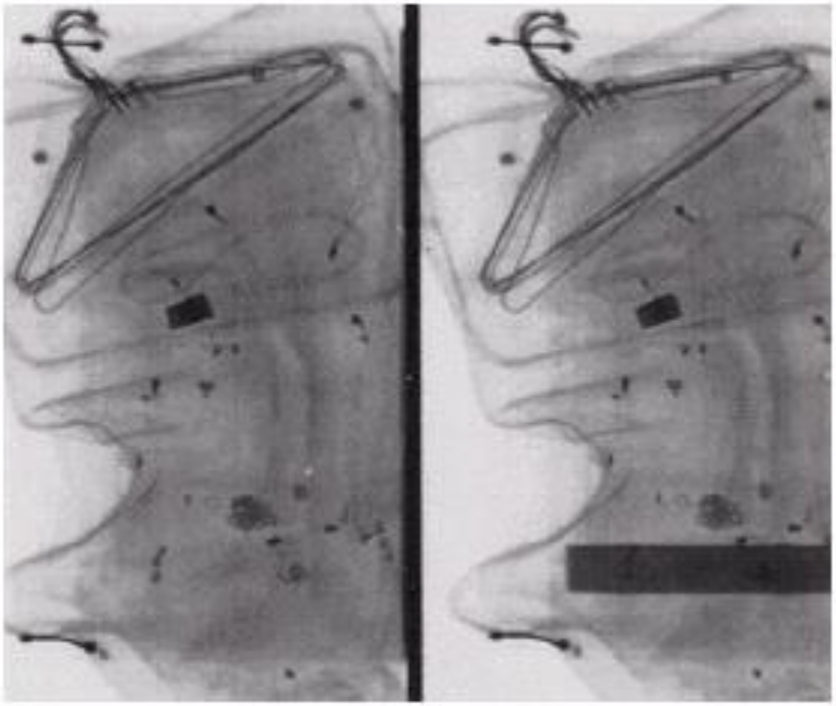
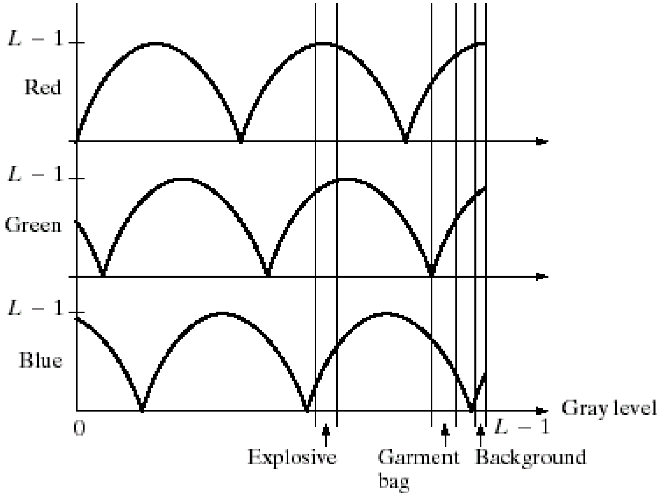


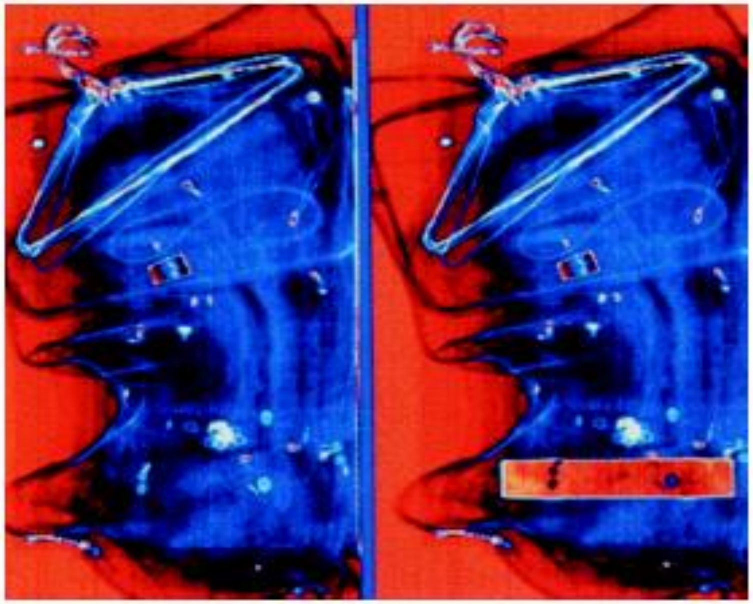
FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_R, f_G, and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

Gray Level To Color Transformation (Cont.)

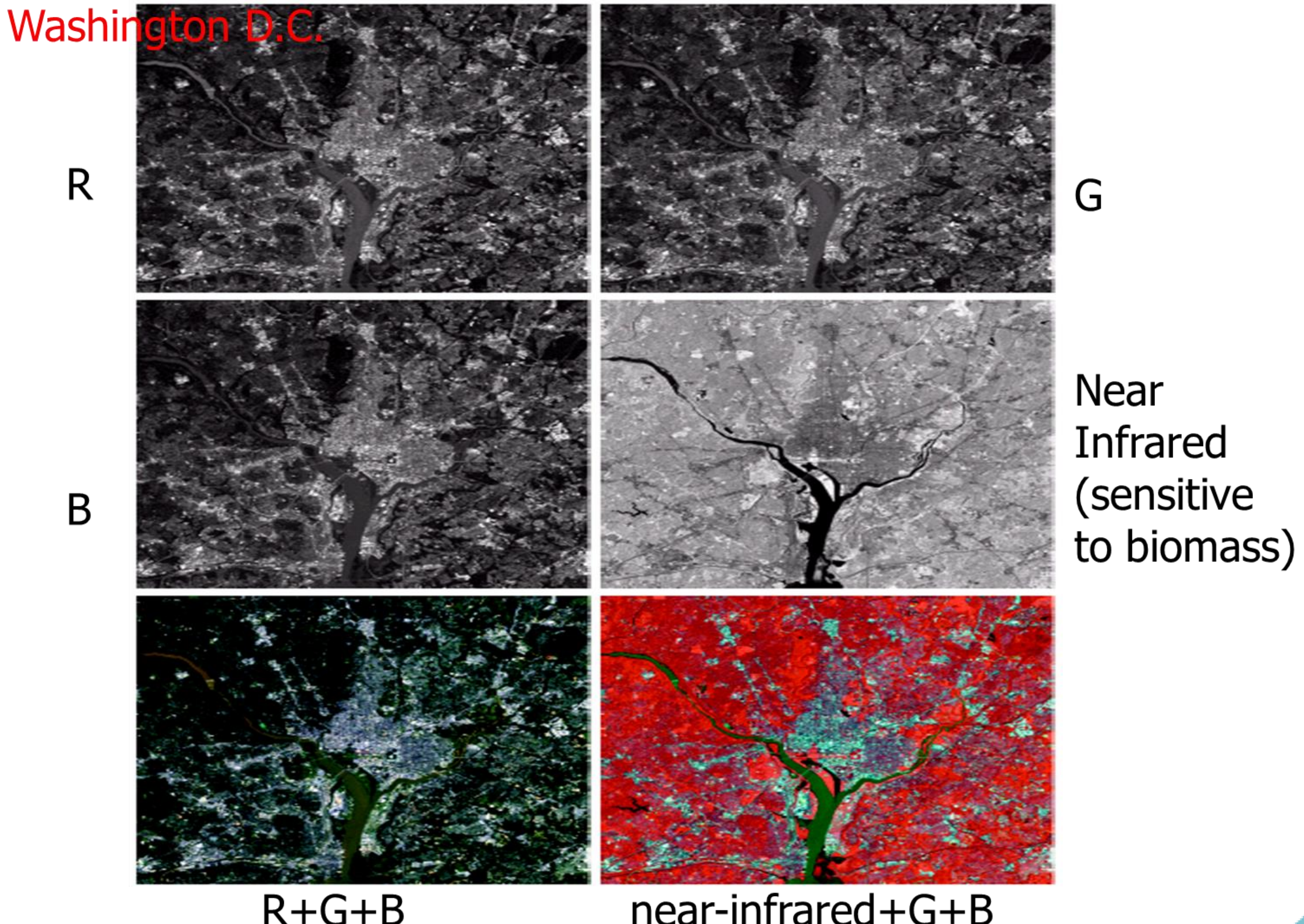
- Application: 1





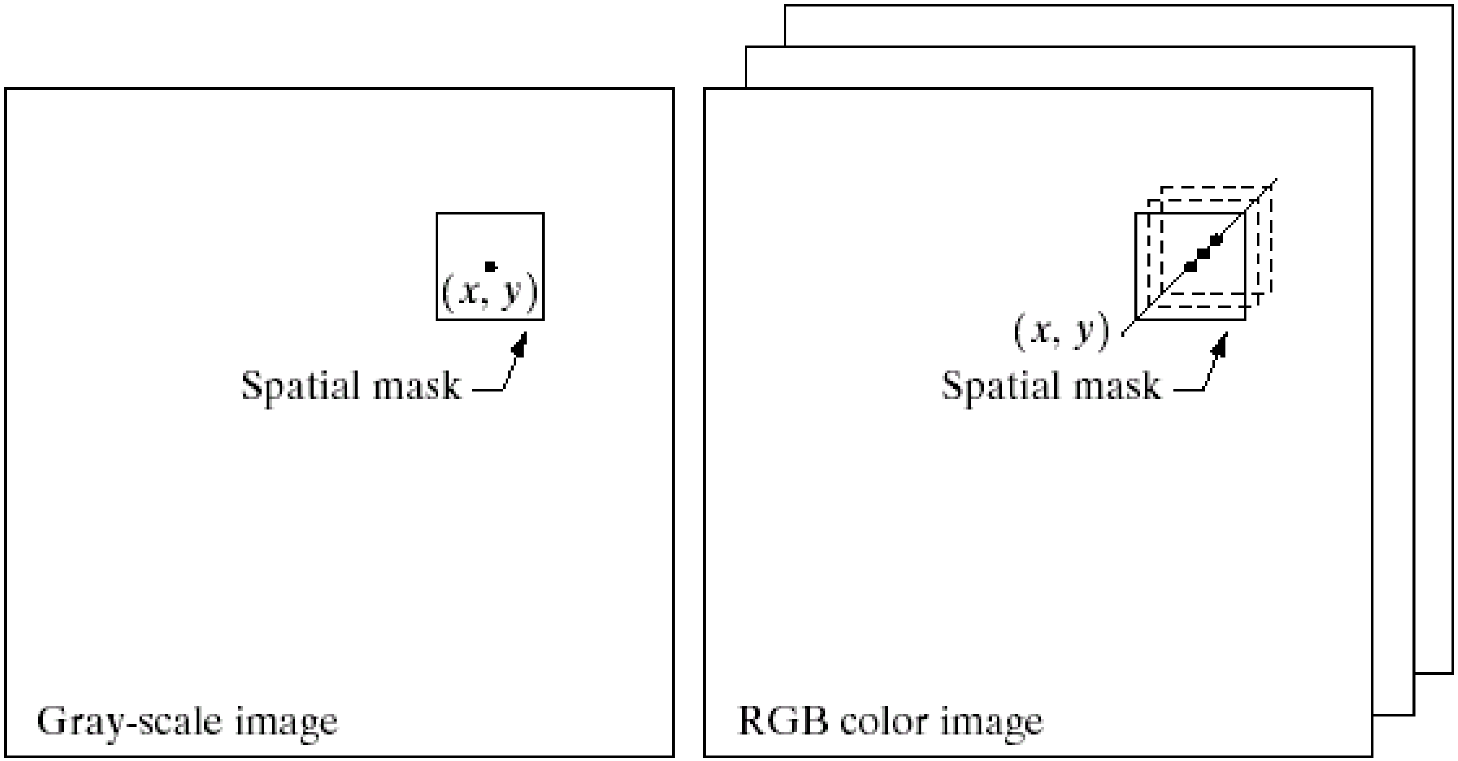


Gray Level To Color Transformation (Cont.)



Color Image Smoothing

- Neighborhood processing



Color Image Smoothing (Cont.)

$$\bar{\mathbf{c}}(x,y) = \frac{1}{K} \sum_{(x,y)\in S_{xy}} \mathbf{c}(x,y)$$

$\boxed{\text{vector processing}}$

Neighborhood
Centered at (x,y)

$$\bar{\mathbf{c}}(x,y) = \begin{bmatrix} \frac{1}{K} \sum_{(x,y)\in S_{xy}} R(x,y) \\ \frac{1}{K} \sum_{(x,y)\in S_{xy}} G(x,y) \\ \frac{1}{K} \sum_{(x,y)\in S_{xy}} B(x,y) \end{bmatrix}$$

$\boxed{\text{per-component processing}}$

Color Image Smoothing (Cont.)

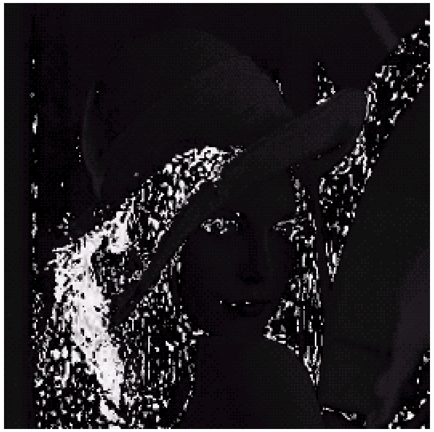
original

Red

Green

Blue

Color Image Smoothing (Cont.)



Hue

Saturation

Intensity

Color Image Smoothing (Cont.)

FIGURE 6.40 Image smoothing with a 5×5 averaging mask. (a) Result of processing each RGB component image. (b) Result of processing the intensity component of the HSI image and converting to RGB. (c) Difference between the two results.

Color Image Sharpening

- We consider image sharpening using the Laplacian
- From vector analysis, we know that the Laplacian of a vector is defined as a vector whose components are equal to the Laplacian or the individual scalar components of the input vector
- In the RGB color system, the Laplacian of vector c is

$$\nabla^2[\mathbf{c}(x, y)] = \begin{bmatrix} \nabla^2 R(x, y) \\ \nabla^2 G(x, y) \\ \nabla^2 B(x, y) \end{bmatrix}$$

Color Image Sharpening (Cont.)

Image Sharpening with The Laplacian

(a) Result of processing each RGB channel
(a) Result of processing the intensity component and converting to RGB
(b) Difference between the two results

Color Quantization / Aproximation

Marwadi University

- Color quantization/approximation is a computer graphics process that reduces the number of colors required to represent an image while preserving the overall human-perceived quality.
- The color image quantization is **to design a colormap and to create a map , by which each color pixel in is replaced by one of the colors in** .
- Thus, a new color image , called the quantized image of , with the colors in is constructed.
- It is a process that reduces the number of distinct colors used in an image

Color Quantization in MATLAB

```
I = imread('cameraman.tif');
imshow(I);
title('Original Image')

%Calculate two threshold levels.
thresh = multithresh(I,7);

%Segment the image into three levels using imquantize .
seg_I = imquantize(I,thresh);

%Convert segmented image into color image using label2rgb and display it.
RGB = label2rgb(seg_I);
figure;
imshow(RGB)
title('RGB Segmented Image with 7 Plan');

%Calculate two threshold levels.
thresh = multithresh(I,2);

%Segment the image into three levels using imquantize .
seg_I = imquantize(I,thresh);

%Convert segmented image into color image using label2rgb and display it.
RGB = label2rgb(seg_I);
figure;
imshow(RGB)
title('RGB Segmented Image with 2 Plan');
```

Color Quantization in MATLAB (Cont.)

Original Image

RGB Segmented Image with 7 Plan

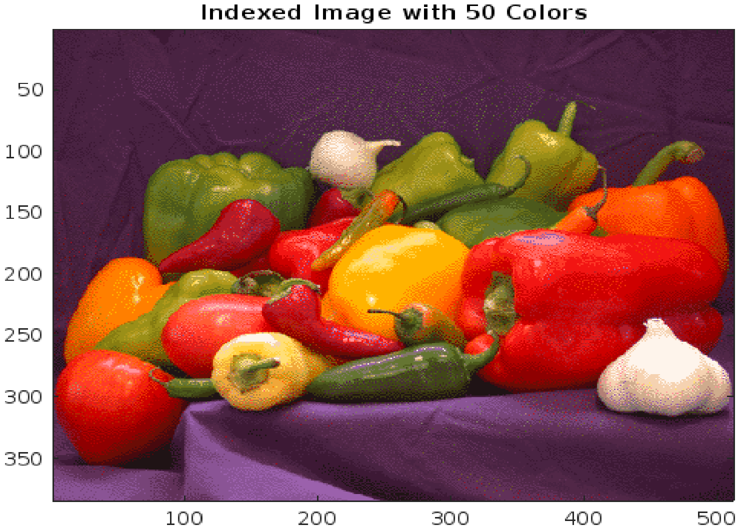
RGB Segmented Image with 2 Plan

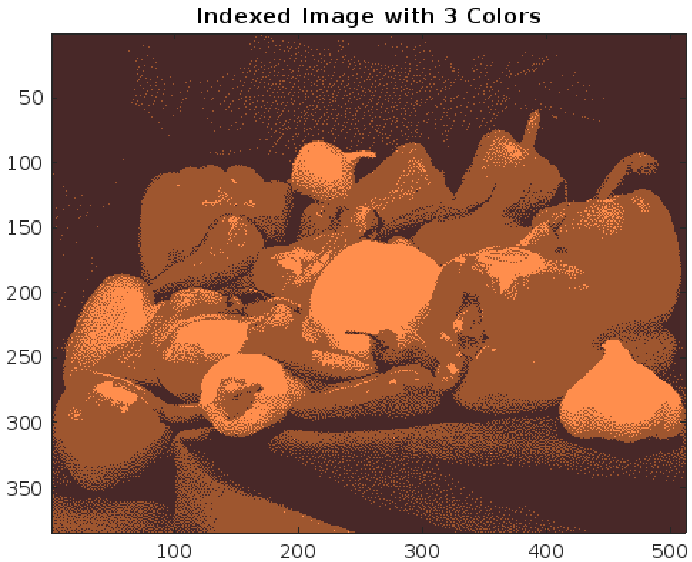
Color Approximation in MATLAB

```
clc;clear;
RGB = imread('peppers.png');
imshow(RGB);
title('Original Image with RGB Colors');

%Convert RGB to an indexed image with 50 colors.
figure
[IND,map] = rgb2ind(RGB,50);
image(IND)
colormap(map)
title('Indexed Image with 50 Colors');
%Reduce the number of colors in the indexed image
%From 50 to only 3 colors by producing a new image, Y,
% and its associated colormap, newmap.
figure
[Y,newmap] = imapprox(IND,map,3);
image(Y)
colormap(newmap)
title('Indexed Image with 3 Colors');
```

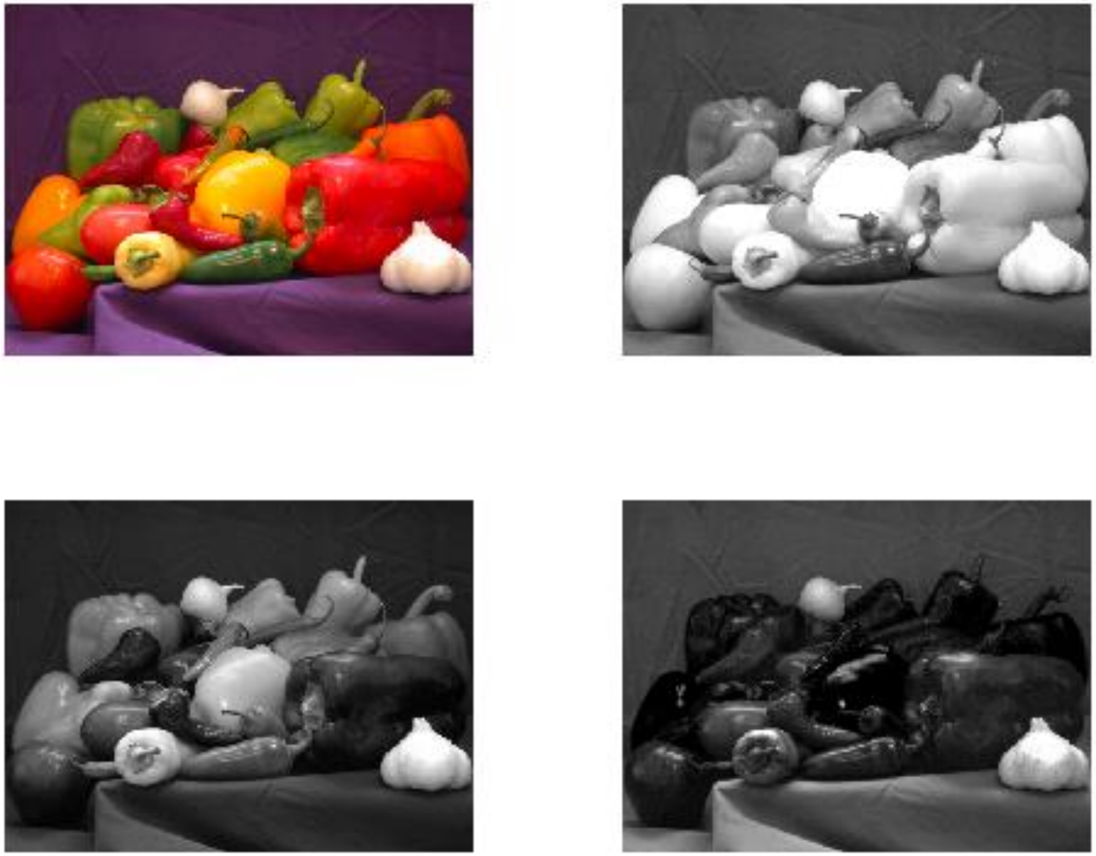
Color Approximation in MATLAB (Cont.)





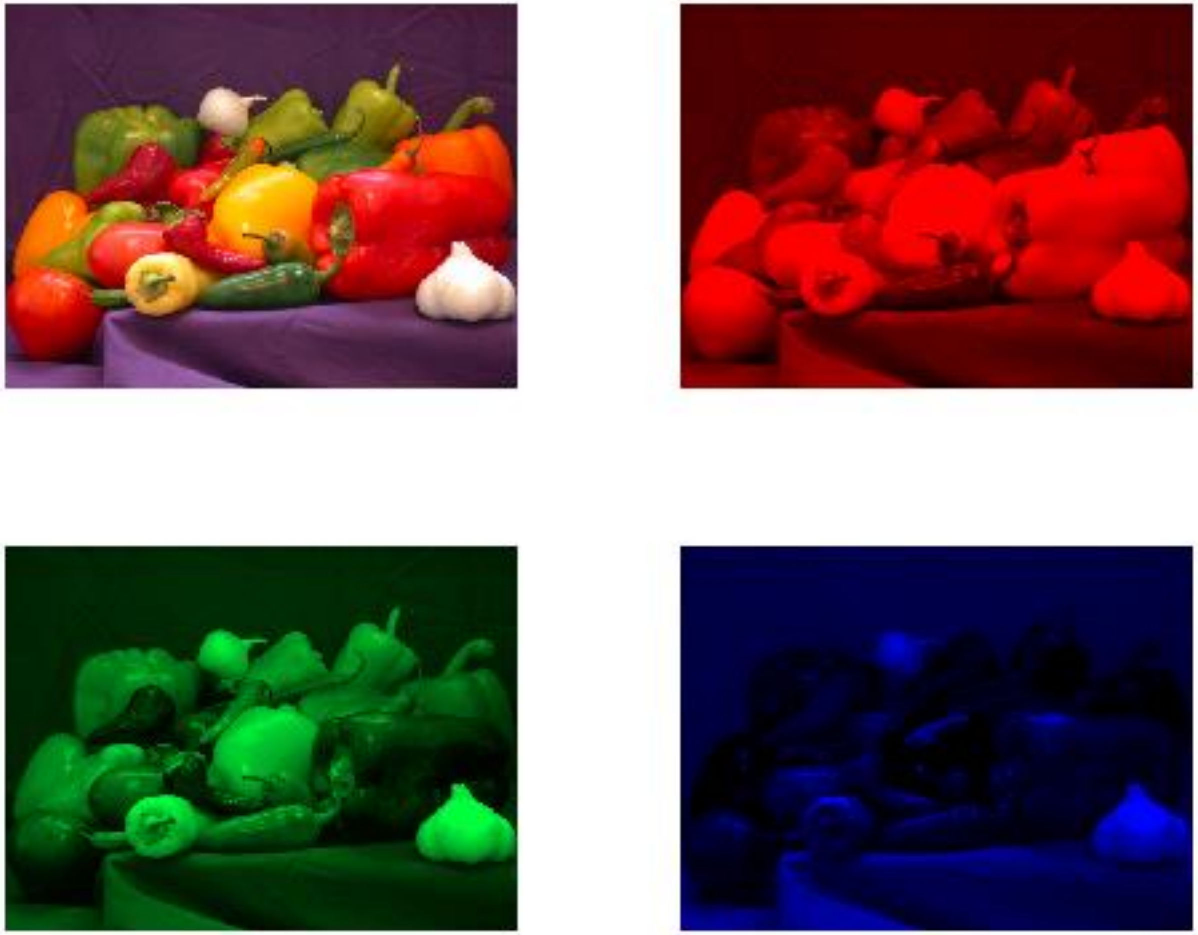
Display Color Image into RGB Components in Gray Image in MATLAB

```
I=imread('peppers.png');
R=I(:,:,1);
G=I(:,:,2);
B=I(:,:,3);
subplot(2,2,1)
imshow(I);
subplot(2,2,2)
imshow(R);
subplot(2,2,3)
imshow(G);
subplot(2,2,4)
imshow(B);
```



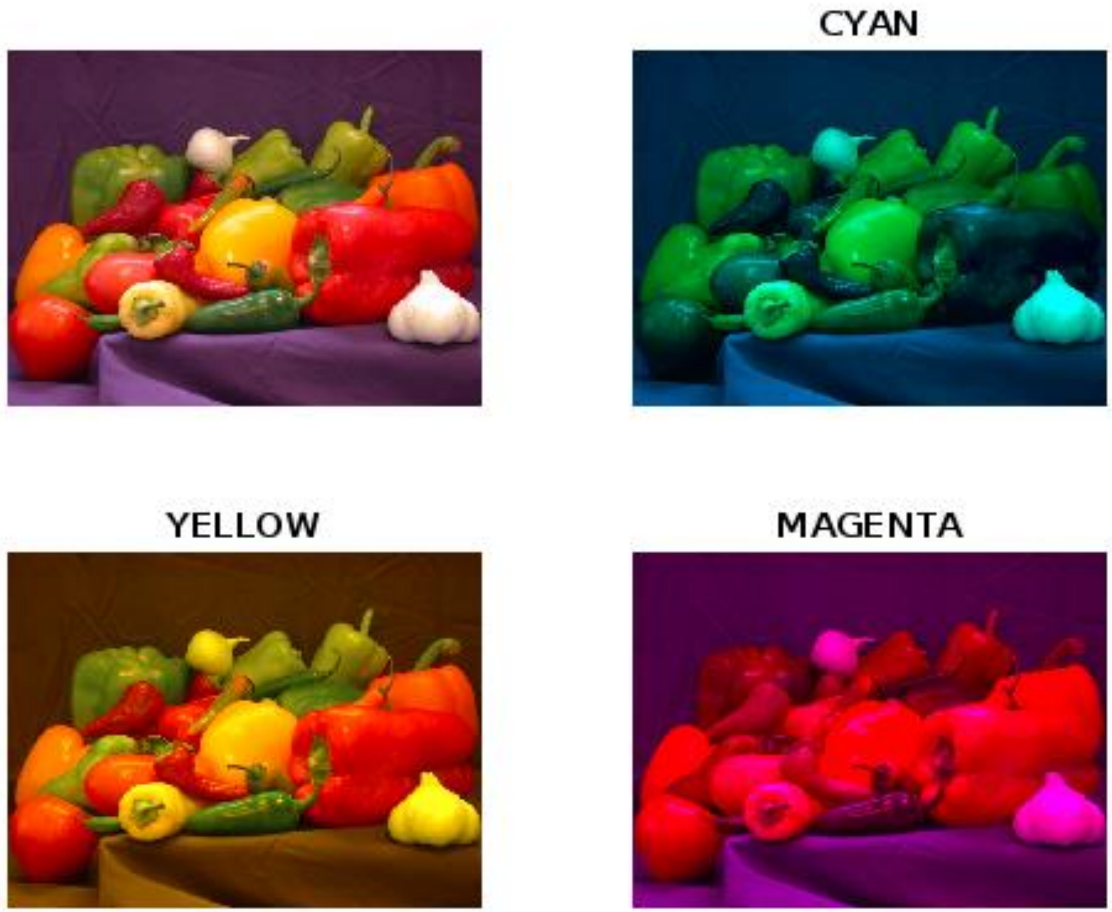
Display Color Image into RGB Components in Color Image in MATLAB

```
I=imread('peppers.png');
RR=I;
RR(:,:,2)=0;
RR(:,:,3)=0;
subplot(2,2,1)
imshow(I);
subplot(2,2,2)
imshow(RR);
subplot(2,2,3)
GG=I;
GG(:,:,1)=0;
GG(:,:,3)=0;
imshow(GG);
subplot(2,2,4)
BB=I;
BB(:,:,1)=0;
BB(:,:,2)=0;
imshow(BB);
```



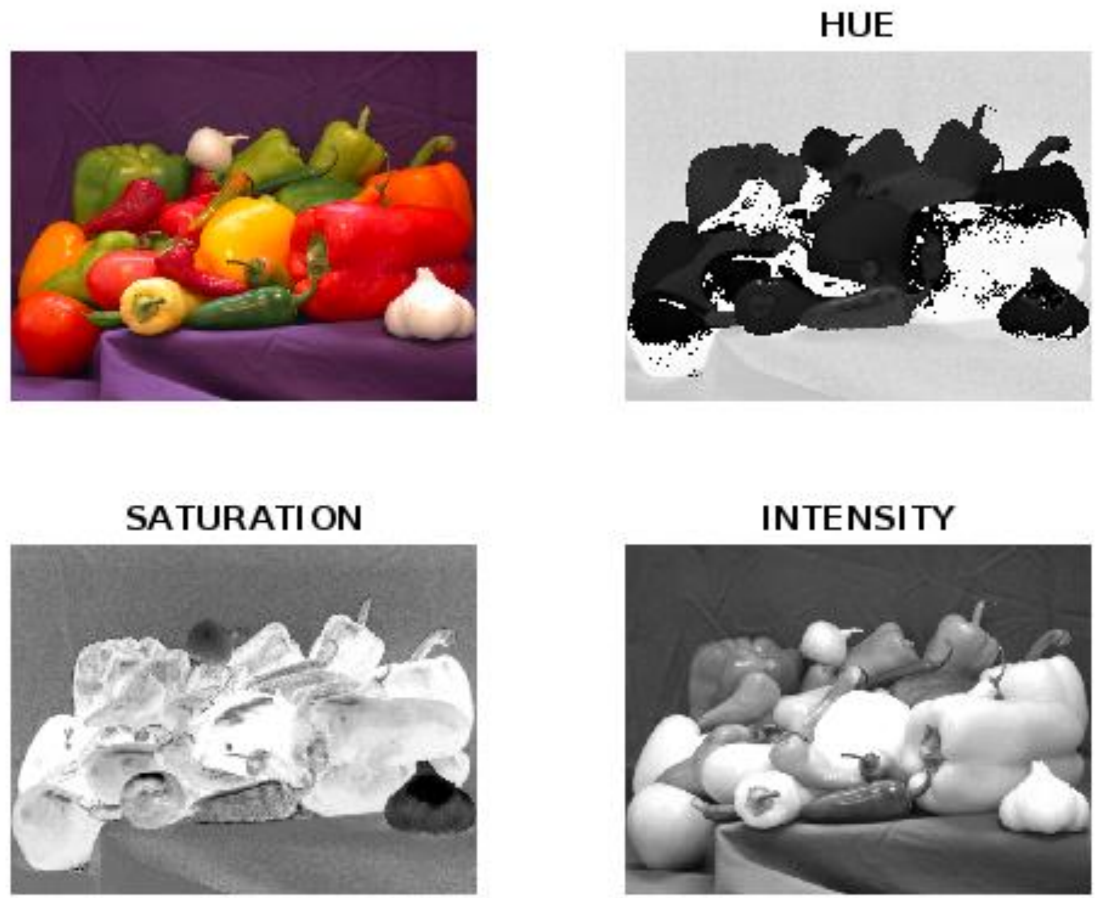
Display Color Image into CMY Components in MATLAB

```
I=imread('peppers.png');
CC=I;
CC(:,:,1)=0;
subplot(2,2,1)
imshow(I);
subplot(2,2,2)
imshow(CC);
title('CYAN');
subplot(2,2,3)
YY=I;
YY(:,:,3)=0;
imshow(YY);
title('YELLOW');
subplot(2,2,4)
MM=I;
MM(:,:,2)=0;
imshow(MM);
title('MAGENTA');
```



Display Color Image into HIS Component in MATLAB

```
I=imread('peppers.png');
HSV=rgb2hsv(I);
H=HSV(:,:,1);
S=HSV(:,:,2);
V=HSV(:,:,3);
subplot(2,2,1)
imshow(I);
subplot(2,2,2)
imshow(H);
title('HUE');
subplot(2,2,3)
imshow(S);
title('SATURATION');
subplot(2,2,4)
imshow(V);
title('INTENSITY');
```




Thank
you