DIGITAL IMAGE PROCESSING

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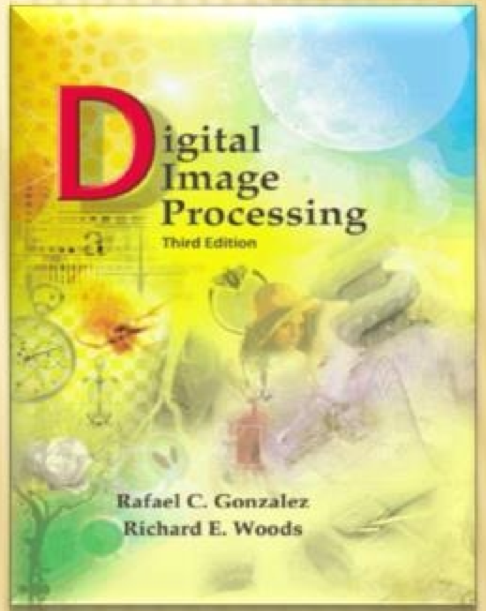

Chapter 6 – Color Image Processing

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6.1 COLOR FUNDAMENTALS

LIGHT

اصول رنگ

- تجزیه نور سفید توسط منشور

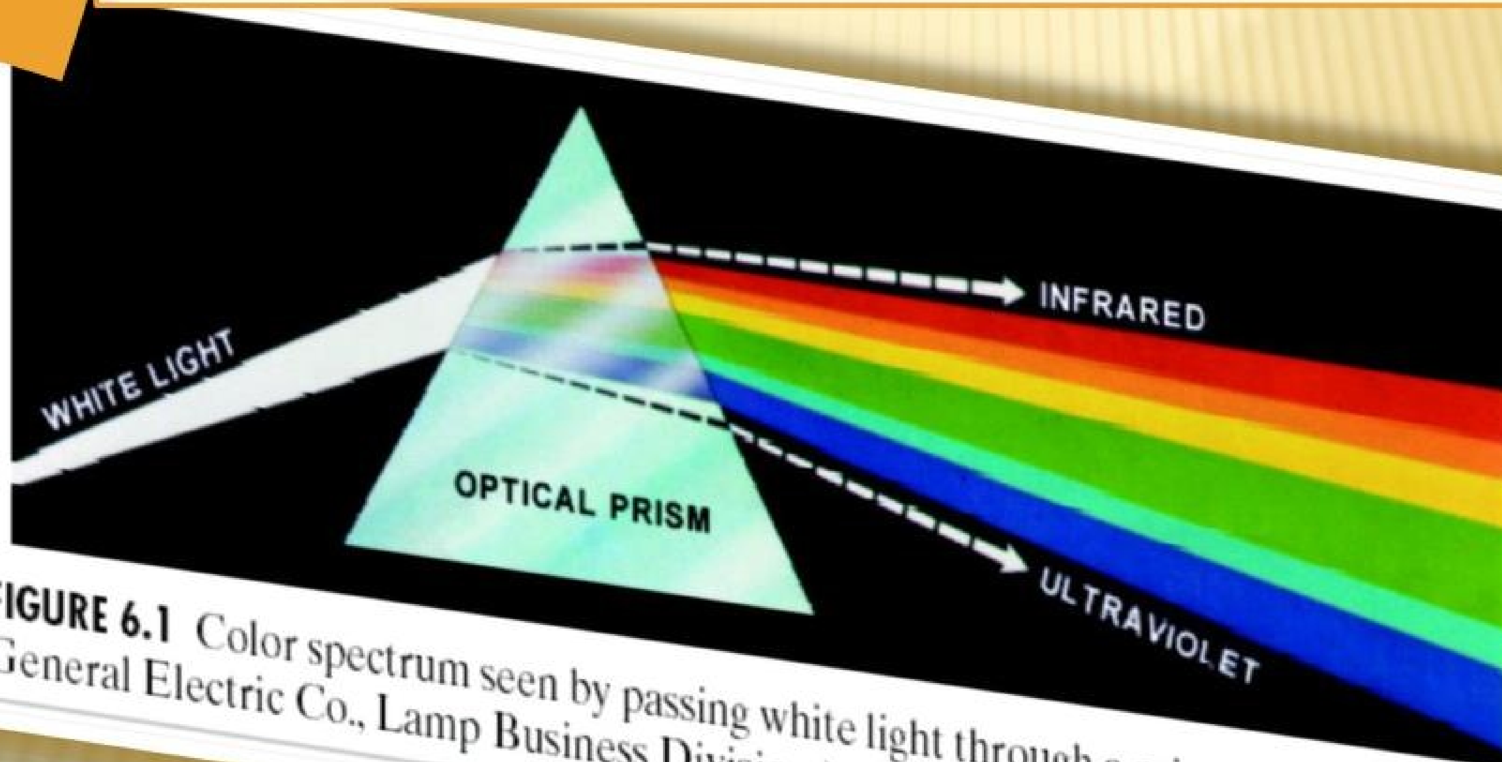
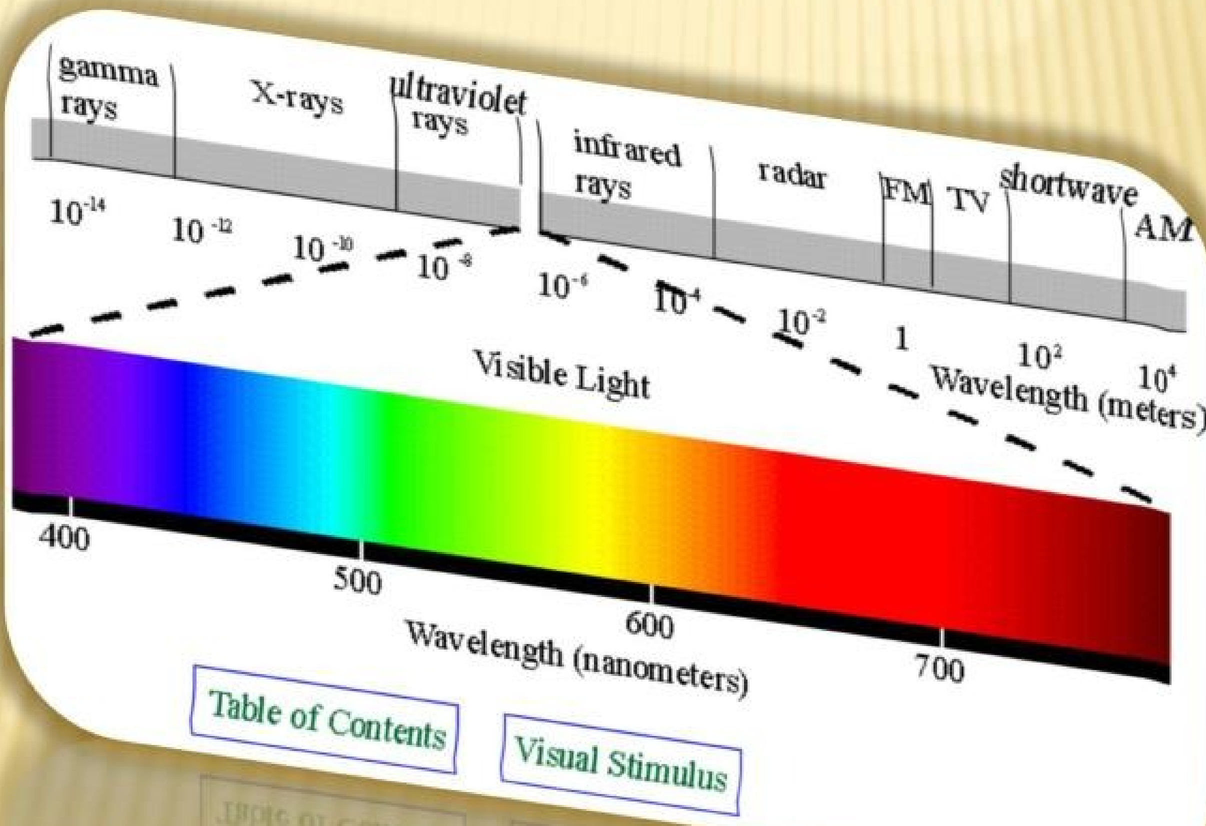


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

LIGHT

اصول رنگ

- طیف نور قابل رویت



ABSORPTION OF LIGHT IN EYE

- **Three** basic quantities to describe the quality of a chromatic light source are:

  radiance :

  total amount of energy that flows from the light source.

  luminance :

  measure of the amount of energy an observer perceives from a light source.

  brightness :

  a subjective descriptor that is practically impossible to measure. It embodies the achromatic notion of intensity .

ABSORPTION OF LIGHT IN EYE

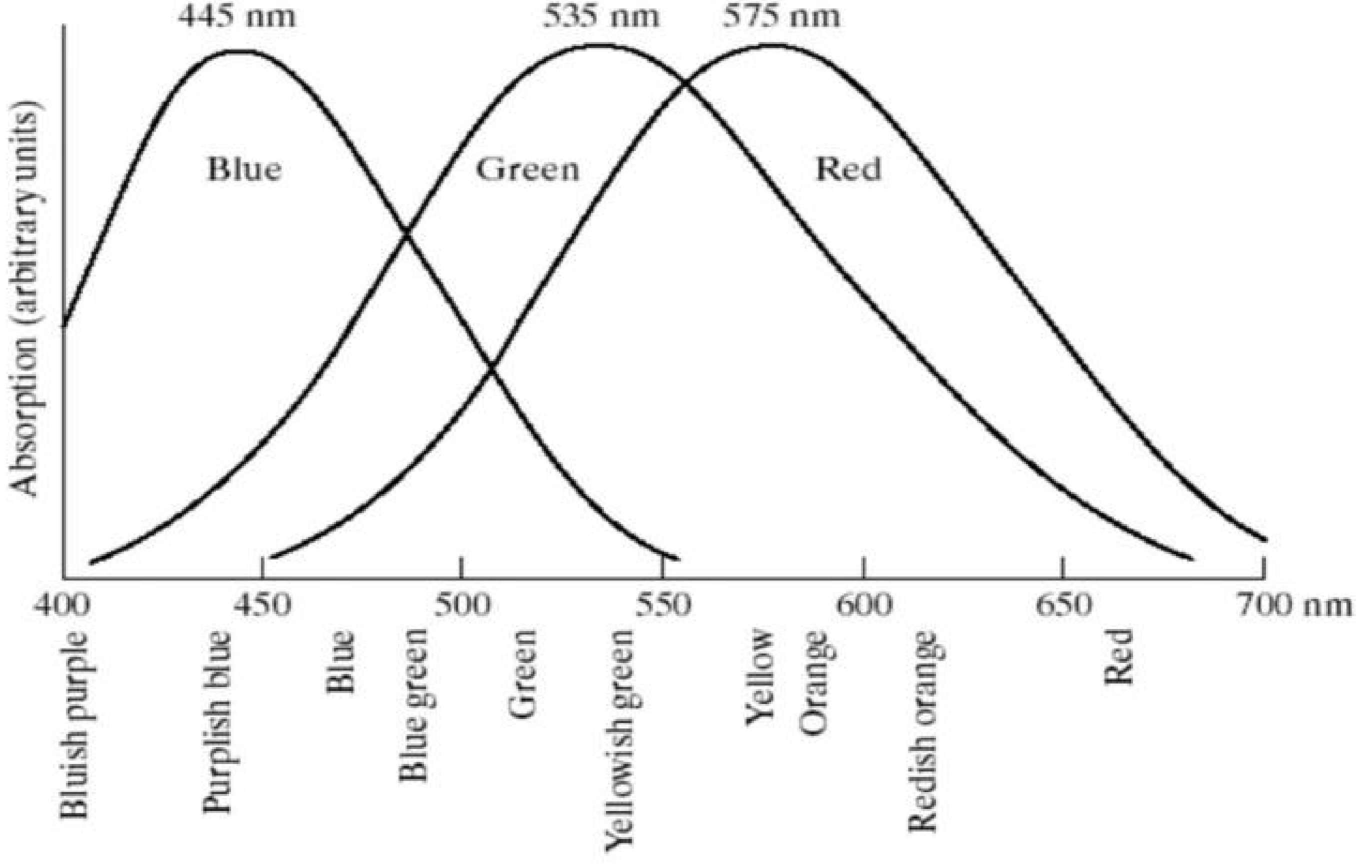
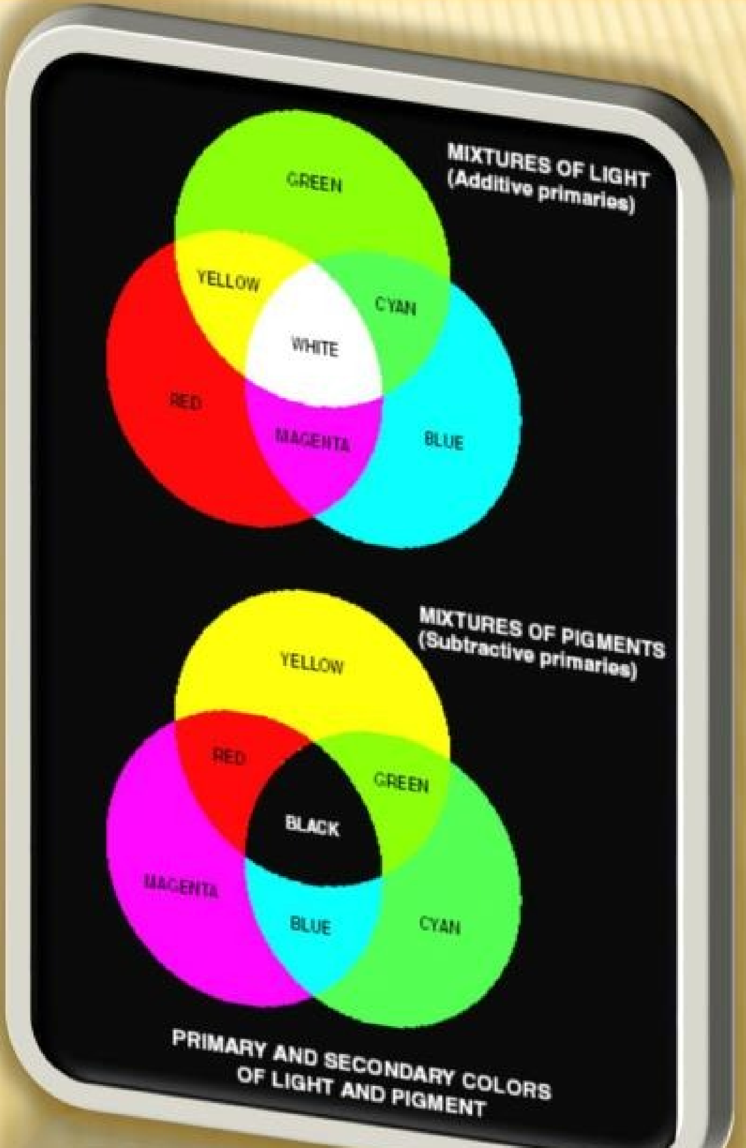


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

PRIMARY & SECONDARY COLORS OF LIGHT

- Additive primary colors: RGB use in the case of light sources such as color monitors.
- RGB add together to get white
- Subtractive primary colors: CMY use in the case of pigments in printing devices
- White subtracted by CMY to get Black



CHARACTERISTICS OF COLORS

- The characteristics generally used to distinguish one color from another are:

BRIGHTNESS(INTENSITY)

- Brightness embody the achromatic notion of intensity.

HUE

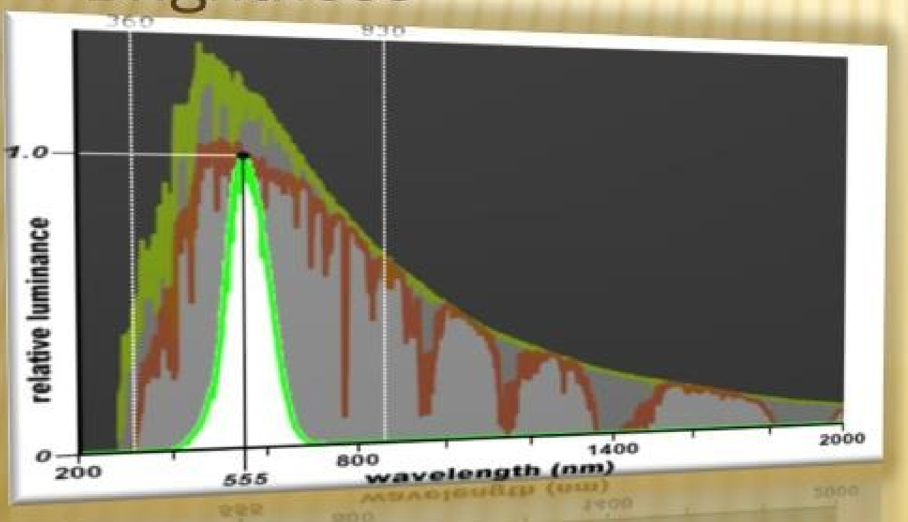
- dominant color corresponding to a dominant wavelength of mixture light wave

SATURATION

- Relative purity or amount of white light mixed with a hue.
- inversely proportional to amount of white .

RADIANCE, LUMINANCE, BRIGHTNESS

- Three basic properties used to describe the quality of chromatic light source:
  - Luminance
  - Radiance
  - Brightness



CHROMATICITY

SATURATION + HUE = CHROMATICITY

- amount of red (X), green (Y) and blue (Z) to form any particular color is called *tristimulus*.

Trichromatic coefficients:

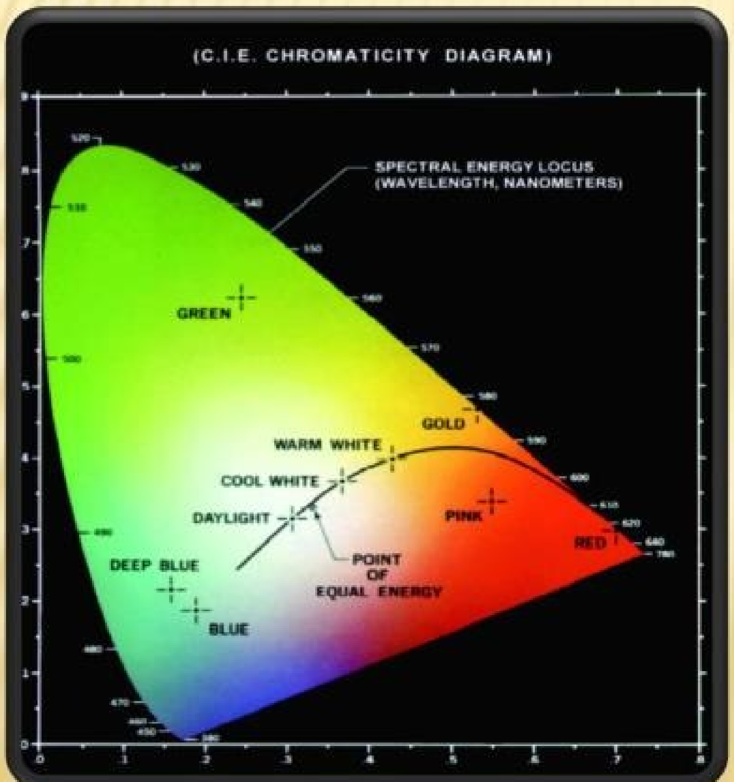
$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

$$x + y + z = 1$$

y



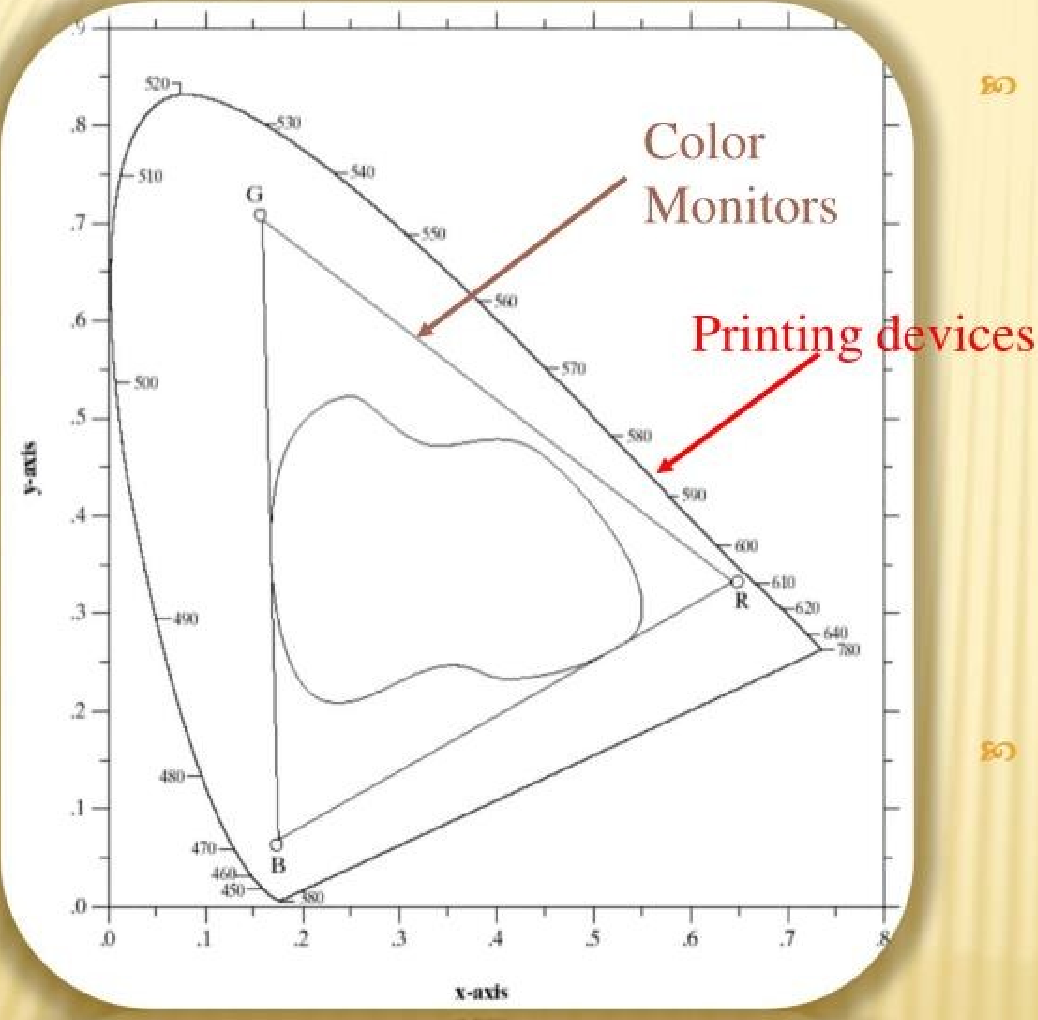
x

Points on the boundary are fully saturated colors

CHROMATICITY

- CIE chromaticity diagram
  - Has superior performance over other color transforms especially in clustering of color distribution and estimate of color difference.
  - Shows color as a function of x (red) and y (green)
  - Useful for color mixing
  - Boundary of the diagram shows fully saturated . As a point leaves the boundary and approaches the point of equal energy, more white light is added to the color and it becomes less saturated .
- CIE color models include CIE XYZ, CIE x,yY, CILE La*b*, and CIE Lu'v'. Derivatives of the CIE XYZ space include CIELUV, CIEUVW, and CIELAB.

COLOR GAMUT OF COLOR MONITORS AND PRINTING DEVICES



- A triangle with vertices at any three fixed colors cannot enclose the entire color region

- it shows that not all colors can be obtained with three single, fixed primaries.

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6.2 COLOR MODELS

Foreword

- 6.2.1 The RGB Color Model
- 6.2.2 The CMY and CMYK Color Model
- 6.2.3 The HSI Color Model

COLOR SPACE OR COLOR SYSTEM

- Purpose of color models: to facilitate the specification of colors in some standard.
- A specification of a coordinate system and a subspace within that system where each color is represented a single point
- Two applied directions for color models:
  - Hardware
  - Applications where color manipulation(color graphics)

- Color Models:
  - RGB models: color monitors
  - CMY (CMYK): color model for color printing
  - YIQ: Color model for color television
  - HIS: a color model for humans to describe and to interpret color; decouple the color and gray-level information.

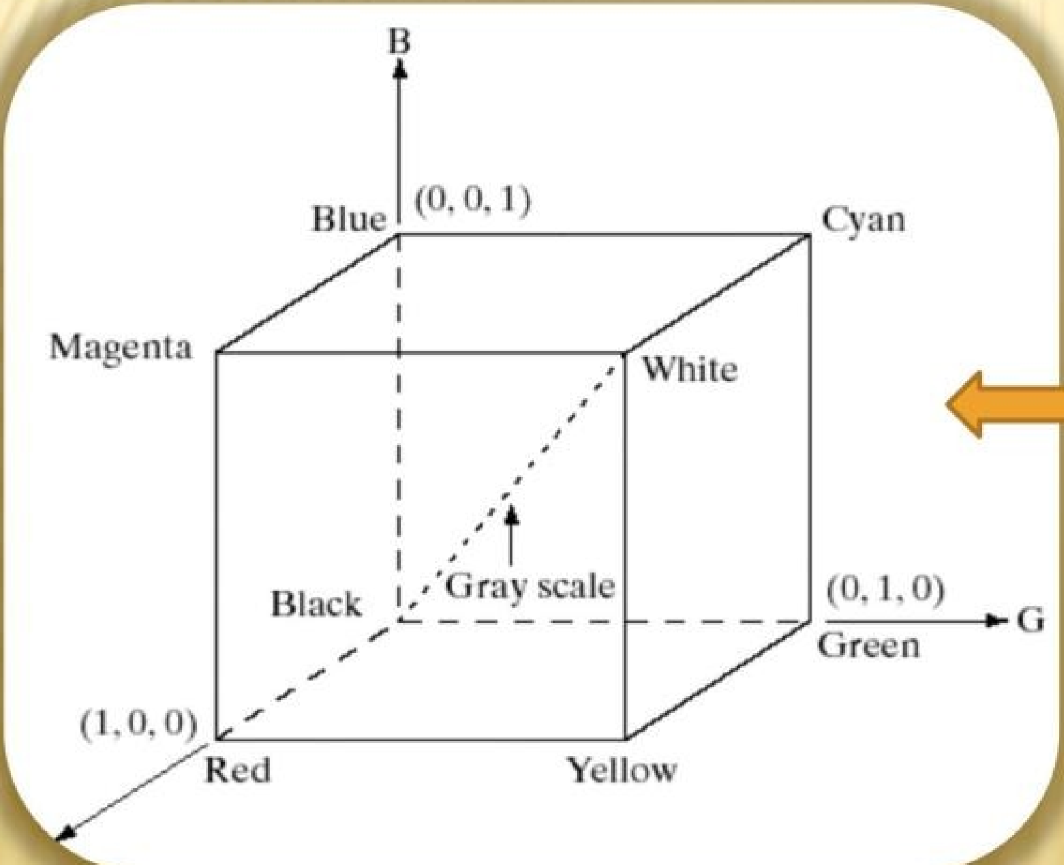
6.2 COLOR MODELS

Foreword

- 6.2.1 The RGB Color Model
- 6.2.2 The CMY and CMYK Color Model
- 6.2.3 The HSI Color Model

RGB COLOR MODEL

- pixel depth : the number of bits used to represent each pixel in RGB space .



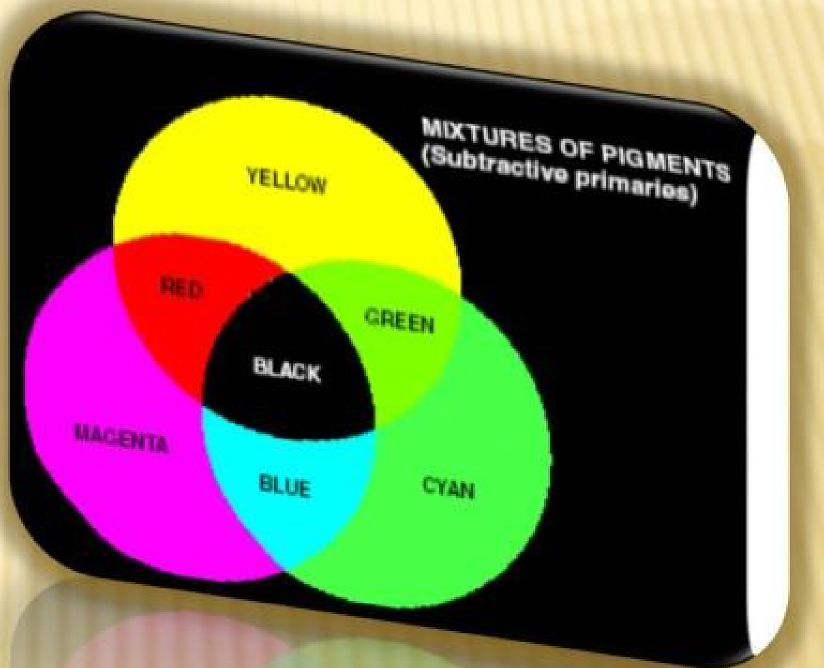
6.2 COLOR MODELS

Foreword

- ☑ 6.2.1 The RGB Color Model
- 6.2.2 The CMY and CMYK Color Model
- 6.2.3 The HSI Color Model

CYM & CYMK COLOR MODELS

- Color printer and copier
- Deposit colored pigment on paper
- Relationship with RGB model:



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

C = Cyan
M = Magenta
Y = Yellow
K = Black

Example :surface coated with pure cyan does not contain red (C = 1 — R)

6.2 COLOR MODELS

Foreword

- ☑ 6.2.1 The RGB Color Model
- ☑ 6.2.2 The CMY and CMYK Color Model
- ✖ 6.2.3 The HSI Color Model

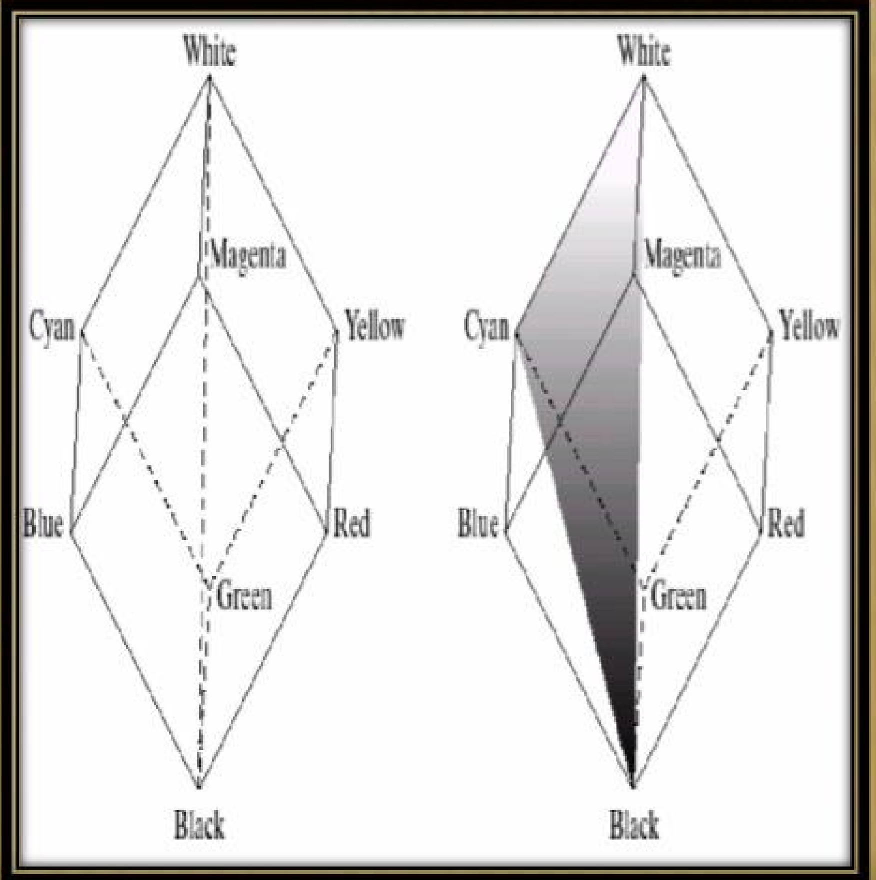
HSI COLOR MODEL

- RGB, CMY models are not good for human interpreting

Hue:	Dominant color	Color carrying information
Saturation:	Relative purity (inversely proportional to amount of white light added)	
Intensity:	Brightness	

CONCEPTUAL RELATIONSHIPS BETWEEN RGB & HSI MODELS

- **extract intensity from an RGB image :** the line (intensity axis) joining the black and white vertices is vertical.
- pass a plane perpendicular to the intensity axis and containing the color point. The intersection of the plane with the intensity axis give a point with intensity value in the range [0,1].
- The boundaries defined by the intersection of each plane with the faces of the cube have either a triangular or hexagonal shape.



CONCEPTUAL RELATIONSHIPS BETWEEN RGB & HIS MODELS

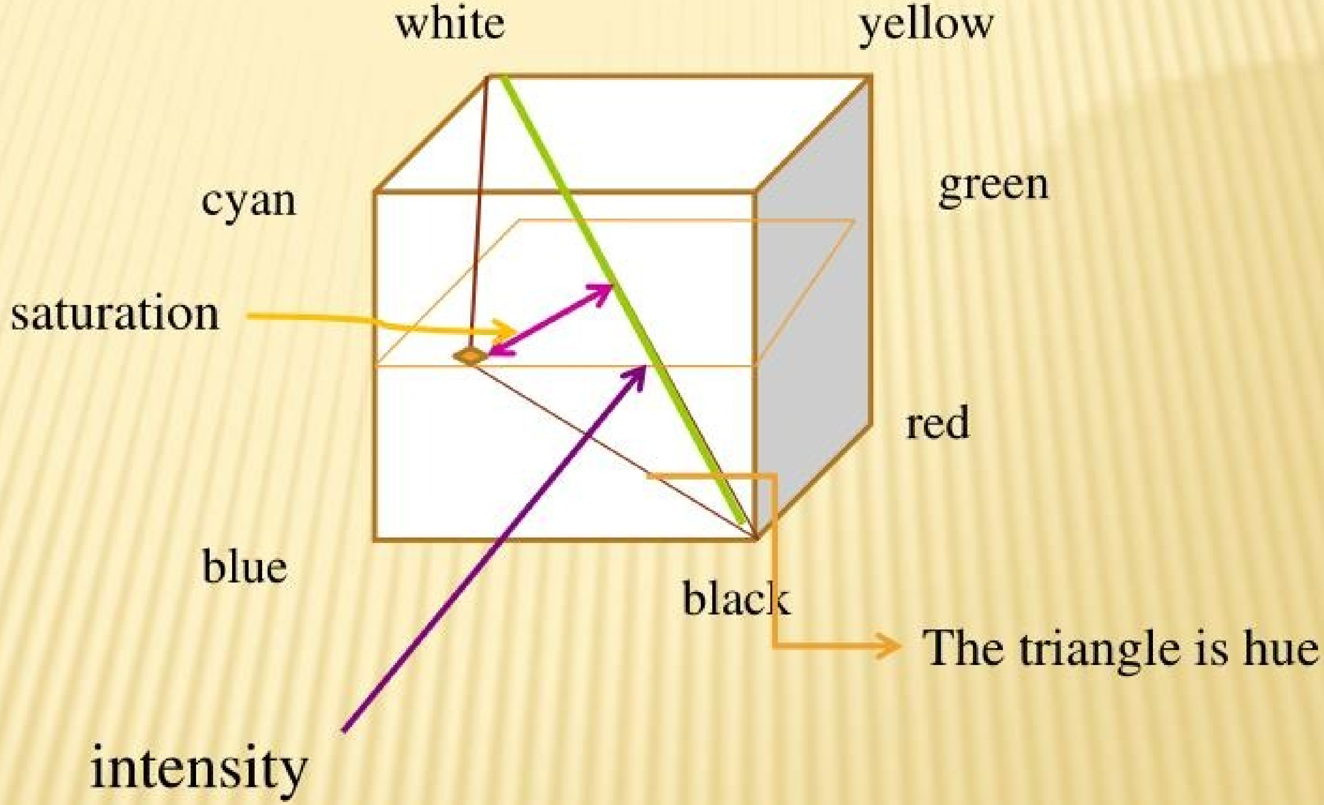
- saturation : increases as a function of distance from the intensity axis .

- Hue : all colors generated by three colors lie in the triangle defined by those colors.(black ,white ,color point).

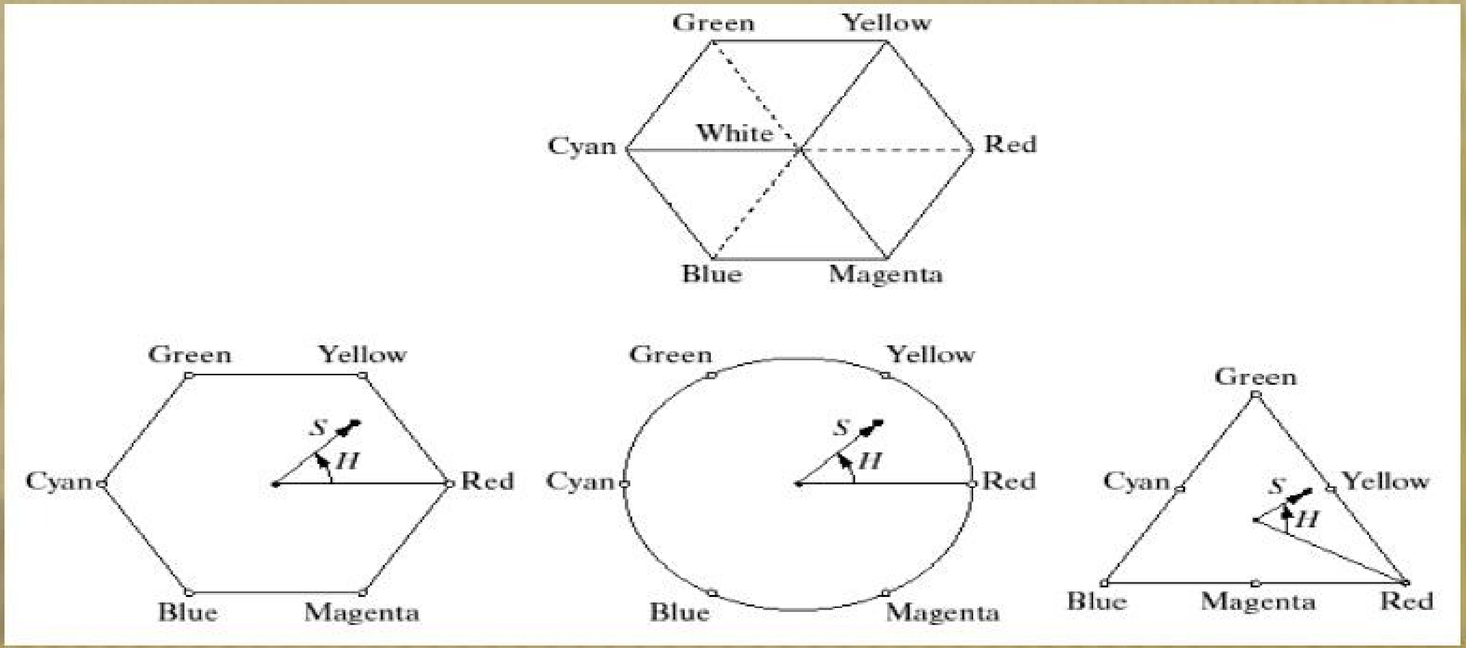
- points on the triangle would have the same hue(black and white cannot change the hue).

- By rotating the shaded plane about the vertical intensity axis, we would obtain different hues.

CONCEPTUAL RELATIONSHIPS BETWEEN RGB & HIS MODELS

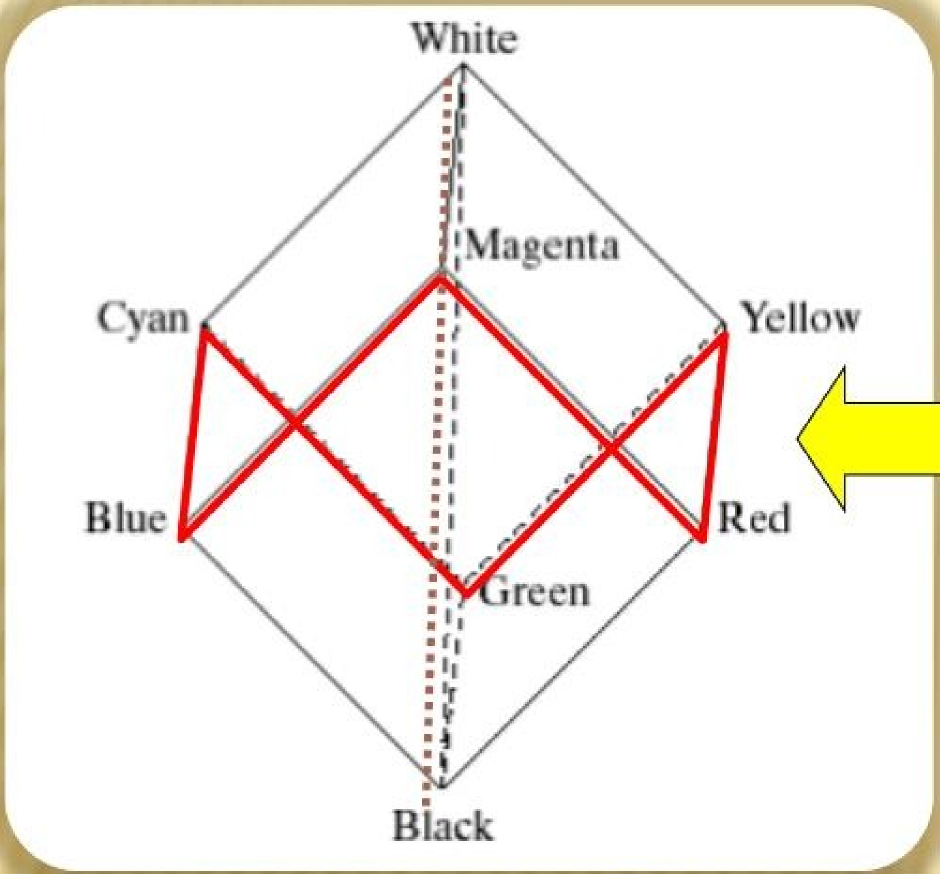


HSI & SATURATION ON COLOR PLANES

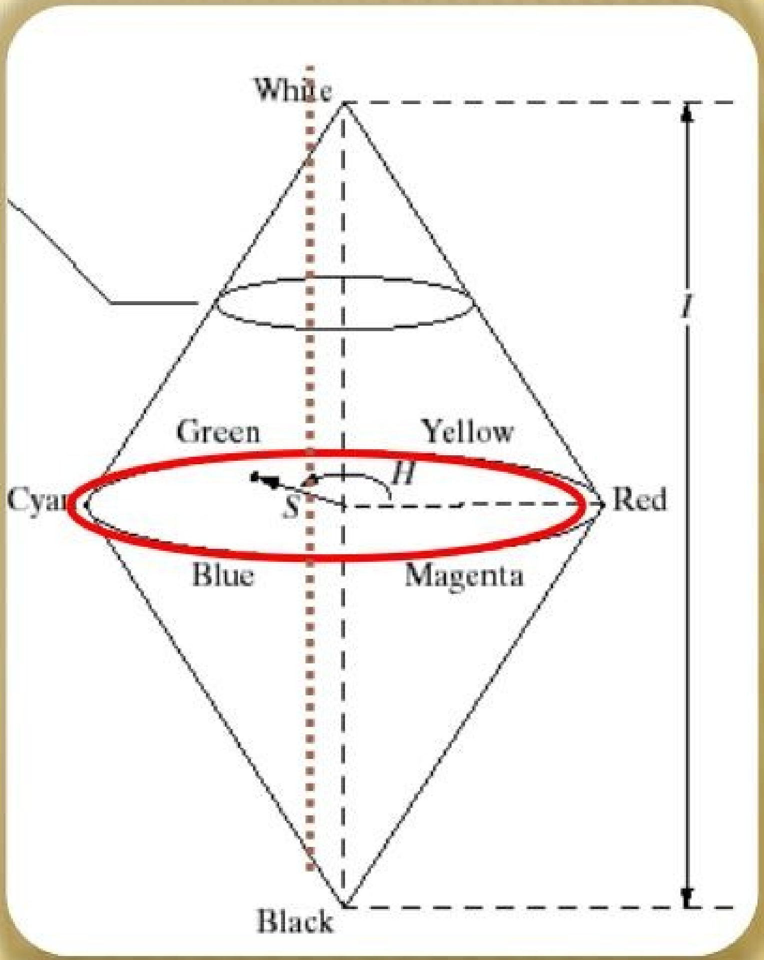


- Hue is an angle from a red axis. Origin is defined by the intersection of the color plane with the vertical intensity axis.
- Saturation is the length of the vector from the origin to the point.

RELATIONSHIP BETWEEN RGB AND HSI COLOR MODELS



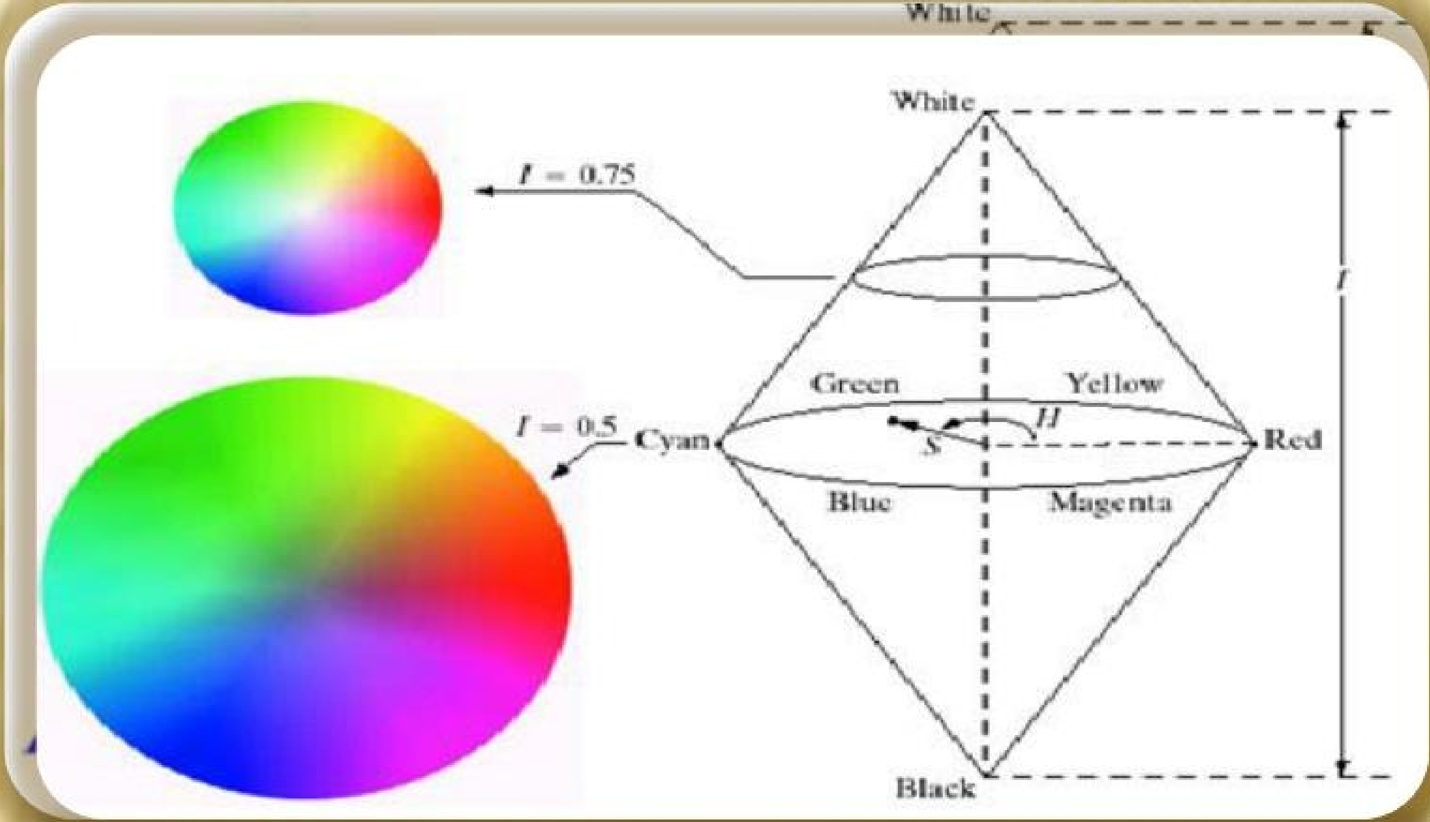
RGB



HSI

HSI

- نمایش رنگها در سیستم HSI



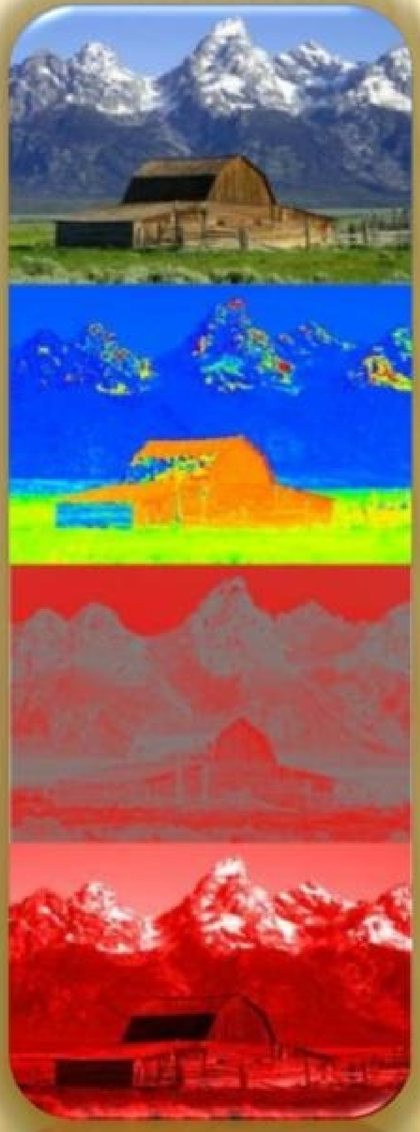
CONVERTING COLORS FROM RGB TO HSI

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

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

$$S = 1 - \frac{3}{R+G+B}$$

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



RGB

Hue

saturation

Intensity

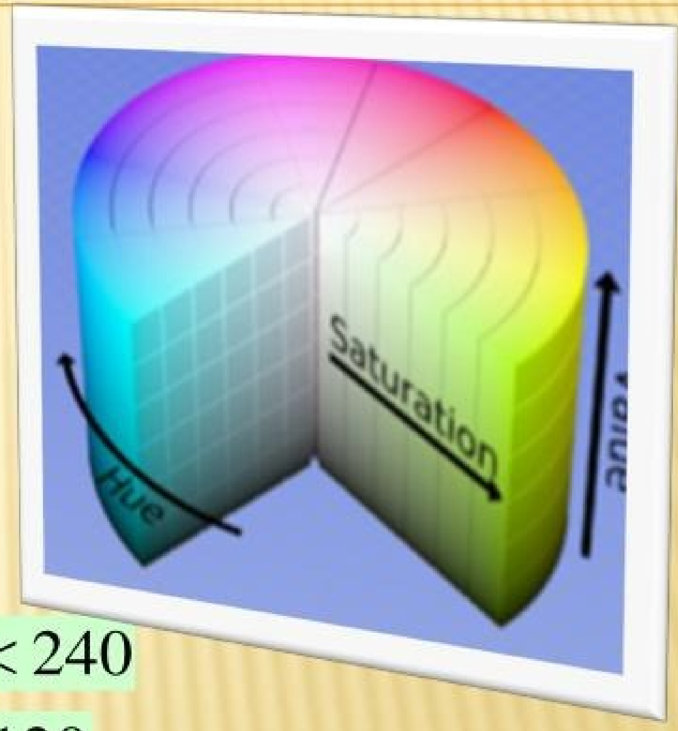
Converting Colors from HSI to RGB

RG sector: $0 \le H < 120$

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

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

$$G = 1 - (R + B)$$



BR sector: $240 \le H \le 360$

$$H = H - 240$$

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

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

$$R = 1 - (G + B)$$

GB sector: $120 \le H < 240$

$$H = H - 120$$

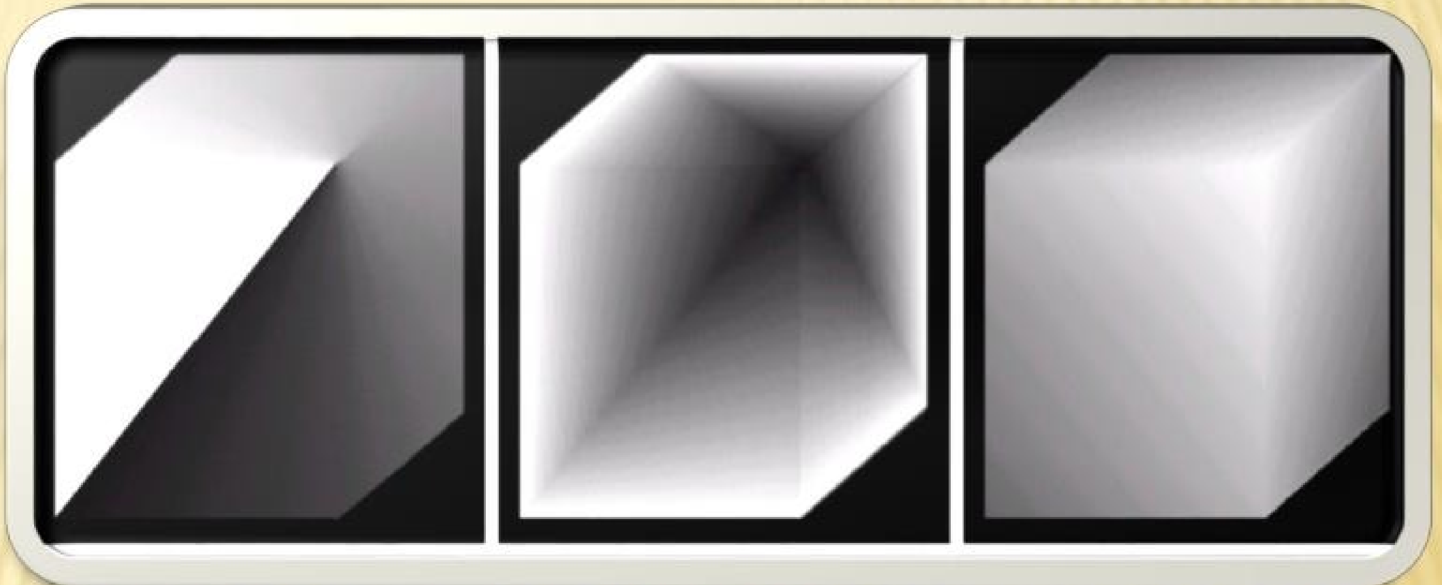
$$R = I(1 - S)$$

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

$$B = 1 - (R + G)$$

EXAMPLE: HSI COMPONENTS OF RGB CUBE

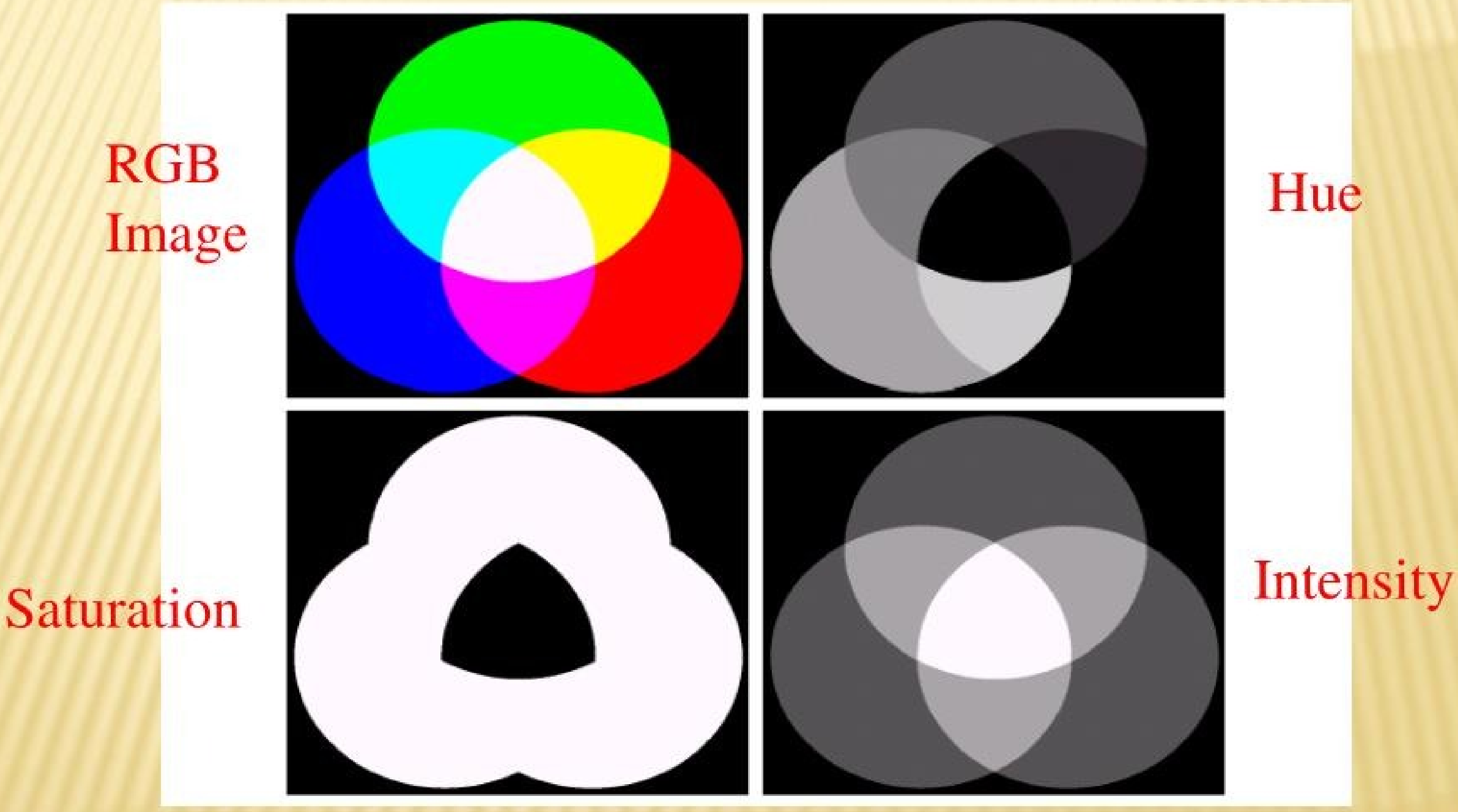
RGB Cube



Hue Saturation Intensity

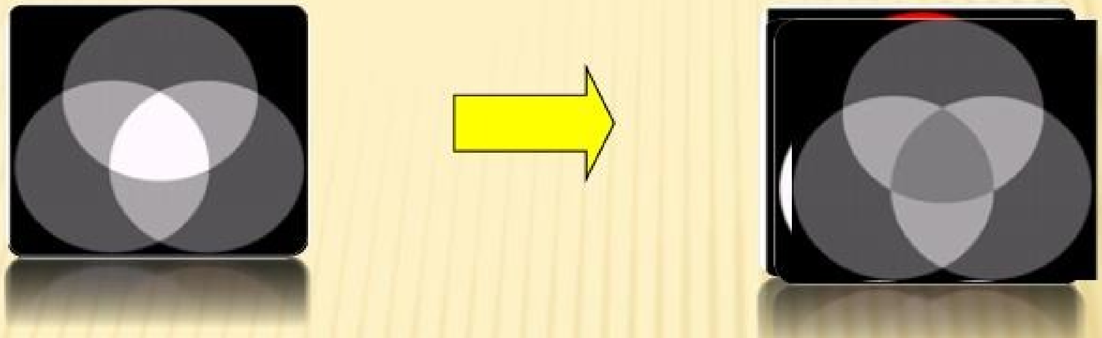
- every pixel in the **intensity** is the average of the RGB values at the corresponding pixel in Fig. 6.8.
- The **saturation** shows darker values toward the white vertex of the RGB cube, colors become less saturated as they approach white.

EXAMPLE: HSI COMPONENTS OF RGB CUBE



EXAMPLE: MANIPULATING HSI COMPONENTS

RGB
Image



Hue : changing to 0 the pixels corresponding to the blue and green regions

Saturation : reduced by half the saturation of the cyan region in component image S

Intensity : reduced by half the intensity of the central white region in the intensity image

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- 6.7 Image Segmentation Base
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6.3 PSEDUCOLOR IMAGE PROCESSING

Foreword

- 6.3.1 Intensity Slicing
- 6.3.2 Intensity to Color Transformations

COLOR IMAGE PROCESSING

- There are 2 types of color image processes:

PSEDUCOLOR IMAGE PROCESS

- Assigning colors to gray values based on a specific criterion. Gray scale images to be processed

  - may be a single image or multiple images such as multi- spectral images.

  - false-color image :

    depicts a subject in colors that differ from those a full-color photograph would show.

  - true-color image :

    is an image that appears to the human eye just like the original subject would be.

PSEUDOCOLOR IMAGE PROCESSING

- Assign colors to monochrome images from the process associated with true color images.
- Differentiate the process of assigning colors to monochrome images from the process associated with true color images.
- Difference between Pseudo-color & false-color :

  pseudo color images made from only one original gray-scale image, rather than two or three.

- Question: Why we need to assign colors to gray scale image?
  - Answer: Human can distinguish different colors better than different shades of gray.

COLOR IMAGE PROCESSING

- There are 2 types of color image processes:

FULL COLOR IMAGE PROCESS

- The process to manipulate real color images such as color photographs.

INTENSITY SLICING

- used in analysis of remotely sensed imagery to enhance the information gathered from an individual brightness band.

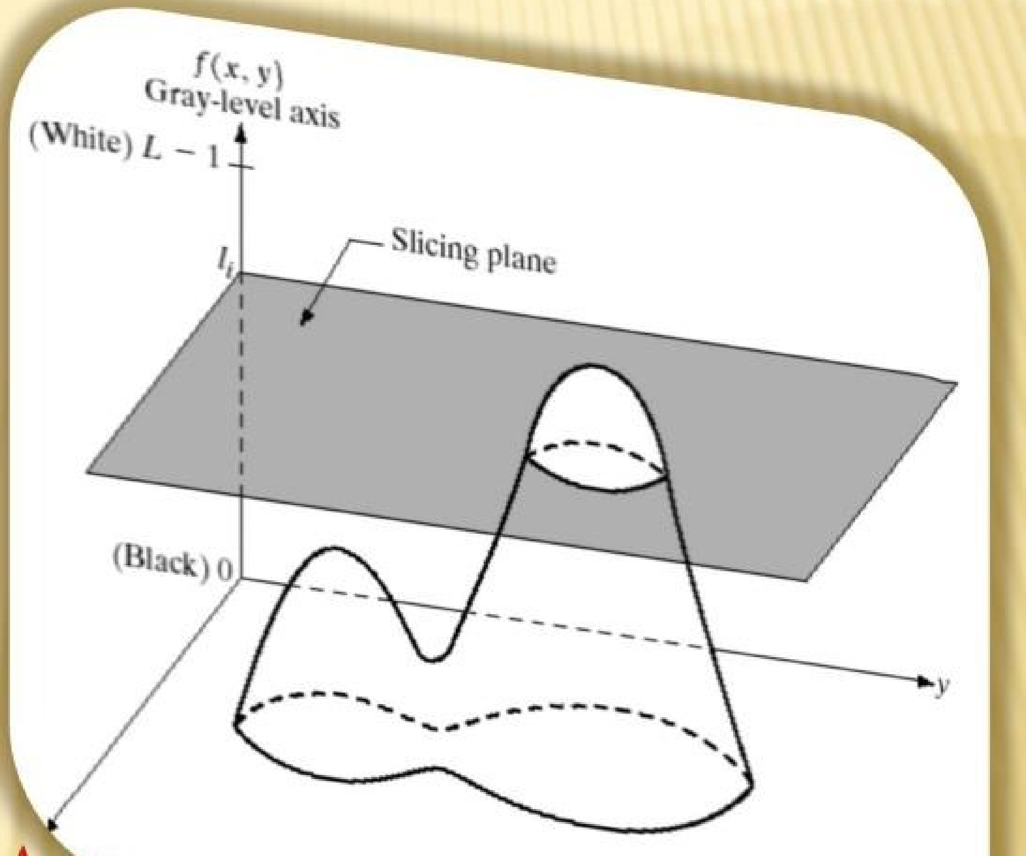
- is done by dividing the range of brightnesses in a single band into intervals, then assigning each interval to a color.

INTENSITY SLICING OR DENSITY SLICING

Formula:

$$g(x,y)=\begin{cases} C_1 & \text{if } f(x,y)\le T \\ C_2 & \text{if } f(x,y)>T \end{cases}$$

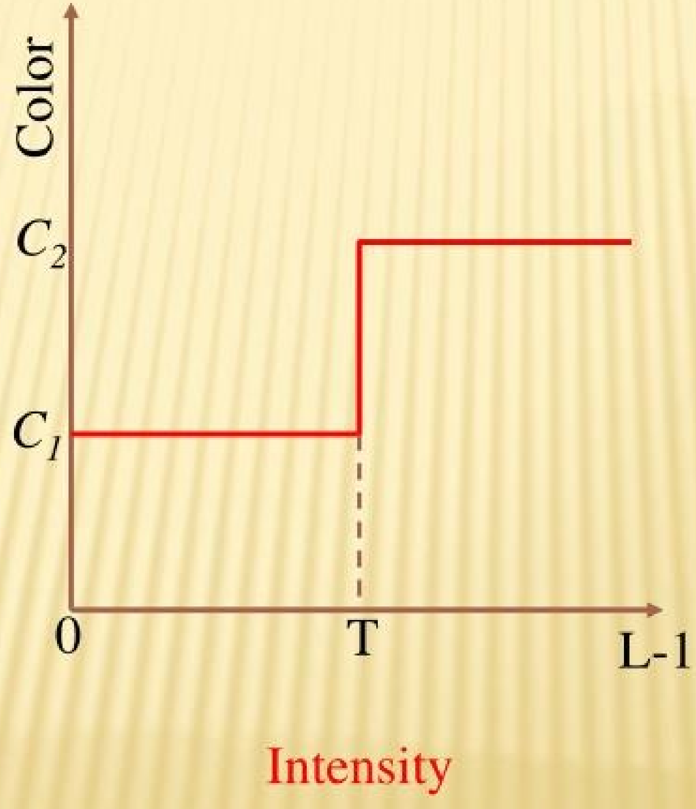
C_1 = Color No. 1
C_2 = Color No. 2



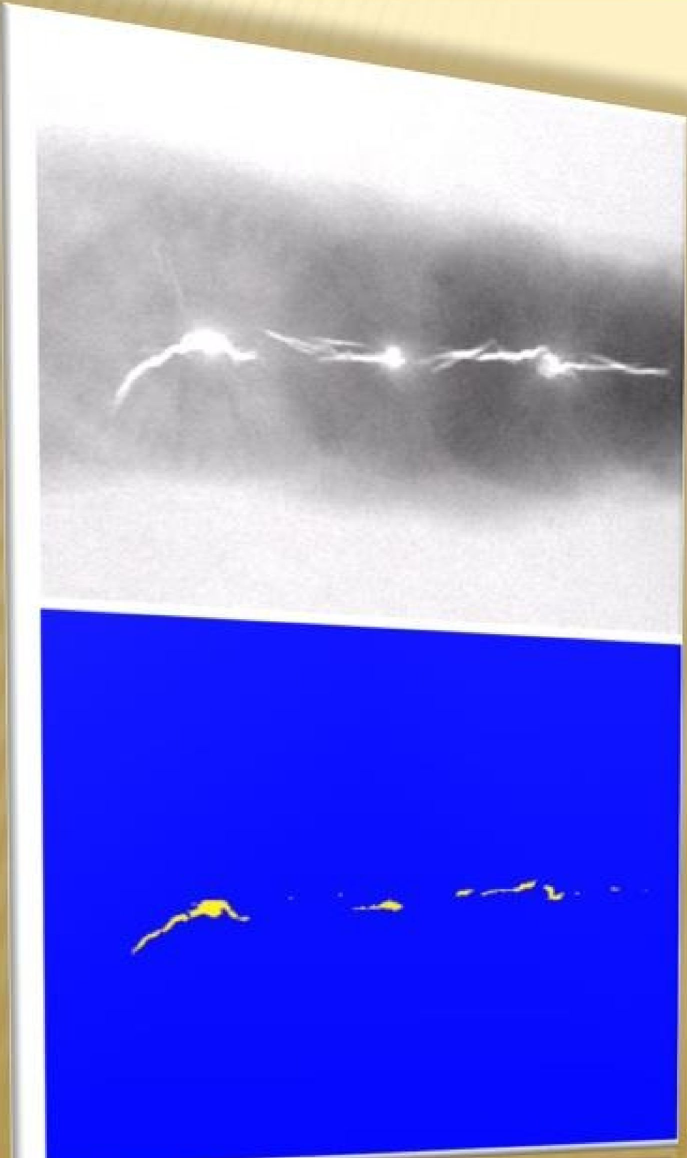
A gray scale image viewed as a 3D surface

INTENSITY SLICING OR DENSITY SLICING

نمایش دیگری از تکنیک بخش بندی شدت



INTENSITY SLICING EXAMPLE

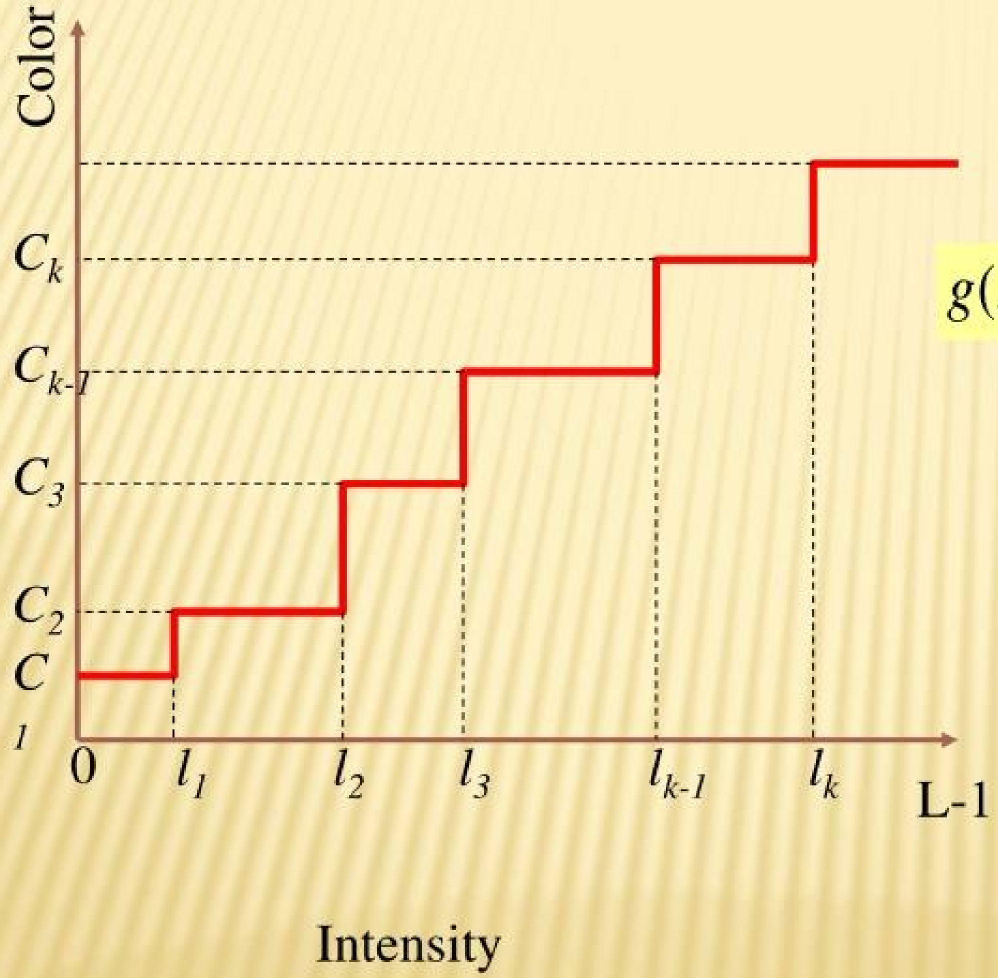


If the exact intensity value or range of Values is known, intensity slicing is a simple , powerful aid in visualization

An X-ray image of a weld with cracks

After assigning a yellow color to pixels with value 255 and a blue color to all other pixels.

MULTI LEVEL INTENSITY SLICING



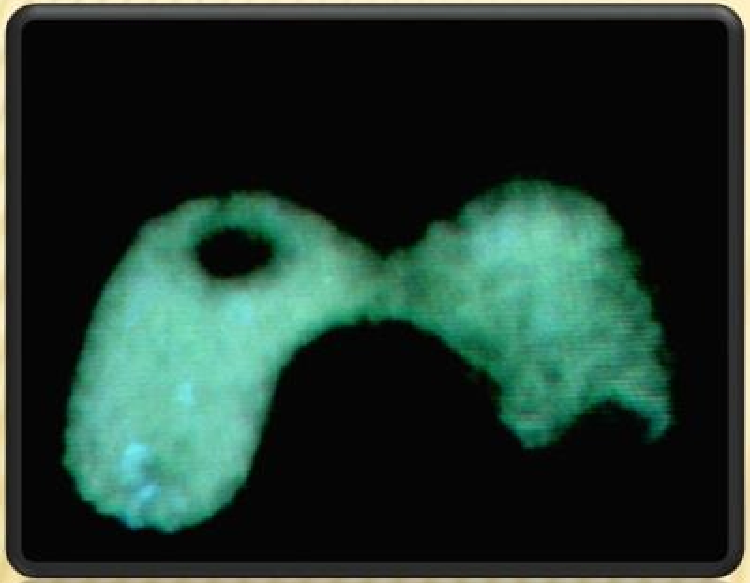
$$g(x,y) = C_k \qquad \text{for } l_{k-1} < f(x,y) \le l_k$$

C_k = Color No. k
l_k = Threshold level k

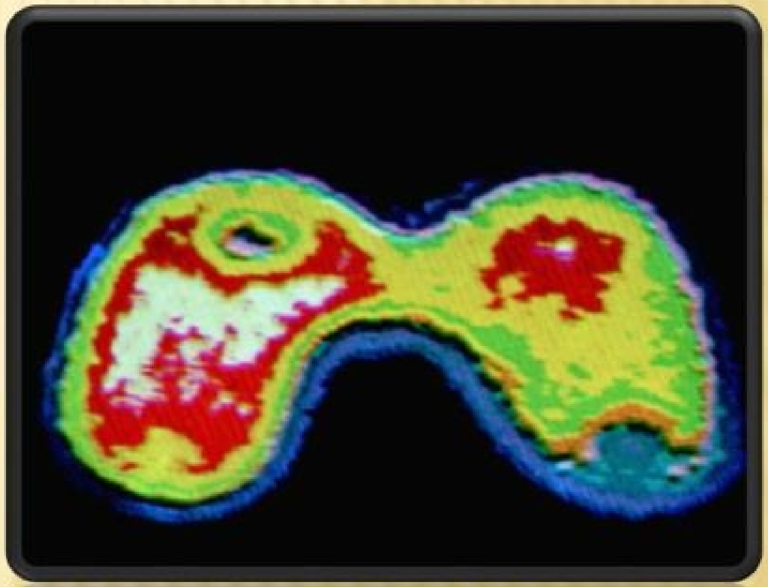
MULTI LEVEL INTENSITY SLICING EXAMPLE

$$g(x, y) = C_k \qquad \text{for } l_{k-1} < f(x, y) \le l_k$$

C_k = Color No. k
l_k = Threshold level k

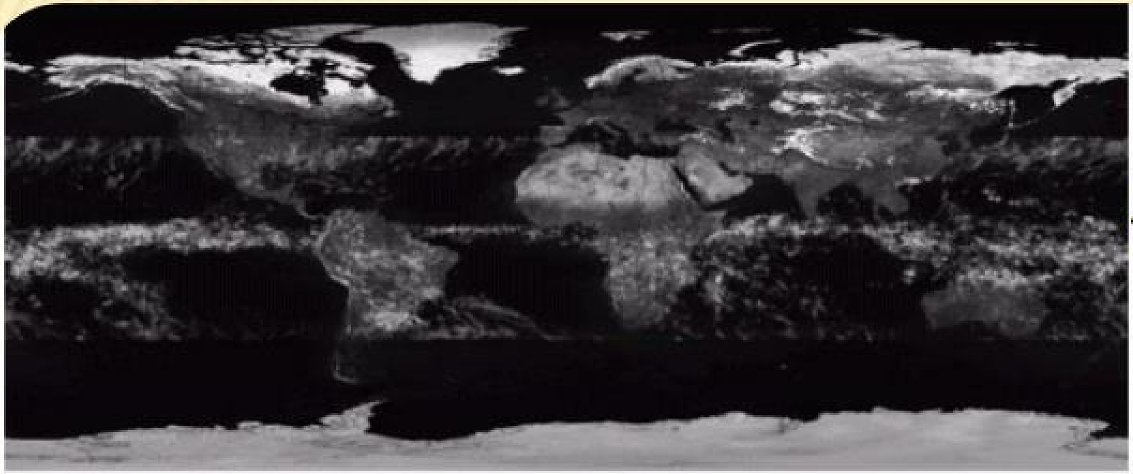


An X-ray image of the Picker Thyroid Phantom.



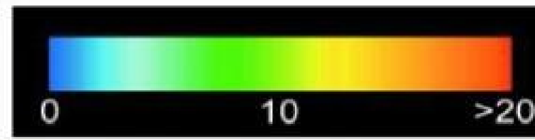
After density slicing into 8 colors

COLOR CODING EXAMPLE

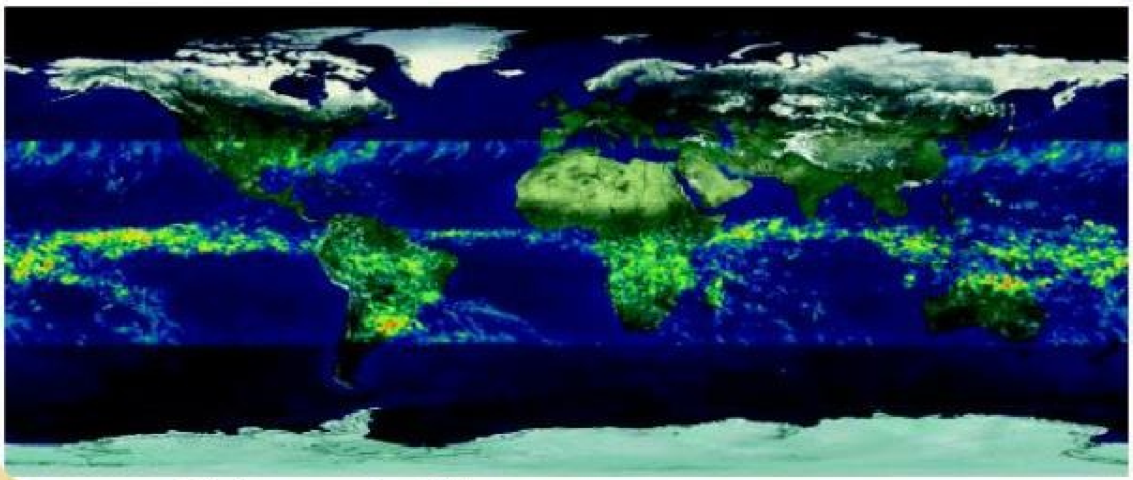


A unique color is assigned to each intensity value.

Gray-scale image of average monthly rainfall.

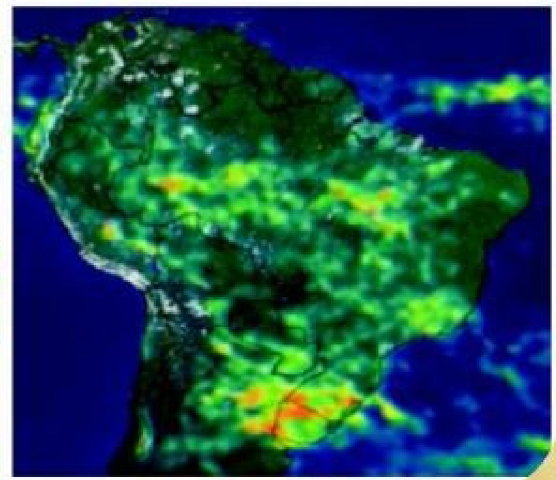


Color map



Color coded image

Blue = low values of rainfall



South America region

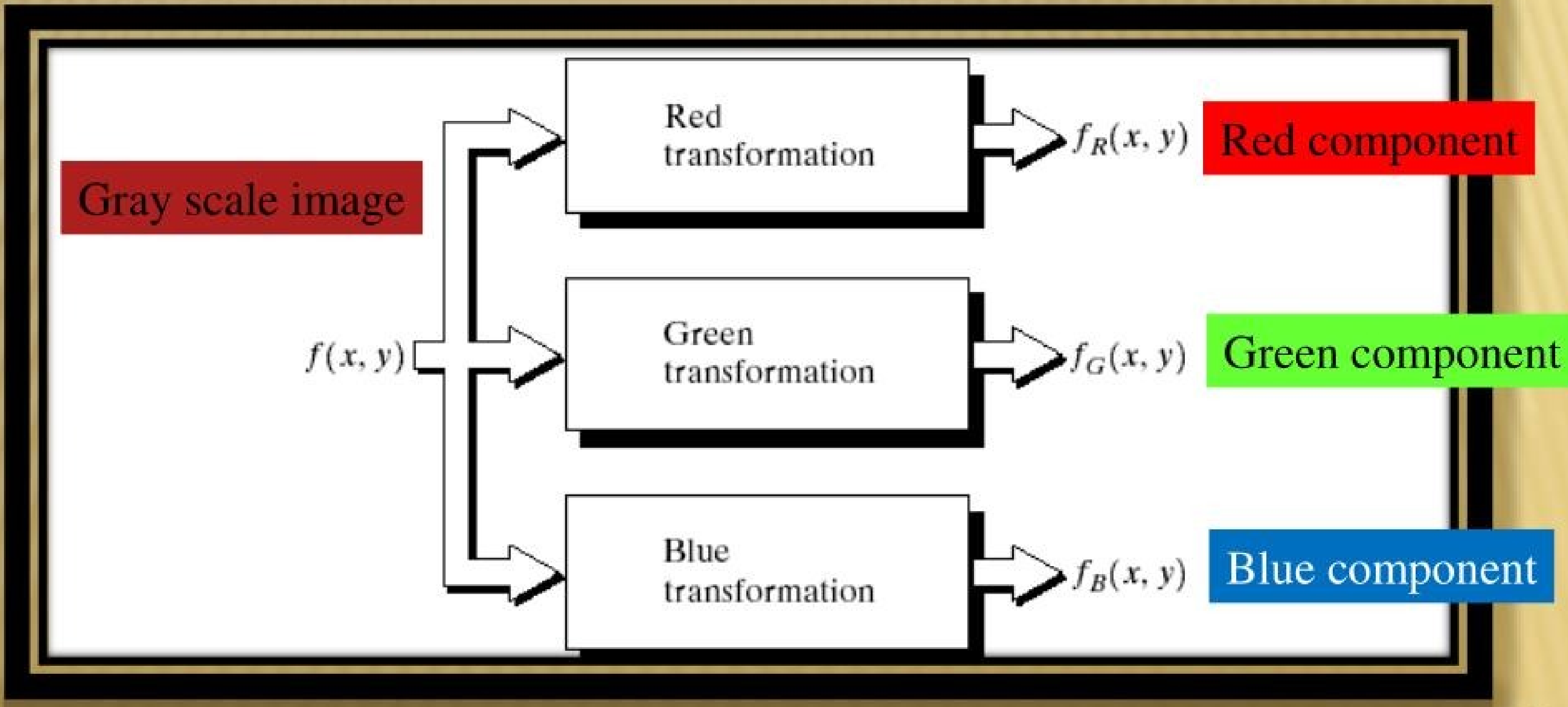
6.3 PSEDUCOLOR IMAGE PROCESSING

Foreword

- 6.3.1 Intensity Slicing
- 6.3.2 Intensity to Color Transformations

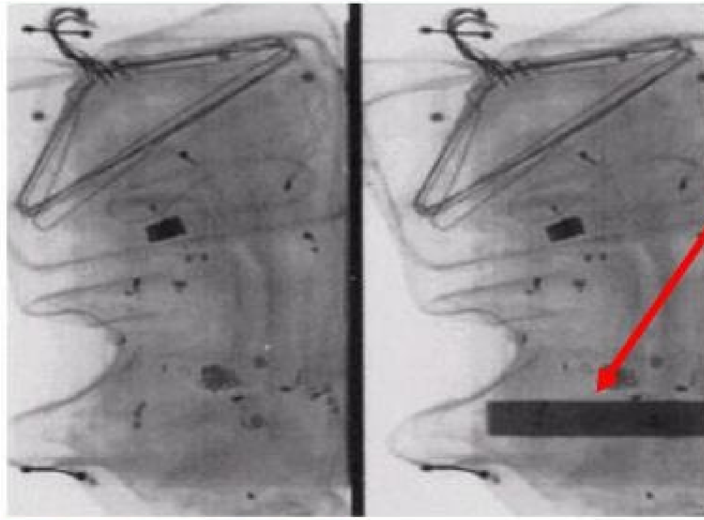
GRAY LEVEL TO COLOR TRANSFORMATION

Assigning colors to gray levels based on specific mapping functions



GRAY LEVEL TO COLOR TRANSFORMATION EXAMPLE

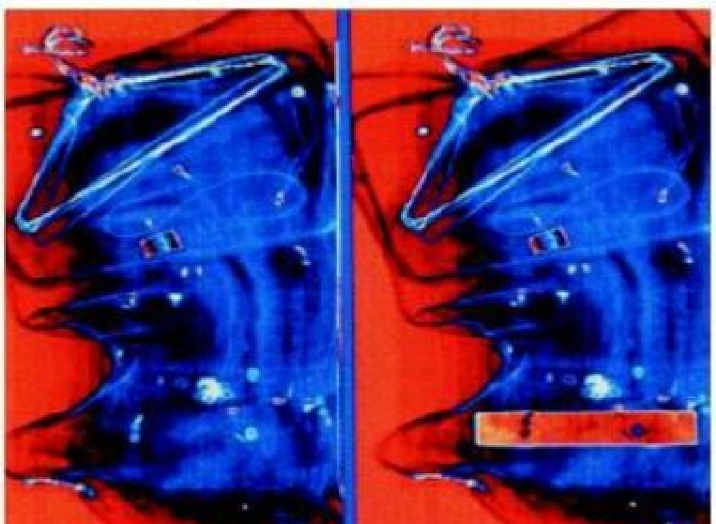
An X-ray image of a garment bag

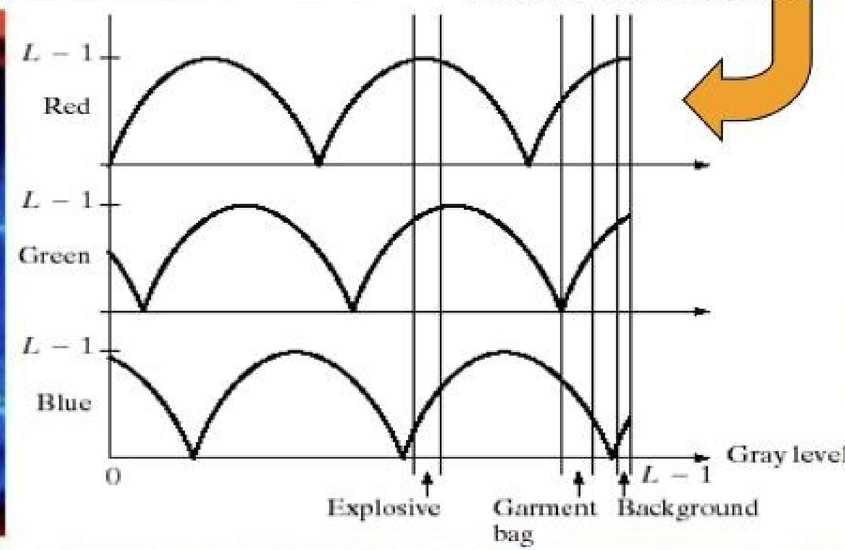


An X-ray image of a garment bag with a simulated explosive device

Transformations

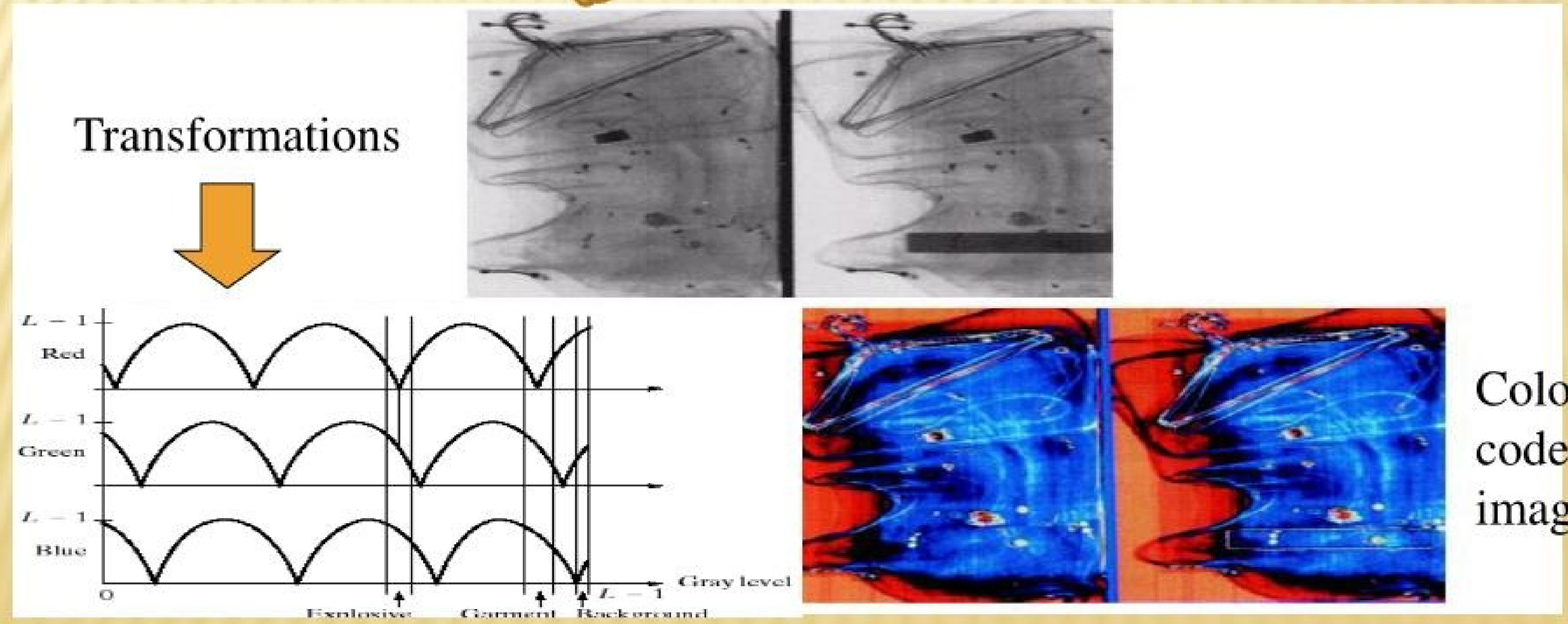
Color coded images



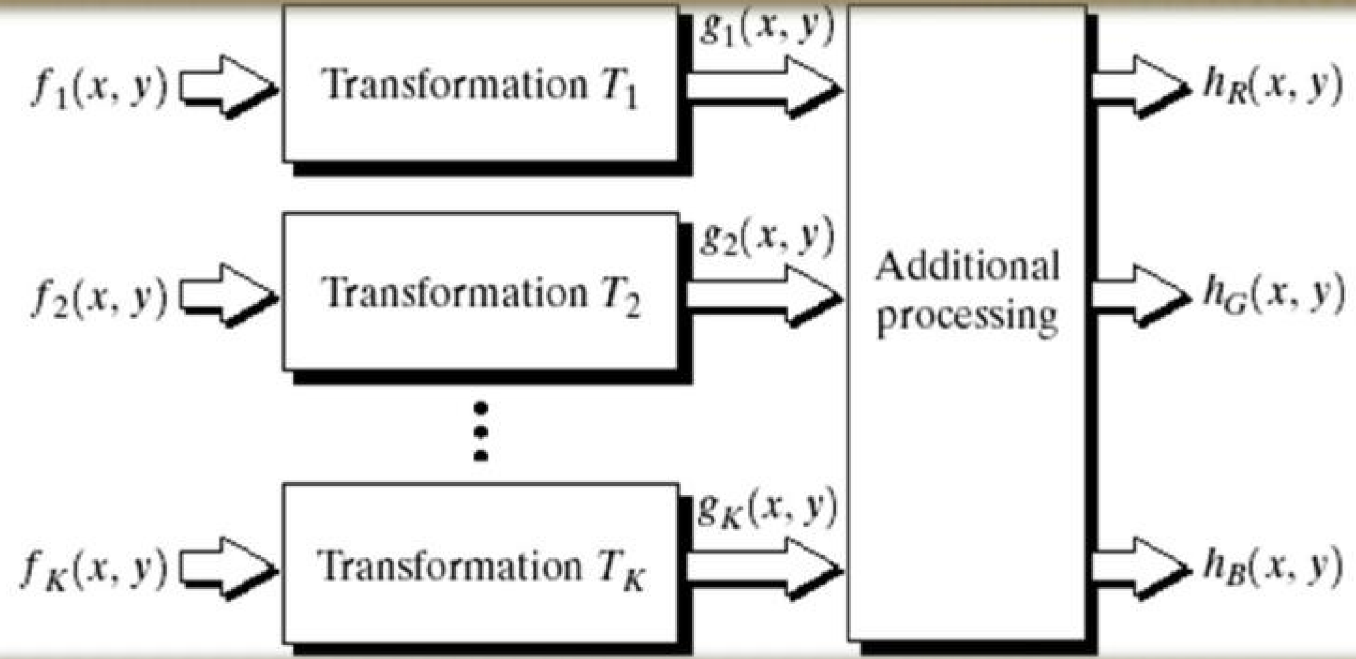


GRAY LEVEL TO COLOR TRANSFORMATION EXAMPLE

Changing the phase and frequency of each sinusoid can emphasize (in color) ranges in the gray scale



PSEUDOCOLOR CODING

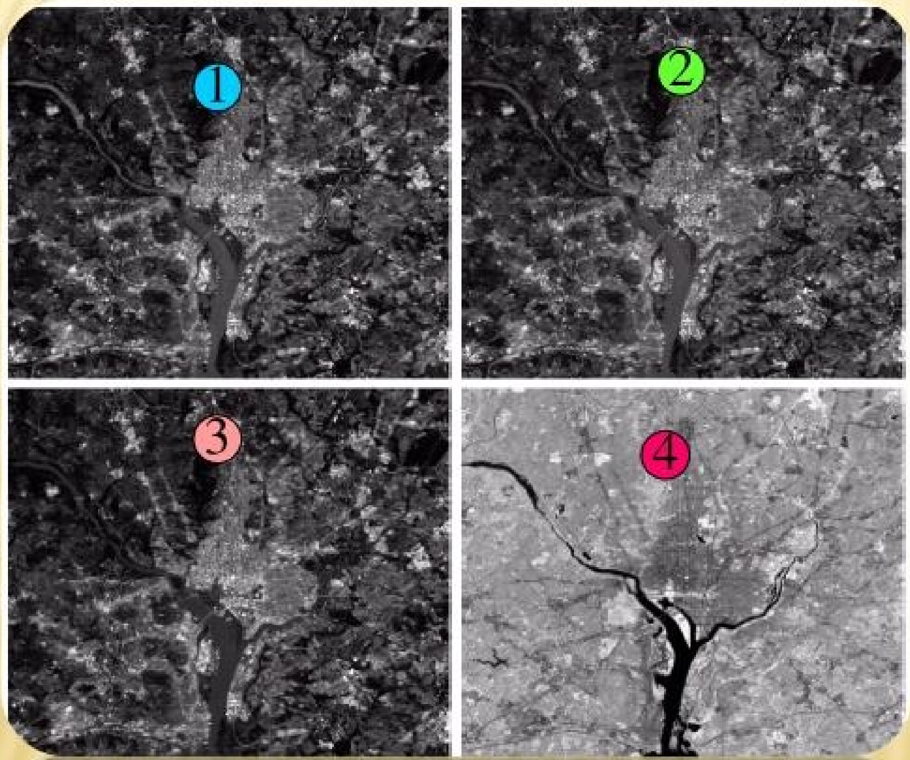


Used in the case where there are many monochrome images such as multispectral satellite images.

PSEUDOCOLOR CODING EXAMPLE

Visible blue
λ= 0.45-0.52 μm
Max water penetration

Visible green
λ= 0.52-0.60 μm
Measuring plant



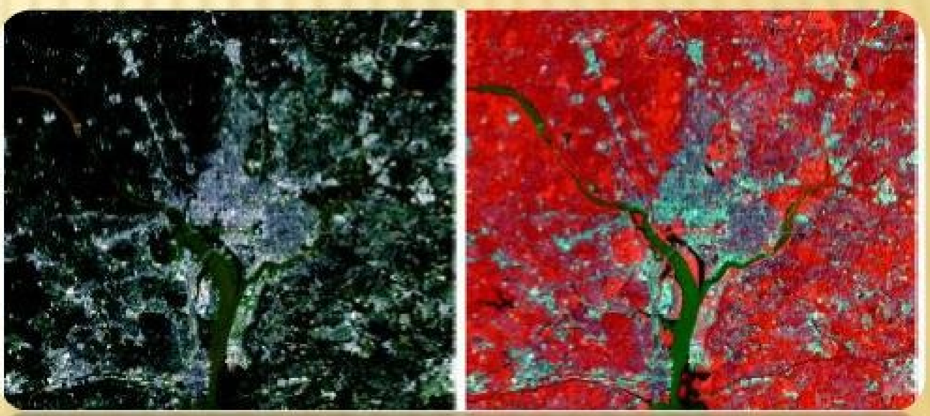
Visible red
λ= 0.63-0.69 μm
Plant discrimination

Near infrared
λ= 0.76-0.90 μm
Biomass and shoreline mapping

Red = 1
Green = 2
Blue = 3

Red = 1
Green = 2
Blue = 4

Color composite images

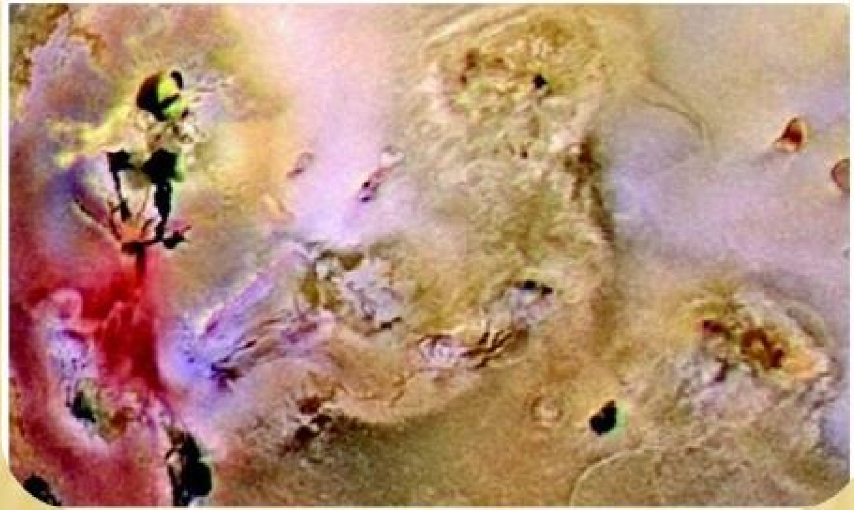


Washington D.C. area

PSEUDOCOLOR CODING EXAMPLE

Psuedocolor rendition of Jupiter moon Io

Yellow areas = older sulfur deposits.
Red areas = material ejected from active volcanoes.



A close-up

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6.4 BASICS OF FULL-COLOR IMAGE PROCESSING

2 Methods:

1. Per-color-component processing:

   process each component separately.

2. Vector processing:

   treat each pixel as a vector to be processed.

Example of per-color-component processing:
smoothing an image by smoothing each RGB component separately.

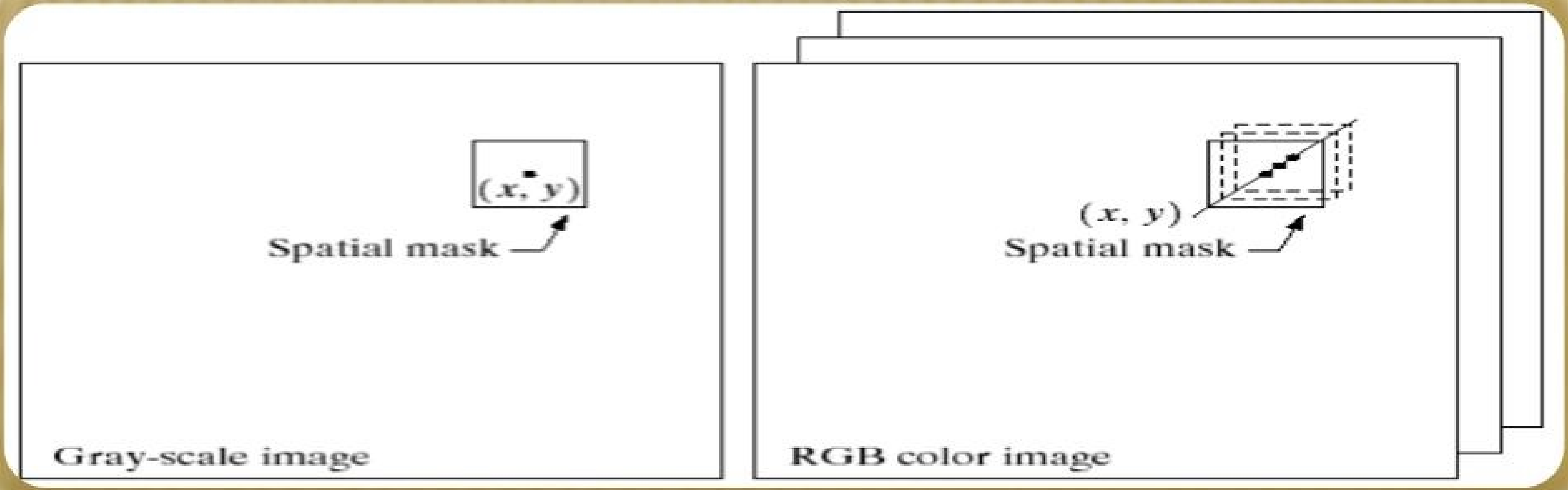
BASICS OF FULL-COLOR IMAGE PROCESSING

- we are interested in image processing techniques formulated in spatial domain :

  For per-color-component= vector-based processing needs conditions:

  1- the process has to be applicable to both vectors and scalars.

  2- the operation on each component of a vector must be independent of the other components



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- ☑ 6.3 Pseudocolor Image Proces
- ☑ 6.4 Basics of Full-Color Image
- ✗ 6.5 Color Transformations
- ✗ 6.6 Smoothing and Sharpenin
- ✗ 6.7 Image Segmentation Base
- ✗ 6.8 Noise in Color Images
- ✗ 6.9 Color Image Compression

6.5 COLOR TRANSFORMATIONS

- 6.5.1 Formulation
- 6.5.2 Color Complements
- 6.5.3 Color Slicing
- 6.5.4 Tone and Color Corrections
- 6.5.5 Histogram Processing

FORMULATION

Use to transform colors to colors.

Formulation: $g(x,y) = T\left[f(x,y)\right]$

$f(x,y)$ = input color image
$g(x,y)$ = output color image
T = operation on f over a spatial neighborhood of (x,y)

When only data at one pixel is used in the transformation, we can express the transformation as:

$$s_i = T_i(r_1, r_2, \ldots, r_n) \qquad i = 1, 2, \ldots, n$$

Where r_i = color component of $f(x,y)$
s_i = color component of $g(x,y)$

For RGB images, $n = 3$

EXAMPLE:
FULL-COLOR IMAGE AND VARIOUIS COLOR SPACE COMPONENTS

Color image

CMYK components

RGB components

HSI components

EXAMPLE: COLOR TRANSFORMATION

Formula for RGB:

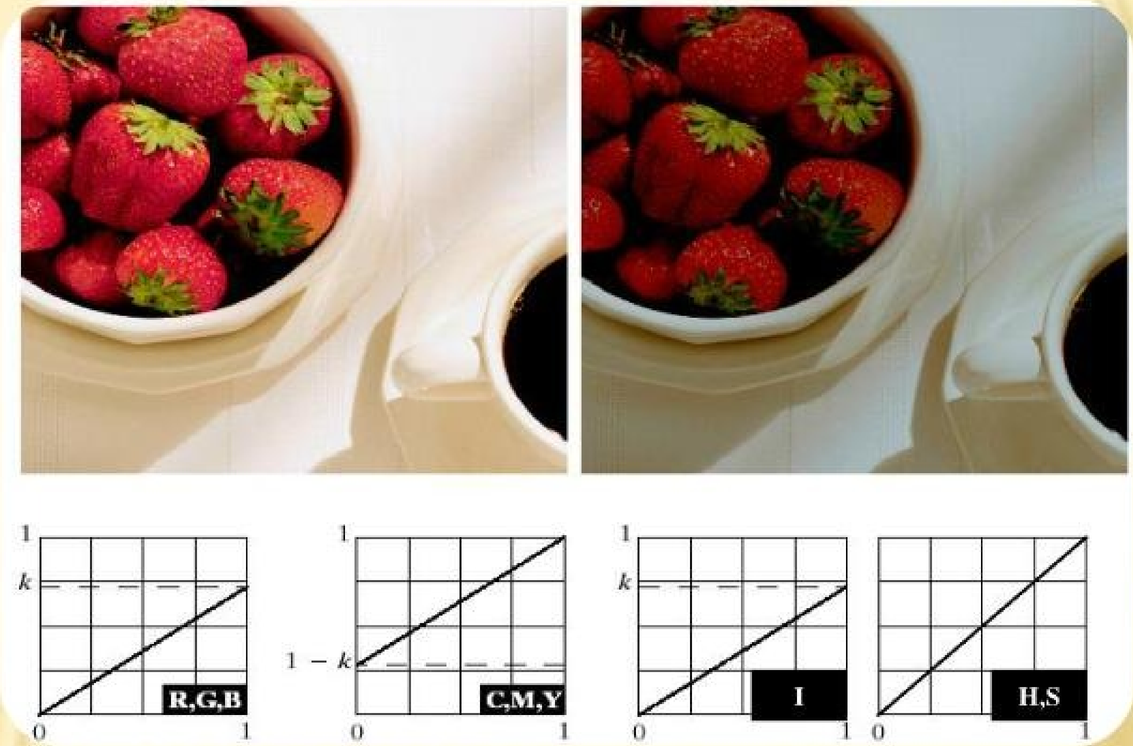
$$s_R(x, y) = kr_R(x, y)$$
$$s_G(x, y) = kr_G(x, y)$$
$$s_B(x, y) = kr_B(x, y)$$

Formula for HSI:

$$s_I(x, y) = kr_I(x, y)$$

Formula for CMY:

$$s_C(x, y) = kr_C(x, y) + (1 - k)$$
$$s_M(x, y) = kr_M(x, y) + (1 - k)$$
$$s_Y(x, y) = kr_Y(x, y) + (1 - k)$$



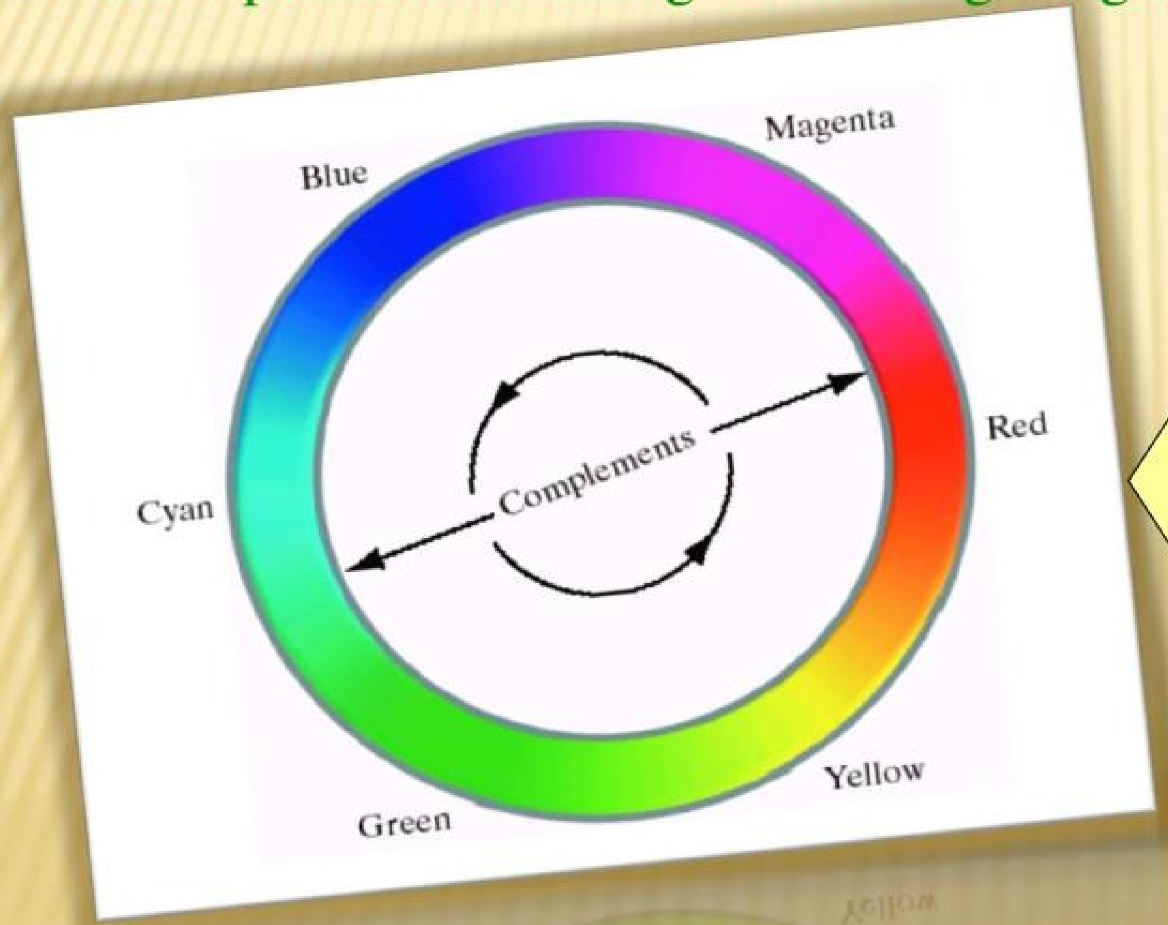
These 3 transformations give the same results.

6.5 COLOR TRANSFORMATIONS

- ☑ 6.5.1 Formulation
- 6.5.2 Color Complements
- 6.5.3 Color Slicing
- 6.5.4 Tone and Color Corrections
- 6.5.5 Histogram Processing

COLOR COMPLEMENTS

- Color complement replaces each color with its opposite color in the color circle of the Hue component.
- This operation is analogous to image negative in a gray scale image.



Color circle

COLOR COMPLEMENT TRANSFORMATION EXAMPLE

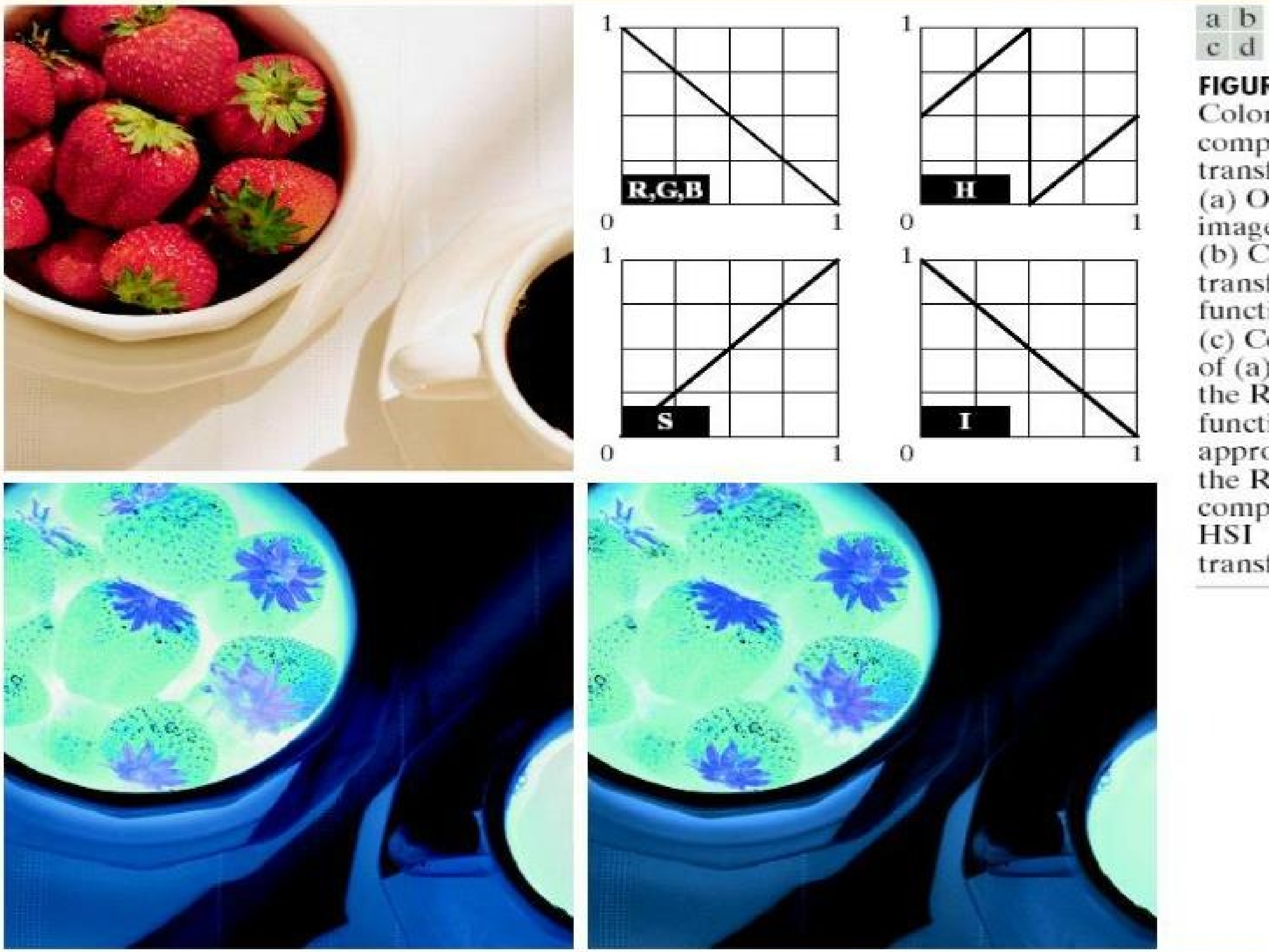


FIGURE 6.33 Color complement transformations. (a) Original image. (b) Complement transformation functions. (c) Complement of (a) based on the RGB mapping functions. (d) An approximation of the RGB complement using HSI transformations.

6.5 COLOR TRANSFORMATIONS

- ☑ 6.5.1 Formulation
- ☑ 6.5.2 Color Complements
- ✖ 6.5.3 Color Slicing
- ✖ 6.5.4 Tone and Color Corrections
- ✖ 6.5.5 Histogram Processing

COLOR SLICING TRANSFORMATION

- We can perform "slicing" in color space:

 if the color of each pixel is far from a desired color more than threshold distance, we set that color to some specific color such as gray, otherwise we keep the original color unchanged.

$$s_i = \begin{cases} 0.5 & \text{if } \left[\left| r_j - a_j \right| > \frac{W}{2} \right]_{any\ 1 \le j \le n} \\ r_i & \text{otherwise} \end{cases}$$

→ Set to gray

→ Keep the original color

$i = 1, 2, \ldots, n$

or

$$s_i = \begin{cases} 0.5 & \text{if } \sum_{j=1}^{n} \left(r_j - a_j \right)^2 > R_0^2 \\ r_i & \text{otherwise} \end{cases}$$

→ Set to gray

→ Keep the original color

$i = 1, 2, \ldots, n$

COLOR SLICING TRANSFORMATION EXAMPLE

After color slicing

Original image

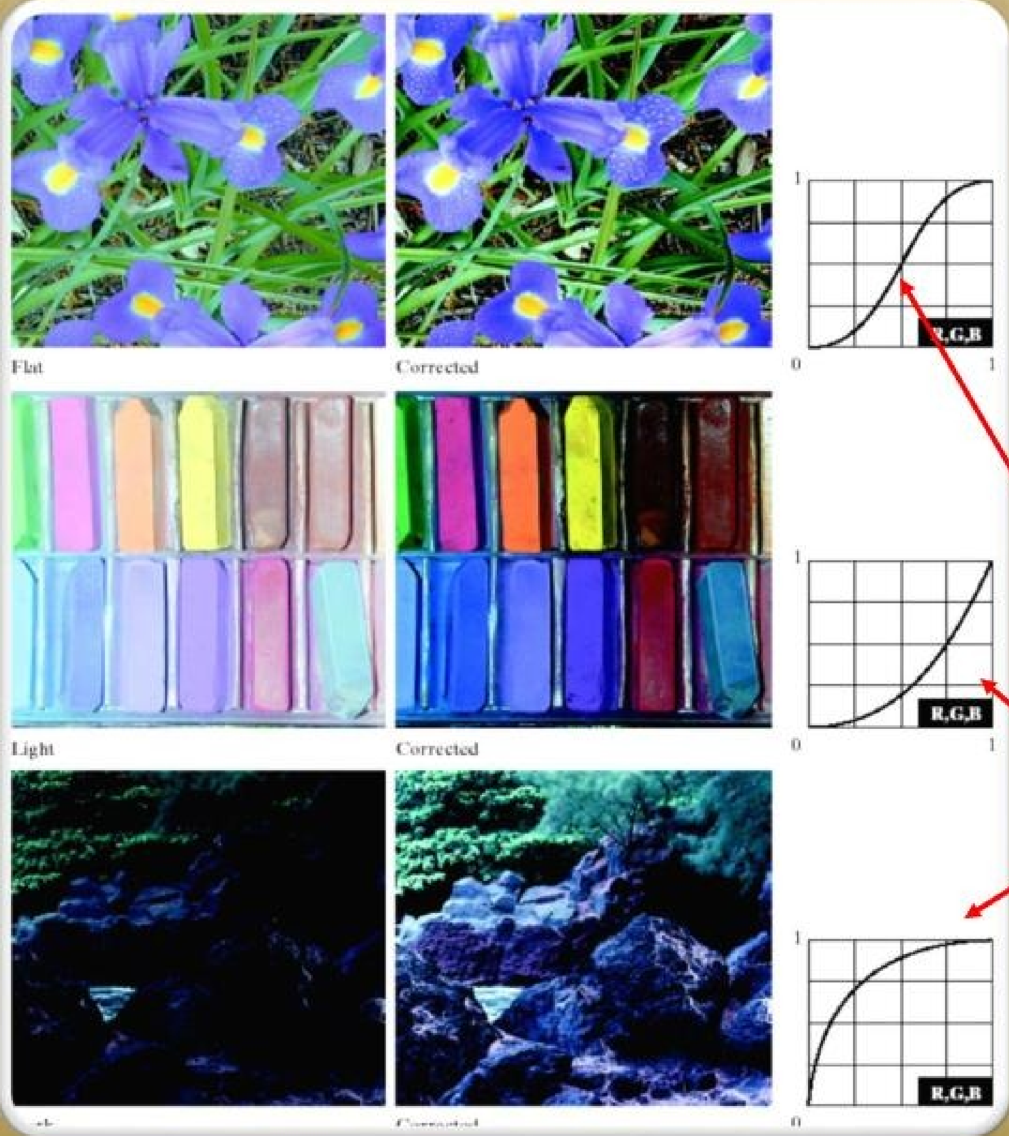
a b

FIGURE 6.34 Color slicing transformations that detect (a) reds within an RGB cube of width $W = 0.2549$ centered at (0.6863, 0.1608, 0.1922), and (b) reds within an RGB sphere of radius 0.1765 centered at the same point. Pixels outside the cube and sphere were replaced by color (0.5, 0.5, 0.5).

6.5 COLOR TRANSFORMATIONS

- ☑ 6.5.1 Formulation
- ☑ 6.5.2 Color Complements
- ☑ 6.5.3 Color Slicing
- ✖ 6.5.4 Tone and Color Corrections
- ✖ 6.5.5 Histogram Processing

TONAL CORRECTION EXAMPLES

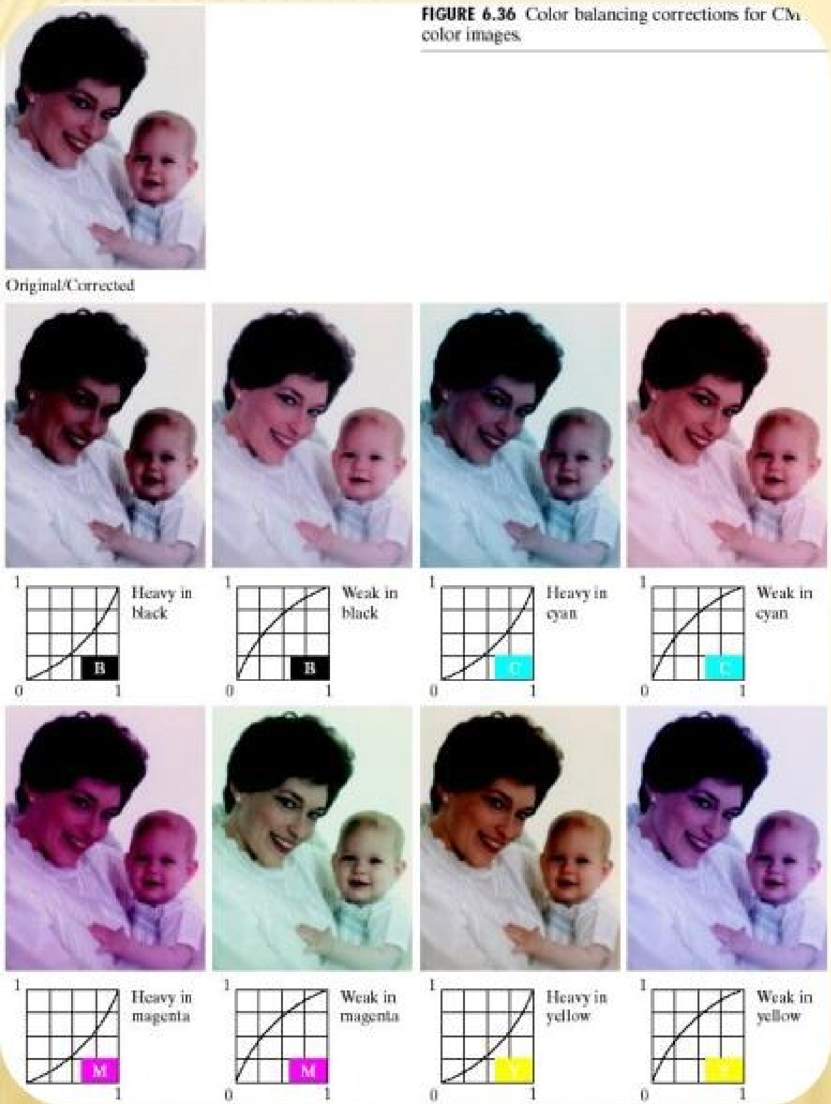


- In these examples, only brightness and contrast are adjusted while keeping color unchanged.
- This can be done by using the same transformation for all RGB components.

Contrast enhancement

Power law transformations

COLOR BALANCING CORRECTION EXAMPLES

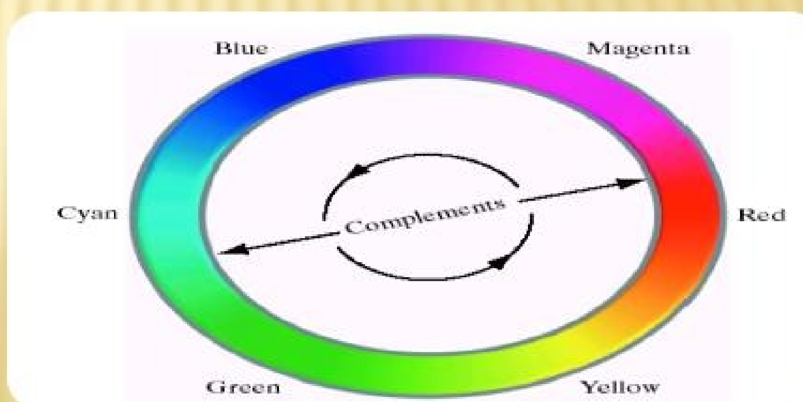


- Color imbalance:

primary color components in white area are not balance.

- We can measure these components by using a color pectrometer.

- Color balancing can be performed by adjusting color components separately as seen in this slide.



6.5 COLOR TRANSFORMATIONS

- ☑ 6.5.1 Formulation
- ☑ 6.5.2 Color Complements
- ☑ 6.5.3 Color Slicing
- ☑ 6.5.4 Tone and Color Corrections
- ✖ 6.5.5 Histogram Processing

HISTOGRAM EQUALIZATION OF A FULL-COLOR IMAGE

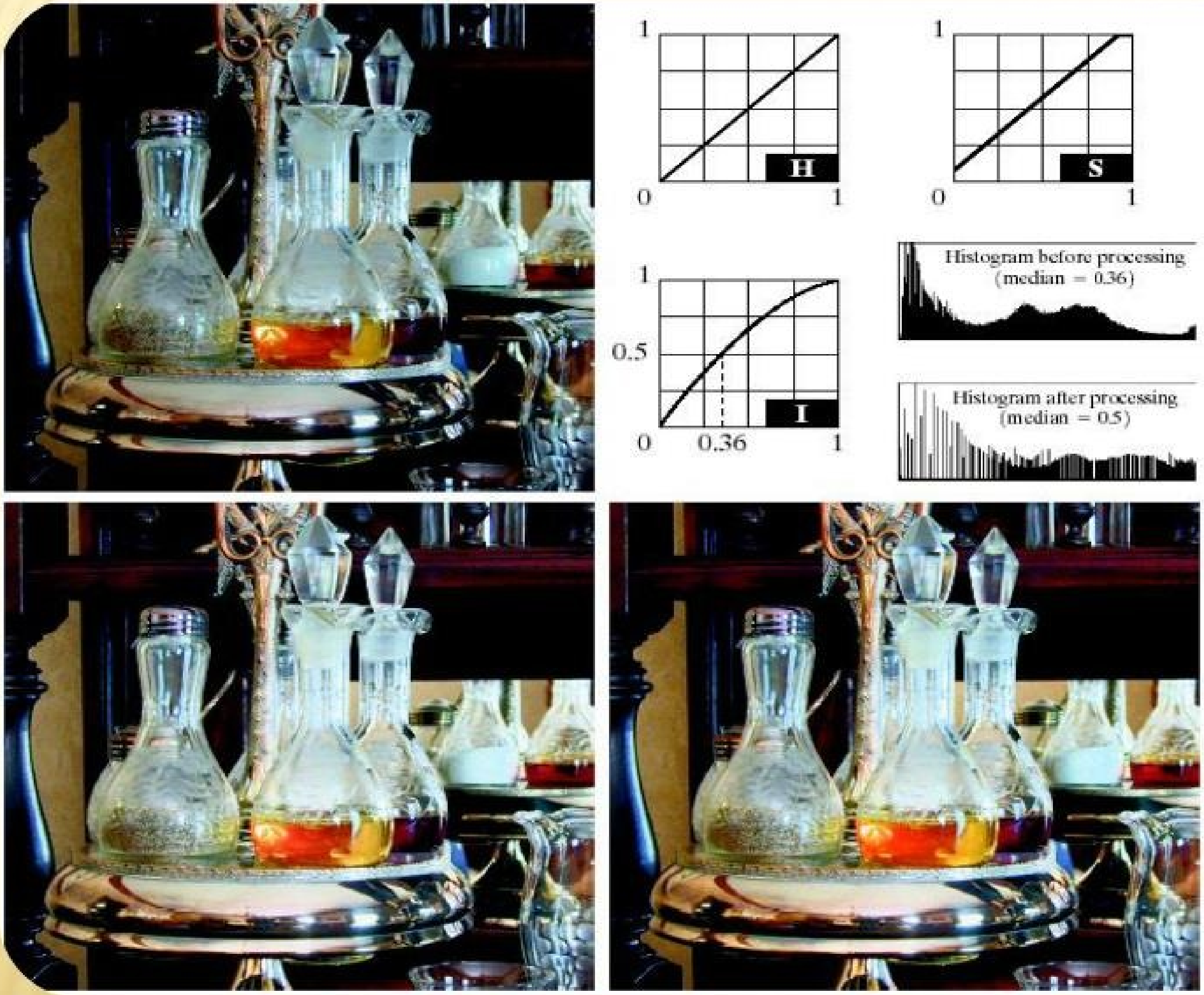
- Histogram equalization of a color image can be performed by adjusting color intensity uniformly while leaving color unchanged.

- The HSI model is suitable for histogram equalization where only Intensity (I) component is equalized.

HISTOGRAM EQUALIZATION OF A FULL-COLOR IMAGE

Original image

After histogram equalization



a b
c d

FIGURE 6.37 Histogram equalization (followed by saturation adjustment) in the HSI color space.

After increasing saturation component

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6.6 SMOOTHING AND SHARPENING

- 6.6.1 Color Image Smoothing
- 6.6.2 Color Image Sharpening

COLOR IMAGE SMOOTHING

2 Methods:

1. Per-color-plane method:

for RGB, CMY color models Smooth each color plane using moving averaging and the combine back to RGB

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

2. Smooth only Intensity component

of a HSI image while leaving H and S unmodified.

Note: 2 methods are not equivalent.

COLOR IMAGE SMOOTHING EXAMPLE (CONT.)

Color image

Red

Green

Blue

COLOR IMAGE SMOOTHING EXAMPLE (CONT.)

Color image

HSI Components

COLOR IMAGE SMOOTHING EXAMPLE (CONT.)

Smooth all RGB components

Smooth only I component of HSI

COLOR IMAGE SMOOTHING EXAMPLE (CONT.)

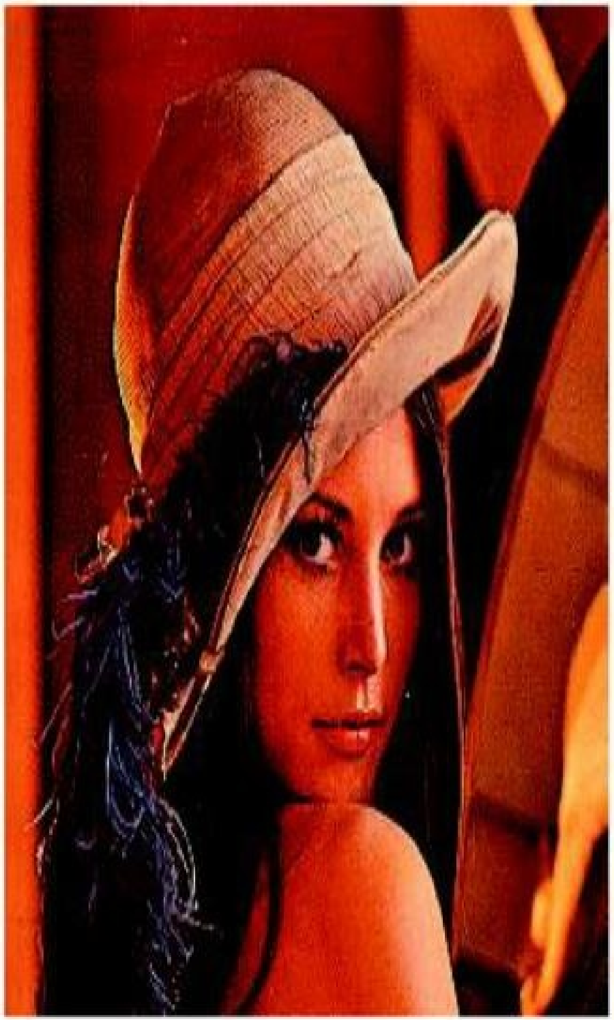
Difference between smoothed results from 2 methods in the previous slide.

6.6 SMOOTHING AND SHARPENING

- ☑ 6.6.1 Color Image Smoothing
- 6.6.2 Color Image Sharpening

COLOR IMAGE SHARPENING

Sharpening all RGB components



Sharpening only I component of HSI

We can do in the same manner as color image smoothing:

1. Per-color-plane method for RGB,CMY images

2. Sharpening only I component of a HSI image

COLOR IMAGE SHARPENING EXAMPLE (CONT.)

Difference between sharpened results from 2 methods in the previous slide.

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6.7 IMAGE SEGMENTATION BASED ON COLOR

Foreword

COLOR SEGMENTATION

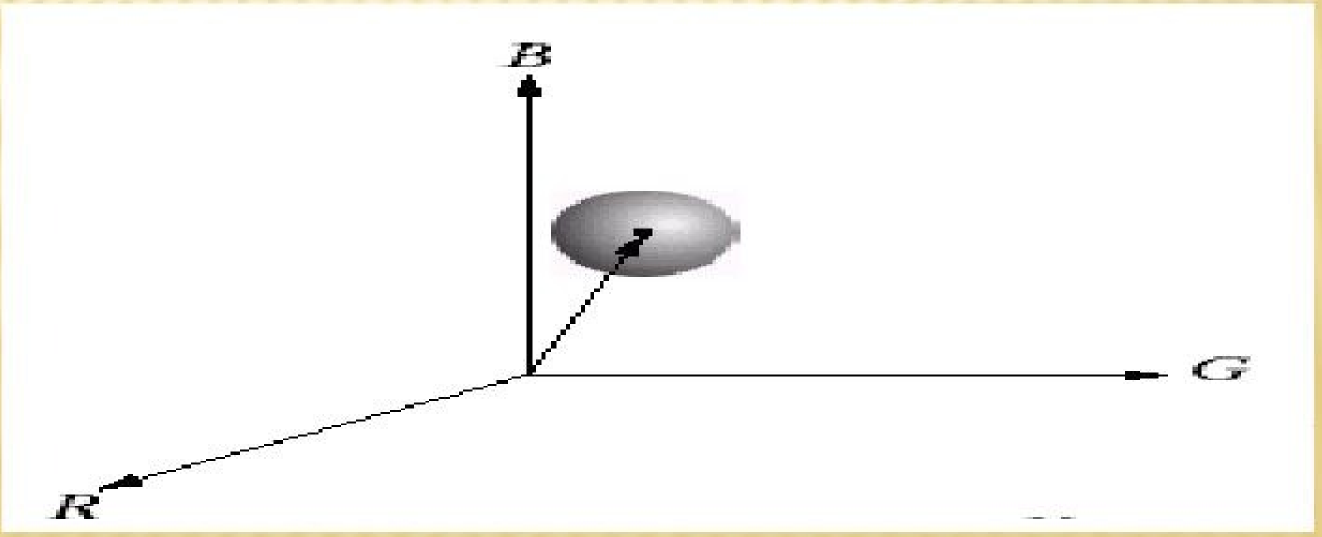
2 Methods:

1. Segmented in HSI color space:

   A thresholding function based on color information in H and S Components. We rarely use I component for color image segmentation.

2. Segmentation in RGB vector space:

   A thresholding function based on distance in a color vector space.

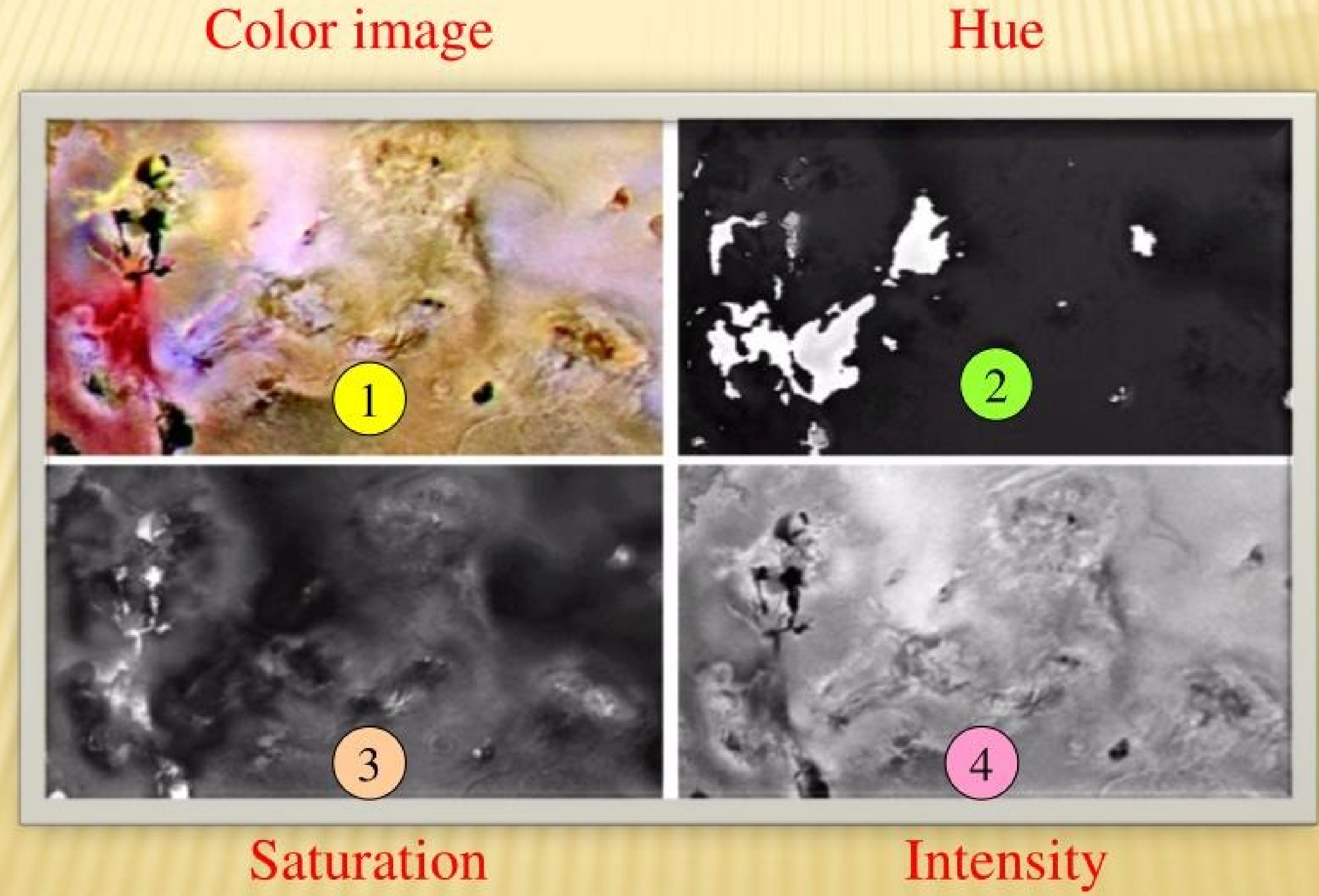


6.7 IMAGE SEGMENTATION BASED ON COLOR

Foreword

- 6.7.1 Segmentation in HIS Color Space
- 6.7.2 Segmentation in RGB Vector Space
- 6.7.3 Color Edge Detection

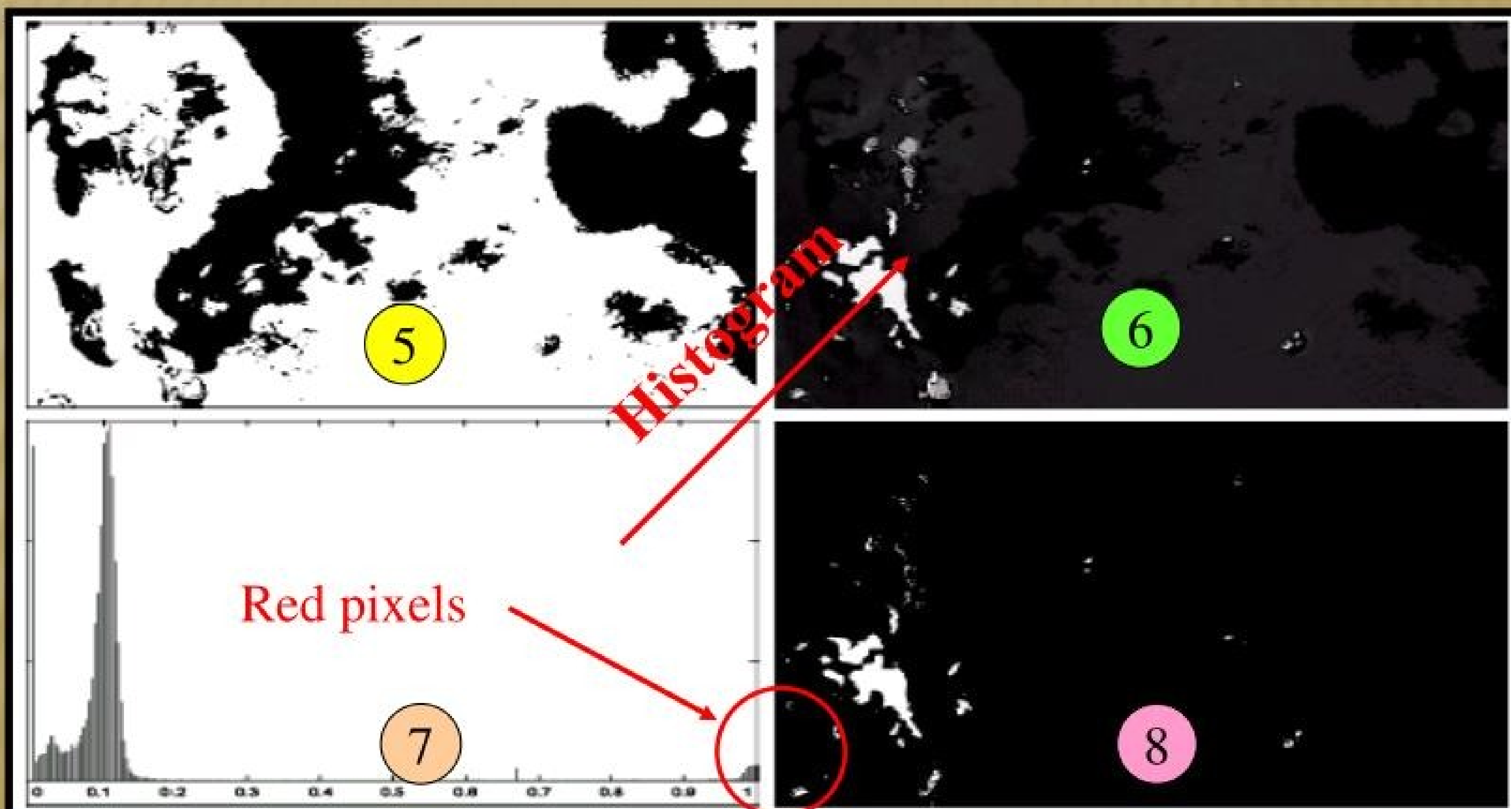
COLOR SEGMENTATION IN HSI COLOR SPACE



COLOR SEGMENTATION IN HSI COLOR SPACE (CONT.)

Binary thresholding of S component with T = 10%

Product of 2 and 5



Segmentation of red color pixels

COLOR SEGMENTATION IN HSI COLOR SPACE (CONT.)

Color image

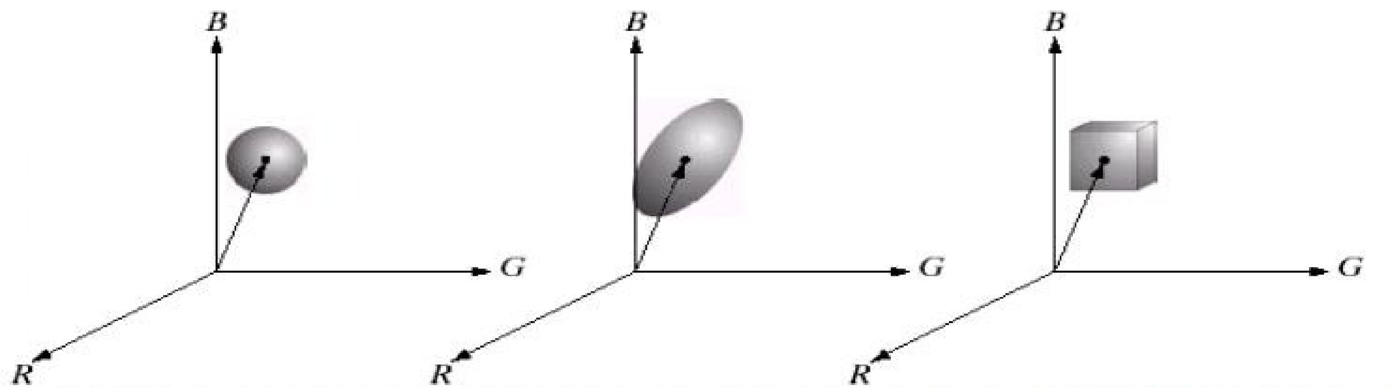
Segmented results of red pixels

6.7 IMAGE SEGMENTATION BASED ON COLOR

Foreword

- ☑ 6.7.1 Segmentation in HIS Color Space
- 6.7.2 Segmentation in RGB Vector Space
- 6.7.3 Color Edge Detection

COLOR SEGMENTATION IN RGB VECTOR SPACE



a b c

FIGURE 6.43 Three approaches for enclosing data regions for RGB vector segmentation.

1. Each point with (R,G,B) coordinate in the vector space represents one color.
2. Segmentation is based on distance thresholding in a vector space

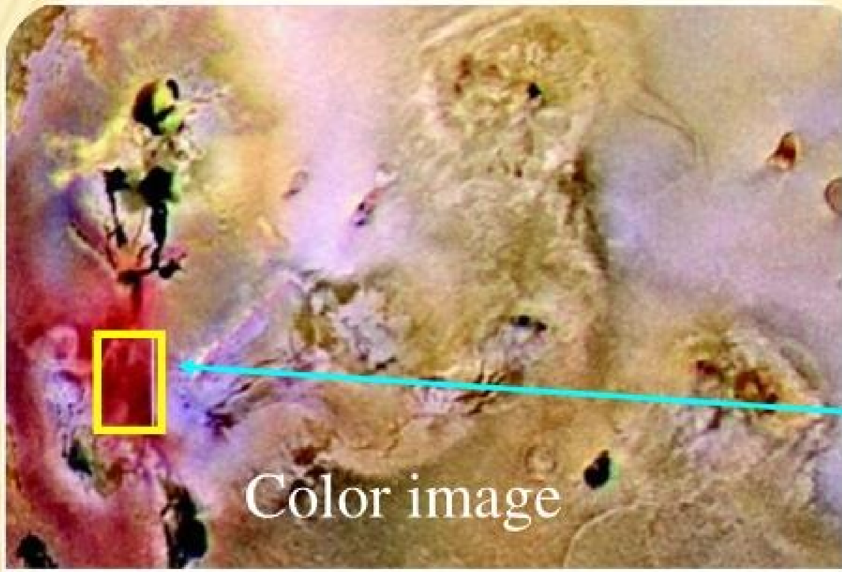
$$g(x,y) = \begin{cases} 1 & \text{if } D(\mathbf{c}(x,y), \mathbf{c}_T) \le T \\ 0 & \text{if } D(\mathbf{c}(x,y), \mathbf{c}_T) > T \end{cases}$$

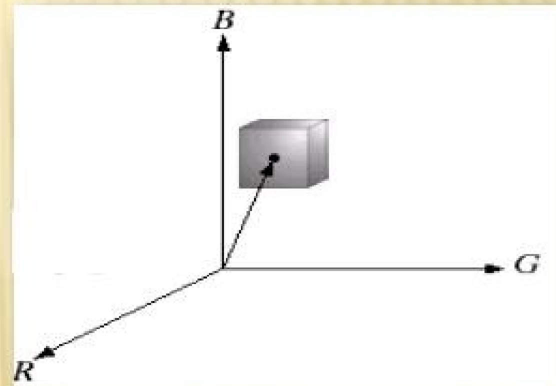
$D(\mathbf{u},\mathbf{v})$ = distance function

$\mathbf{c}_T$ = color to be segmented.

$\mathbf{c}(x,y)$ = RGB vector at pixel (x,y).

EXAMPLE: SEGMENTATION IN RGB VECTOR SPACE





Reference color $\mathbf{c}_T$ to be segmented

$\mathbf{c}_T$ = average color of pixel in the box

- Results of segmentation in RGB vector space with Threshold value

T = 1.25 times the SD of R,G,B values In the box

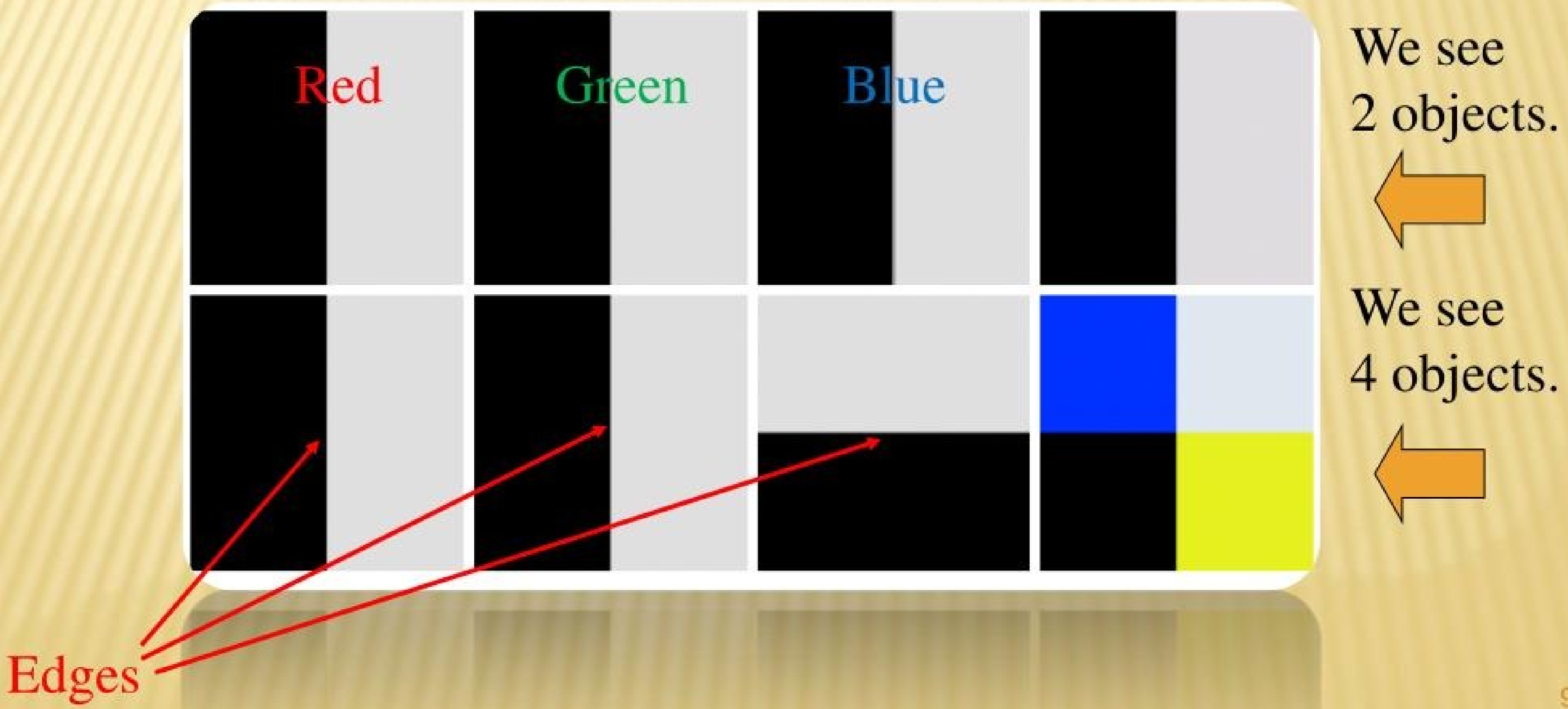
6.7 IMAGE SEGMENTATION BASED ON COLOR

Foreword

- ☑ 6.7.1 Segmentation in HIS Color Space
- ☑ 6.7.2 Segmentation in RGB Vector Space
- ✖ 6.7.3 Color Edge Detection

GRADIENT OF A COLOR IMAGE

- Since gradient is define only for a scalar image, there is no concept of gradient for a color image.
- We can't compute gradient of each color component and combine the results to get the gradient of a color image.



GRADIENT OF A COLOR IMAGE (CONT.)

One way to compute the maximum rate of change of a color image which is close to the meaning of gradient is to use the following formula: Gradient computed in RGB color space:

$$F(\theta) = \left\{ \frac{1}{2} \left[(g_{xx} + g_{yy}) + (g_{xx} - g_{yy}) \cos 2\theta + 2 g_{xy} \sin 2\theta \right] \right\}^{\frac{1}{2}}$$

$$\theta = \frac{1}{2} \tan^{-1} \left[\frac{2 g_{xy}}{(g_{xx} - g_{yy})} \right]$$

$$g_{xx} = \left| \frac{\partial R}{\partial x} \right|^2 + \left| \frac{\partial G}{\partial x} \right|^2 + \left| \frac{\partial B}{\partial x} \right|^2$$

$$g_{yy} = \left| \frac{\partial R}{\partial y} \right|^2 + \left| \frac{\partial G}{\partial y} \right|^2 + \left| \frac{\partial B}{\partial y} \right|^2$$

$$g_{xy} = \frac{\partial R}{\partial x} \frac{\partial R}{\partial y} + \frac{\partial G}{\partial x} \frac{\partial G}{\partial y} + \frac{\partial B}{\partial x} \frac{\partial B}{\partial y}$$

GRADIENT OF A COLOR IMAGE EXAMPLE

Original image

Obtained using the formula in the previous slide

Sum of gradients of each color component

Difference between 2 and 3

GRADIEEXAMPLENT OF A COLOR IMAGE

Gradients of each color component

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6.8 NOISE IN COLOR IMAGES

NOISE IN COLOR IMAGES

Noise can corrupt each color component independently.

FIGURE 6.48
(a)–(c) Red, green, and blue component images corrupted by additive Gaussian noise of mean 0 and variance 800. (d) Resulting RGB image. [Compare (d) with Fig. 6.46(a).]

Noise is less noticeable in a color image

NOISE IN COLOR IMAGES

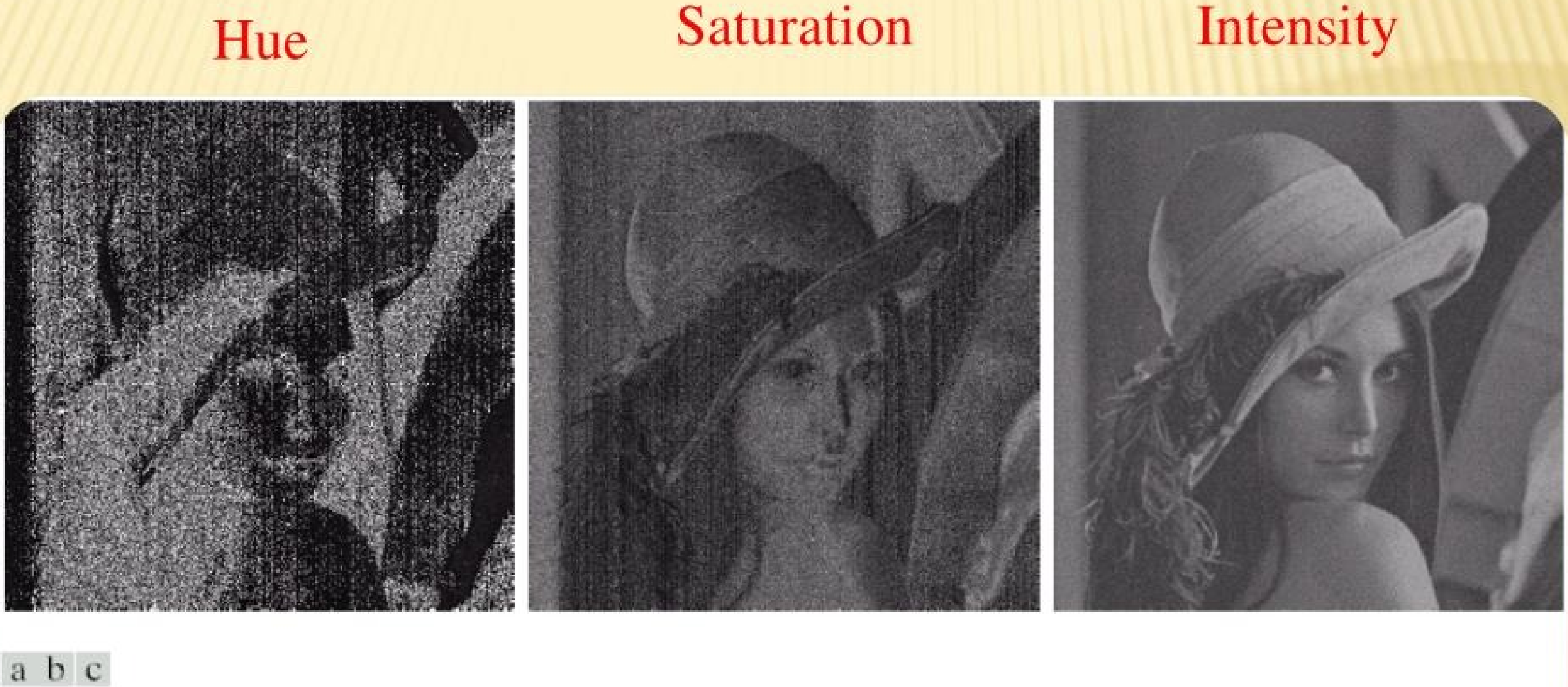

FIGURE 6.49 HSI components of the noisy color image in Fig. 6.48(d). (a) Hue. (b) Saturation. (c) Intensity.

NOISE IN COLOR IMAGES

FIGURE 6.50 (a) RGB image with green plane corrupted by salt-and-pepper noise. (b) Hue component of HSI image. (c) Saturation component. (d) Intensity component.

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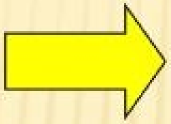
6.9 COLOR IMAGE COMPRESSION

COLOR IMAGE COMPRESSION

JPEG2000 File



Original image

After lossy compression with ratio 230:1

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THE END

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