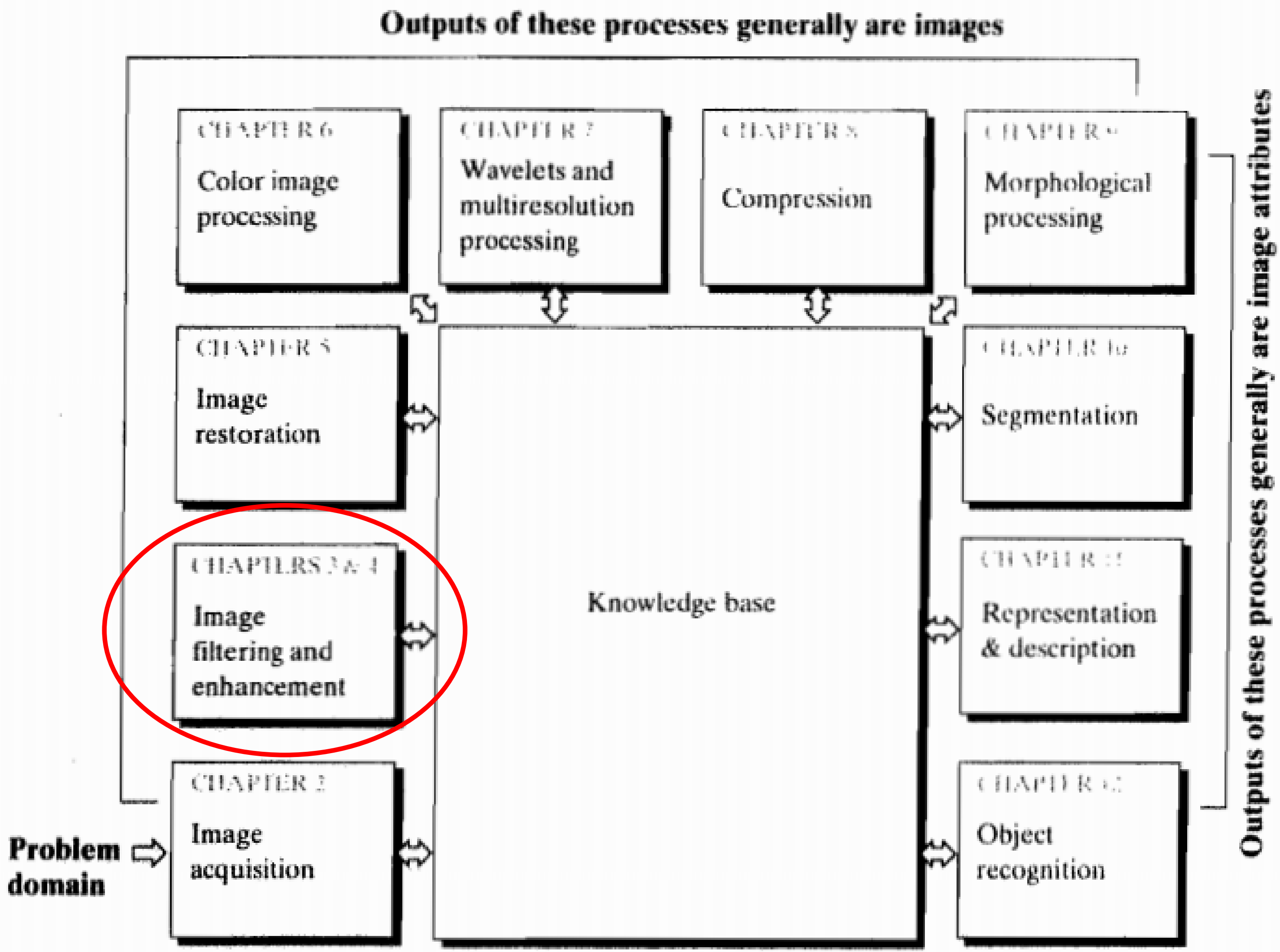
# Chapter 6

# Color Image Processing

# Remember?

**FIGURE 1.23** Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.



# Color Image Processing

## Background

- In automated image analysis, color is a powerful descriptor, which simplifies object identification and extraction.

- The human eye can distinguish between thousands of color shades and intensities but only about 20-30 shades of gray. Hence, use of color in human image processing would be very effective.

# Color Image Processing

# Color Image Processing

In color theory,

- **Tint** is a mixture of a color with white, which reduces darkness,
- **Shade** is a mixture with black, which increases darkness.
- **Intensity** refers to the degree of purity of a color. A highly intense color is bright and a low-intensity color is more neutral or muted.

# Color Image Processing

Color image processing consists of two parts:

- Pseudo-color processing and
- Full color processing.

# Color Image Processing

In **pseudo-color processing**, (false) colors are assigned to a monochrome image.

- Monochrome images consist of only black and white colors. The **color code** will be RGB(0,0,0) for black and RGB(255,255,255) for white.
- A **monochromic** image is composed of one color (or **values** of one color), more likely grayscale image
- A **false-color image** is an image that depicts an object in colors that differ from those a photograph (a **true-color image**) would show.

# Color Image Processing

# Color Image Processing

This true-color image shows the area in actual colors, e.g., the vegetation appears in green. It covers the full visible spectrum using the red, green and blue / green spectral bands of the satellite mapped to the RGB color space of the image.

The same area as a false-color image using the near infrared, red and green spectral bands mapped to RGB – this image shows vegetation in a red tone, as vegetation reflects most light in the near infrared.

# Color Image Processing

- In full-color processing, images are acquired with full color sensors/cameras.

- This has become common in the last decade or so, due to the easy and cheap availability of color sensors and hardware.

# Color Image Processing

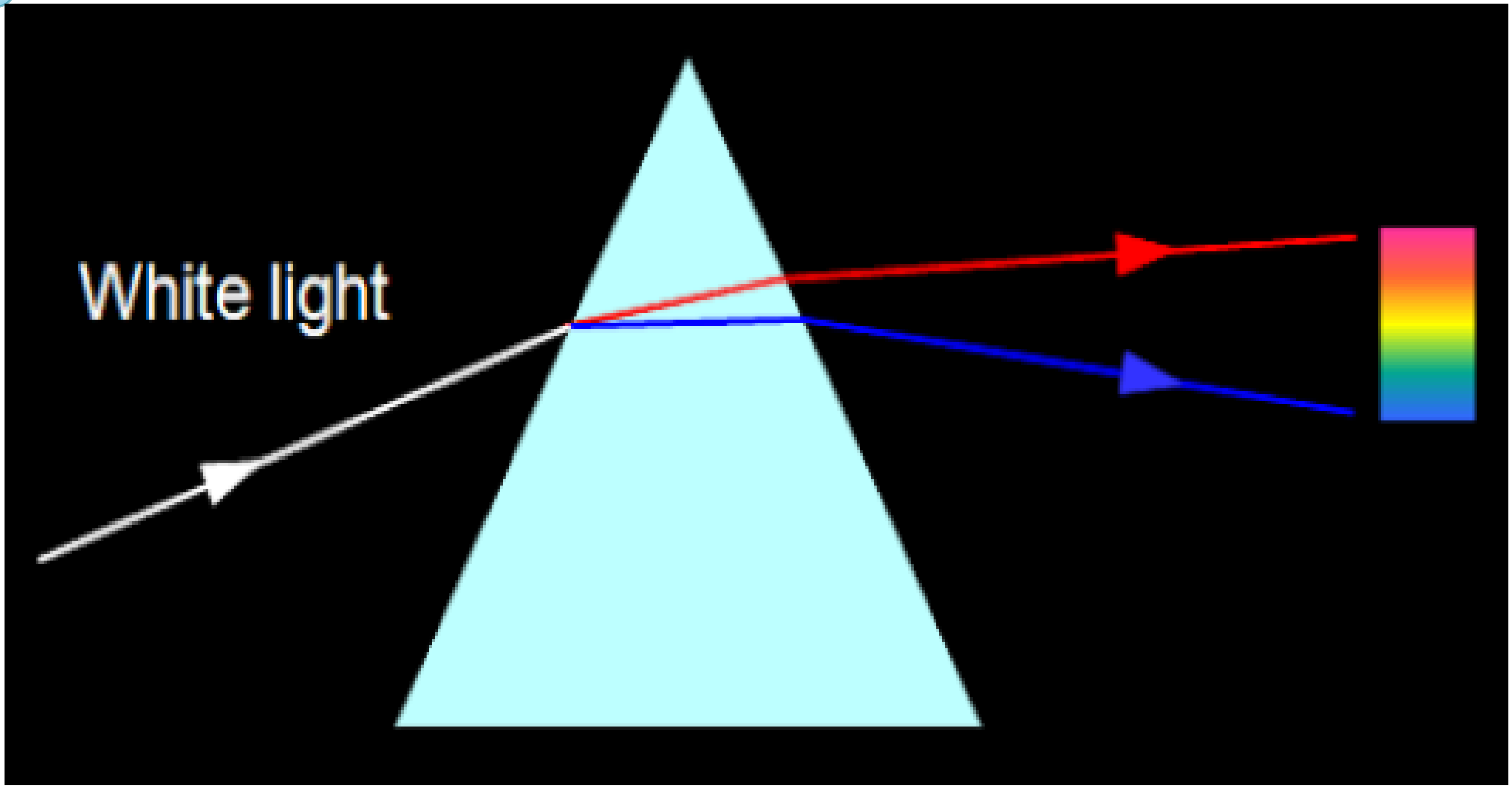
# Color Fundamentals

When a beam of sunlight is passed through a glass prism, the emerging beam of light is not white but consists of a continuous spectrum of colors (Sir Isaac Newton, 1666).

**color spectrum** - the distribution of **colors** produced when light is dispersed by a prism.

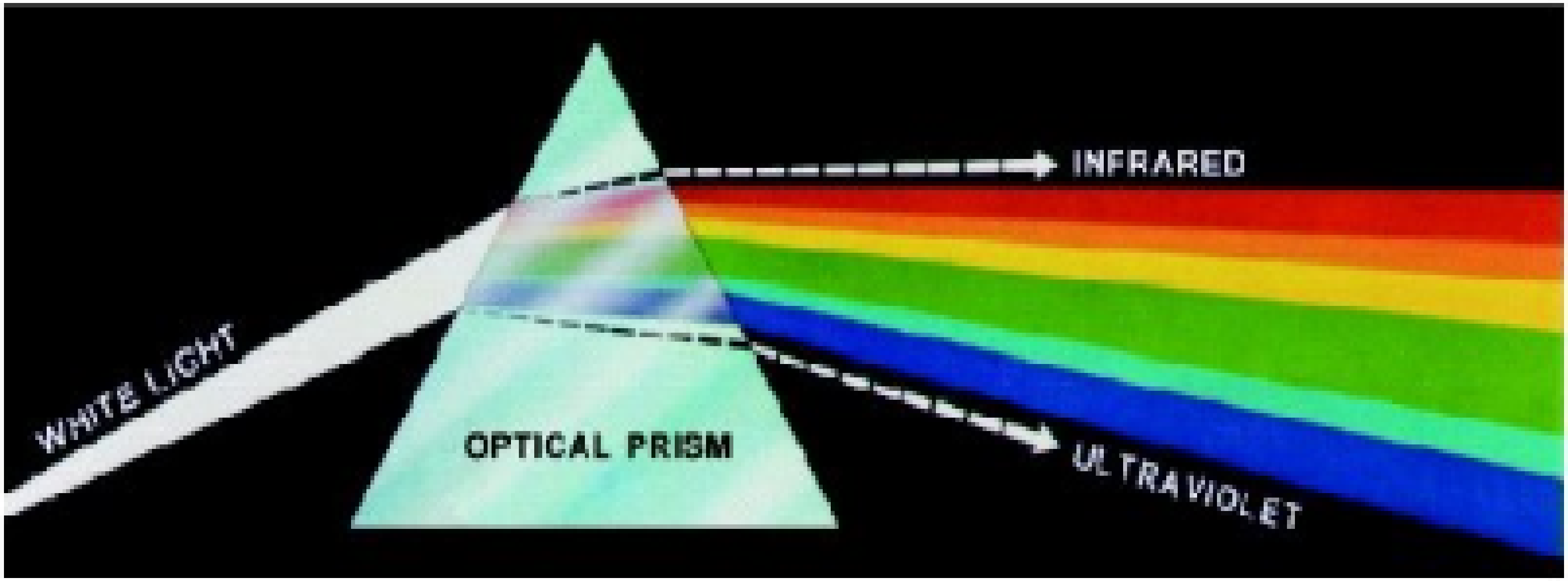
The color spectrum can be divided into six broad regions: violet, blue, green, yellow, orange, and red.

# Color spectrum/prism

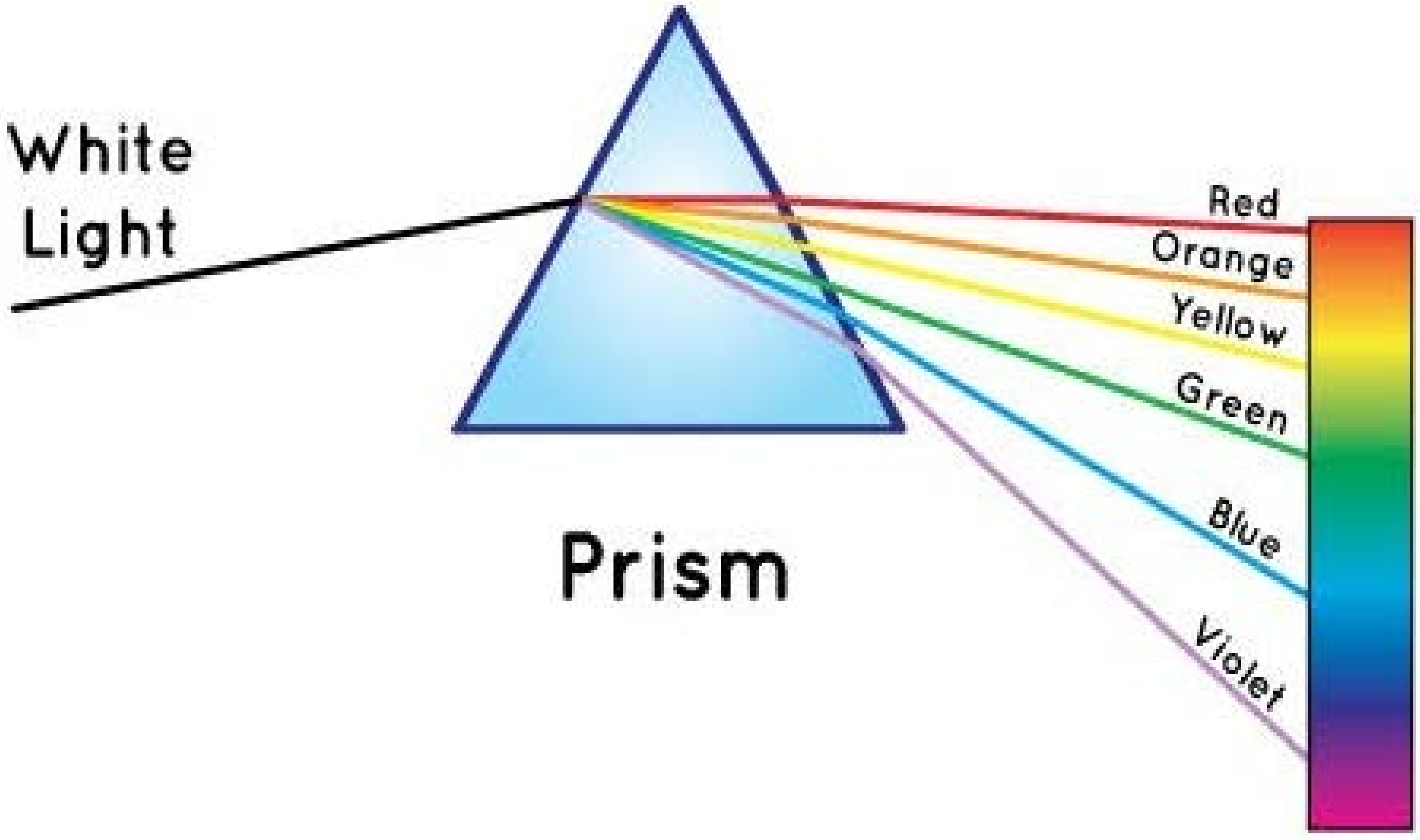


# Color spectrum/prism

- When passing through a prism, a beam of sunlight is decomposed into a spectrum of colors : violet, blue, green, yellow, orange, red



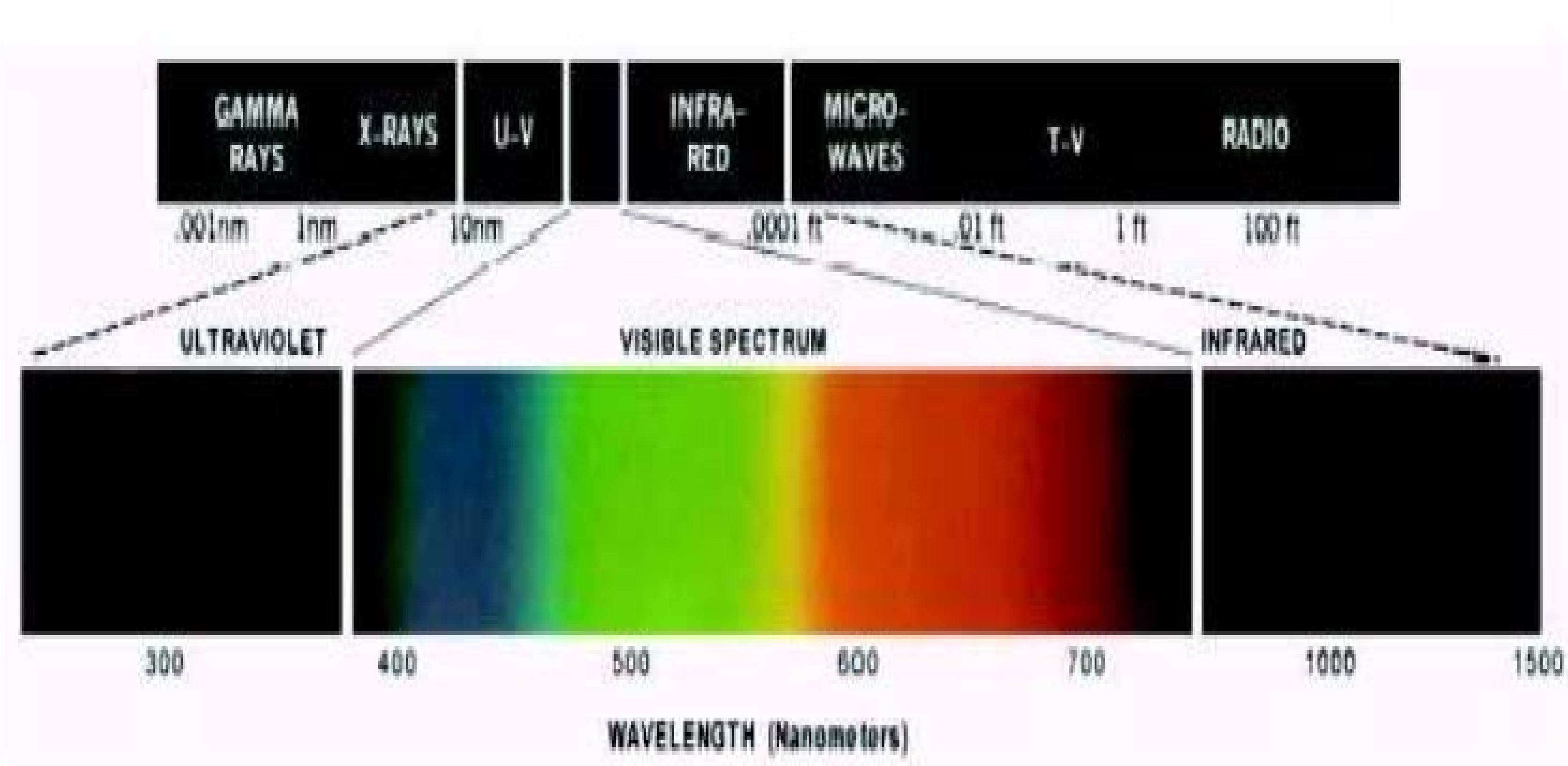
# Color spectrum/prism



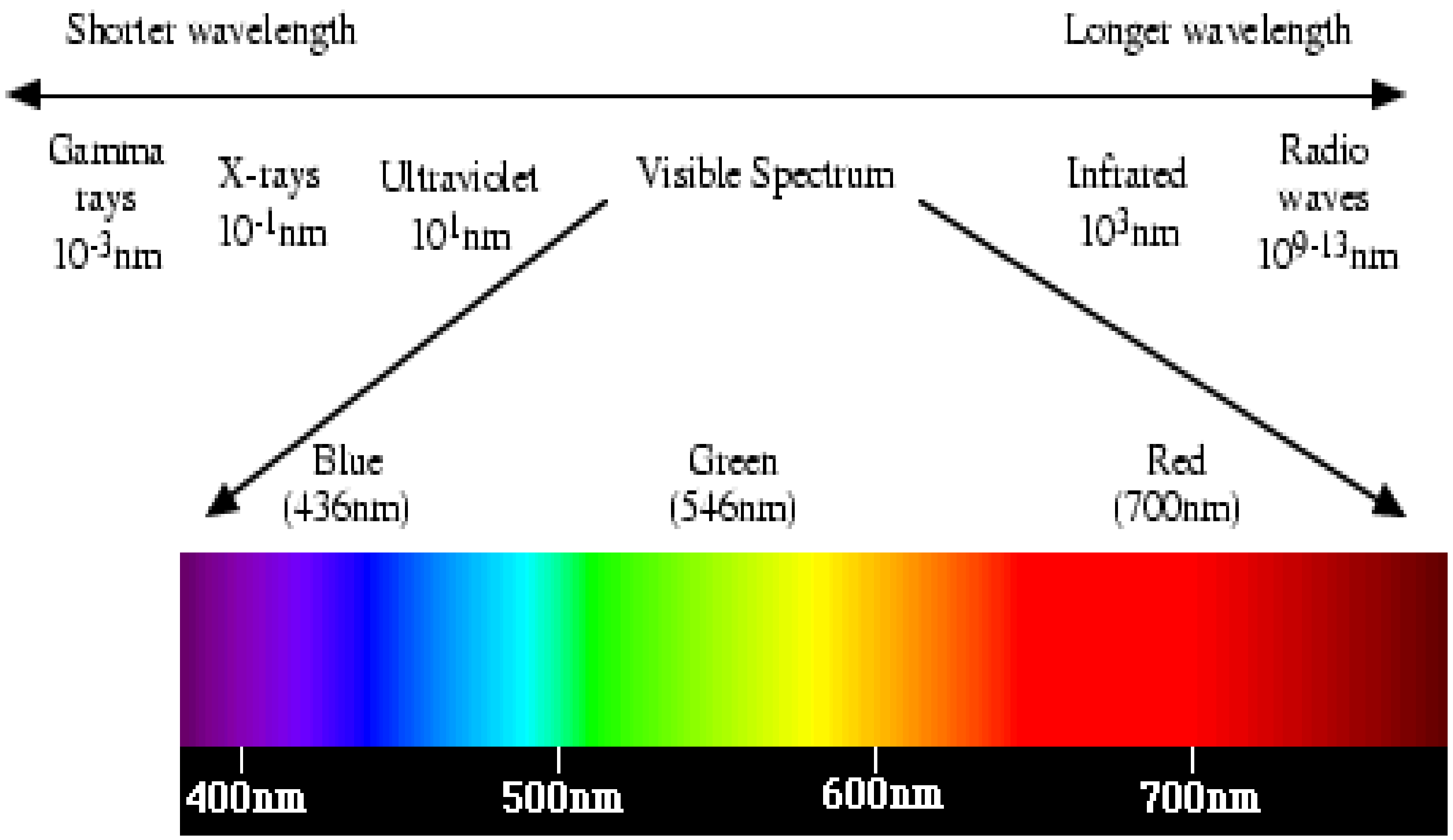
# Color Image Processing

- The different colors in the spectrum do not end abruptly (suddenly) but each color blends smoothly into the next.
- Color perceived by the human eye depends on the nature of light reflected by an object.
- Light that is relatively balanced in all visible wavelengths is perceived as white.
- Objects that appear green reflect more light in the 500-570 nm range (absorbing other wavelengths of light).
- Characterization of light is important for the understanding of color.

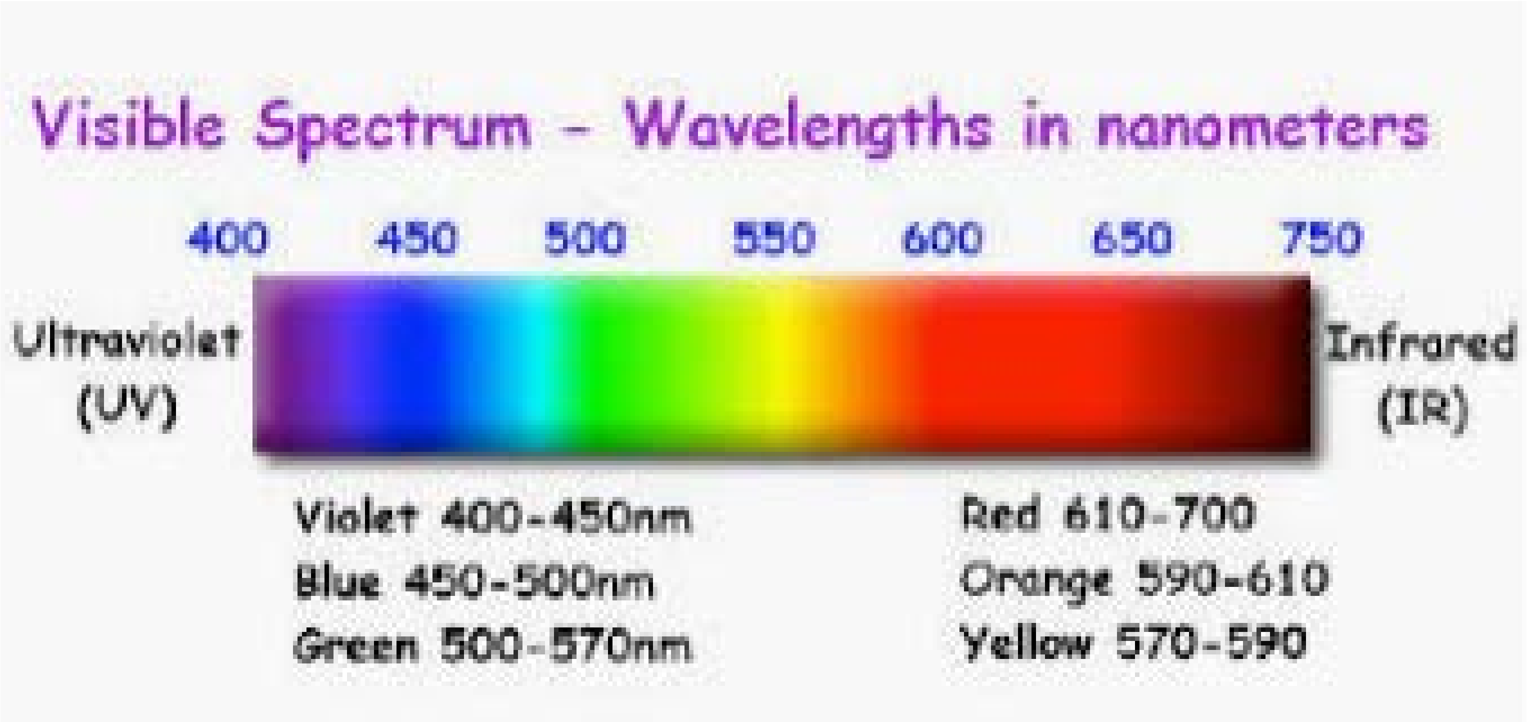
# Color spectrum/prism



# Color Image Processing



# Color Image Processing



# Color Image Processing

If the light is achromatic (devoid of color), its only attribute is its intensity (amount of light). This is what we have been dealing with so far.

The term gray level refers to the scalar measure of the intensity of light --- black to grays to white. •

Chromatic light spans the electromagnetic (EM) spectrum from approximately 400 nm to 700 nm.

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

# Color Image Processing

**Radiance** is the total amount of light that flows from a light source (measured in Watts).

**Luminance** gives a measure of the amount of energy an observer perceives from a light source (measured in lumens).

**Brightness** is a subjective descriptor that is impossible to measure.

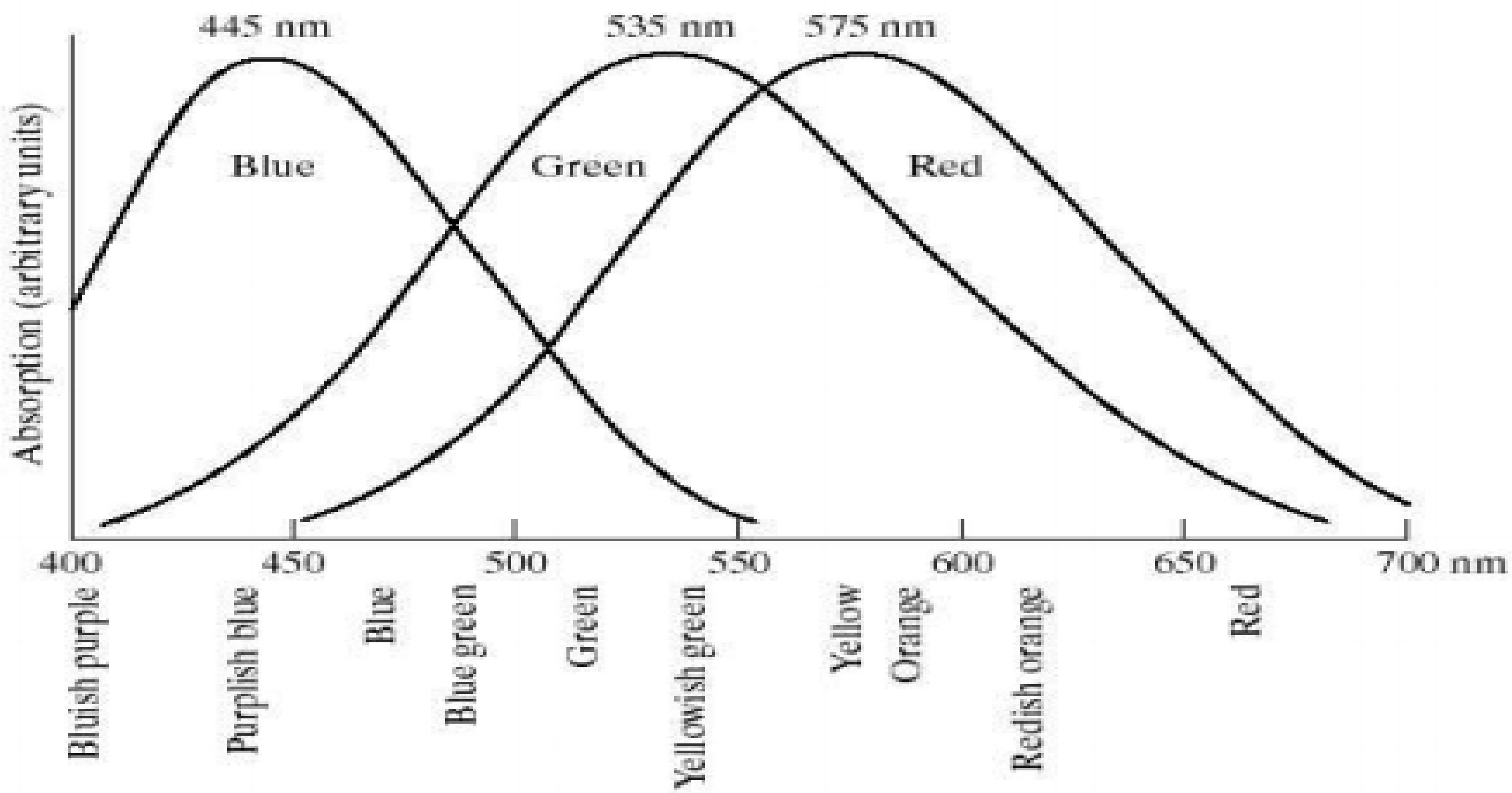
# Color Image Processing

- Cones in the retina are responsible for color perception in the human eye.

- Six to seven million cones in the human eye can be divided into three categories: red light sensitive cones (65%), green light sensitive cones (33%) and blue light sensitive cones (2%).

# Color Image Processing

Absorption of light by the three types of cones is illustrated in the figure below:



# Color Image Processing

Due to the absorption characteristics of the human eye, all colors perceived by the human can be considered as a variable combination of the so called three primary colors:

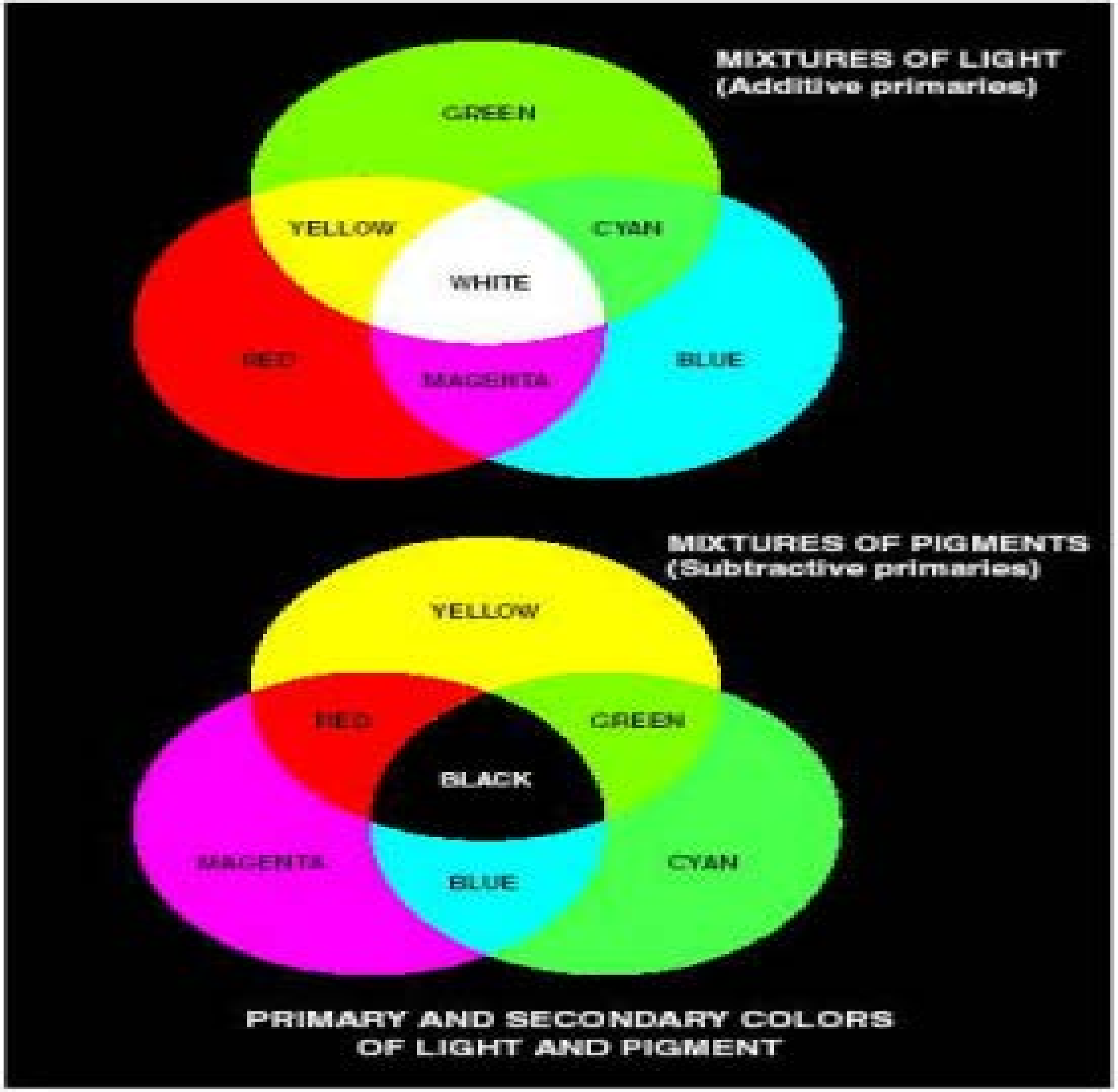
- Red (R) (700 nm)
- Green (G) (546.1 nm)
- Blue (B) (435.8 nm)

# Color Image Processing

- The wavelengths for the three primary colors are established by standardization by the CIE (International Commission on Illumination). They correspond to the experimental curve only approximately.

- Note that the specific color wavelengths are used mainly for standardization. It is not possible to produce all colors purely by combining these specific wavelengths.

# Color Image Processing




**Pigment**: a substance that imparts black or white or a color to other materials;

# Color Image Processing

- Primary colors

a) Red
b) Green
c) Blue

When primary colors are added produce secondary colors:

- Magenta (red + blue)
- Cyan (green + blue)
- Yellow (red + green)

# Color Image Processing

- Mixing the three primaries, or a secondary with its opposite primary, in the right intensities produces white light.

- A primary color of pigment is defined as one that subtracts or absorbs a primary color of light and reflects or transmits the other two.

- Therefore, the primary colors of pigments are magenta, cyan, and yellow, and the secondary pigment colors are red, green, and blue.

- Mixing the three pigment primaries, or a secondary with its opposite primary, in the right intensities produces black.

# Color Image Processing

- Color television or a computer monitor is an example of additive nature of the color of light. The inside of the screen is coated with dots of phosphor, each being capable of producing one of the three primary colors. A combination of light of the three primary colors produces all the different colors we see.

- Printing is an example of the subtractive nature of color pigments. For example, a pigment of red color actually absorbs light of all wavelengths, except that corresponding to red color.

# Color Image Processing

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

- Brightness (or value) embodies the chromatic notion of intensity.

- Hue is an attribute associated with the dominant wavelength in a mixture of light waves. It represents the dominant color as perceived by an observer (ex. orange, red, violet).

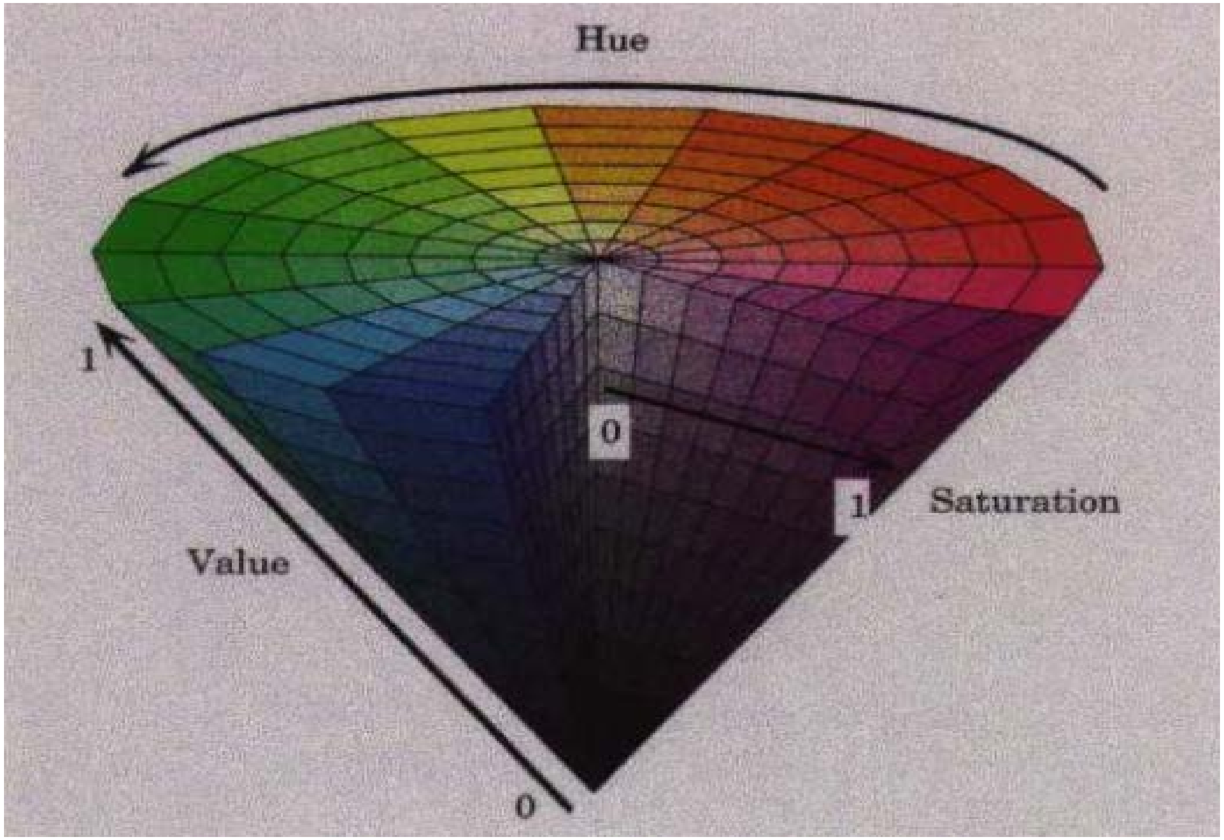
# Color Image Processing

- Saturation refers to the relative purity or the amount of white light mixed with a hue. Pure colors are fully saturated. Colors such as pink (red + white) and lavendar (violet + white) are less saturated.

*The intensity is determined by the actual amount of light, with more light corresponding to more intense colours.*

# Color Image Processing

- Hue and saturation together are called chromaticity. A color can be described in terms of its brightness and chromaticity.



# Color Image Processing

**Tristimulus values**

The amounts of red, green, and blue needed to form any particular color are called the tristimulus values and are denoted by X, Y, and Z, respectively.

# Color Image Processing

- In general, color is specified by its three **trichromatic coefficients**:

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

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

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

- Naturally, $x + y + z = 1$.

For any value of x (red) and y (green), the corresponding value of z (blue) is given by $z = 1 - (x + y)$.

# Color Image Processing

## Color Models

➢The purpose of a color model (or color space or color system) is to facilitate the specification of color in some standard fashion.

➢A color model is a specification of a 3-D coordinate system and a subspace within that system where each color is represented by a single point.

➢Most color models in use today are either based on hardware (color camera, printer) or on applications involving color manipulation (computer graphics, animation).

# Color Image Processing

In image processing, the hardware based color models mainly used are: RGB, CMYK, and HSI.

• The RGB (red, green, blue) color system is used mainly in color monitors and video cameras.

• The CMYK (cyan, magenta, yellow, black) color system is used in printing devices.

• The HSI (hue, saturation, intensity) is based on the way humans describe and interpret color. It also helps in separating the color and grayscale information in an image.

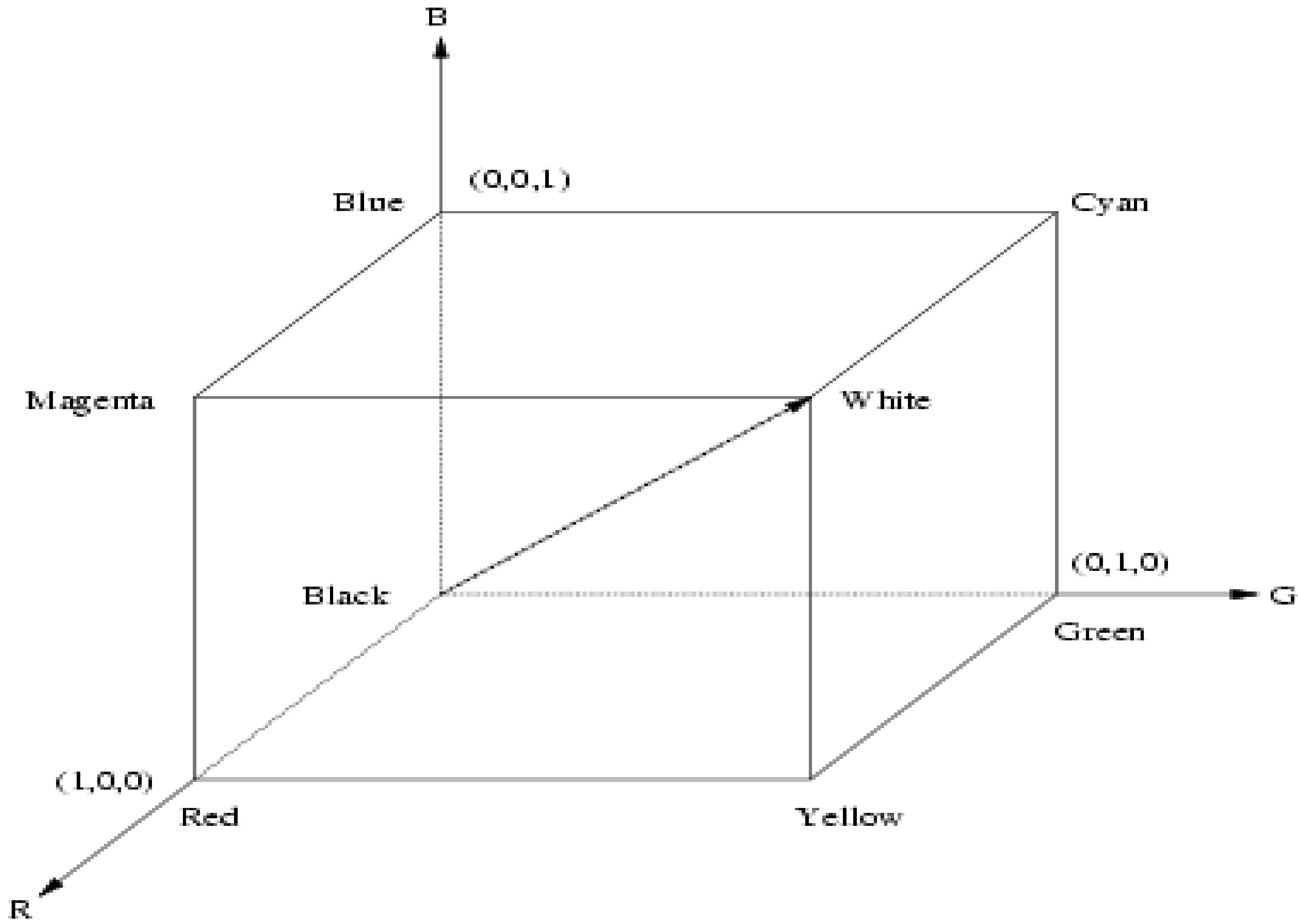
# Color Image Processing

## RGB Color model

- Each color appears in its primary spectral components of red (R), green (G), and blue (B).

- Mainly used for hardware such as color monitors and color video camera.

# Color Image Processing



# Color Image Processing

- It is based on a Cartesian coordinate system. All color values are normalized so that the values of R, G, and B are in the range [0,1]. Thus, the color subspace of interest is the unit cube.

- The primary colors red, green, and blue correspond to three corners of the cube, whereas the secondary colors cyan, magenta, and yellow correspond to three other corners. Origin (0,0,0) represents black and (1,1,1) represents white. • Grayscale (monochrome) is represented by the diagonal joining black to white.

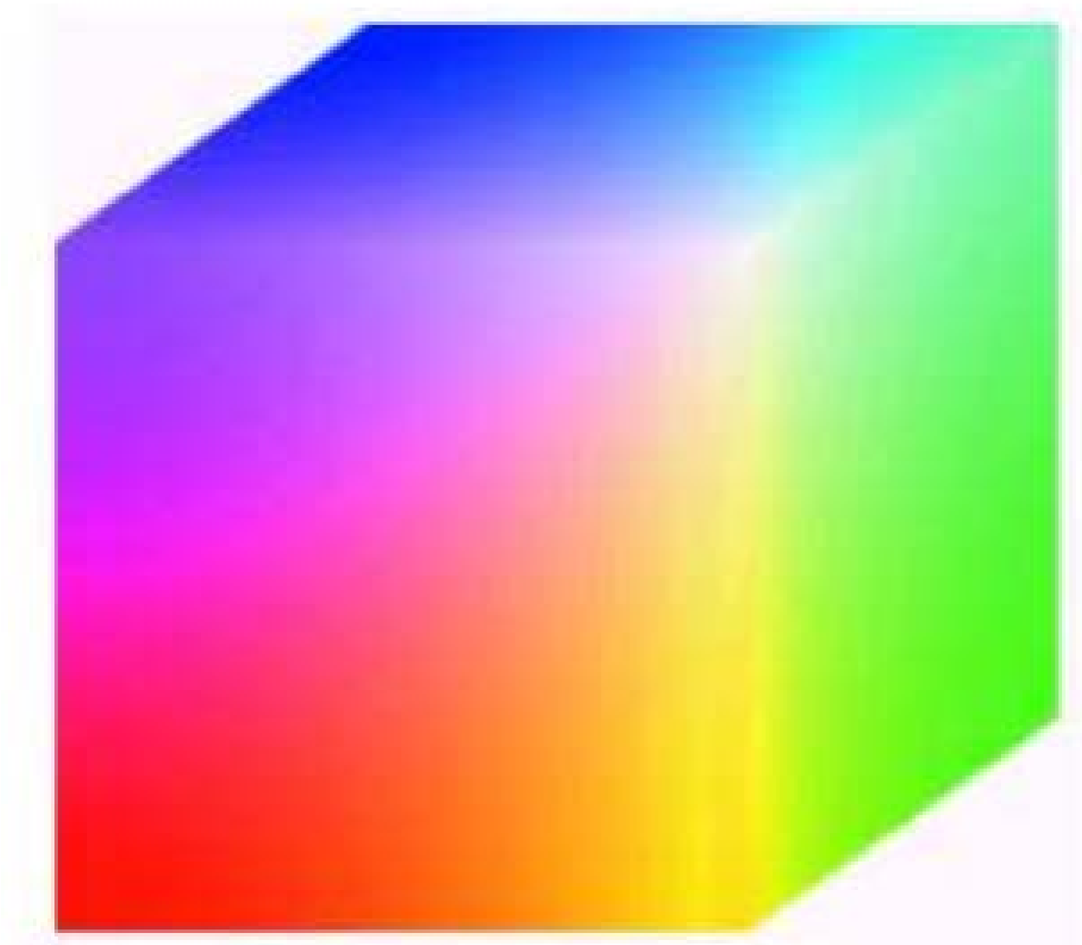
# Color Image Processing

- The number of bits used to represent each pixel in RGB space is called pixel depth.

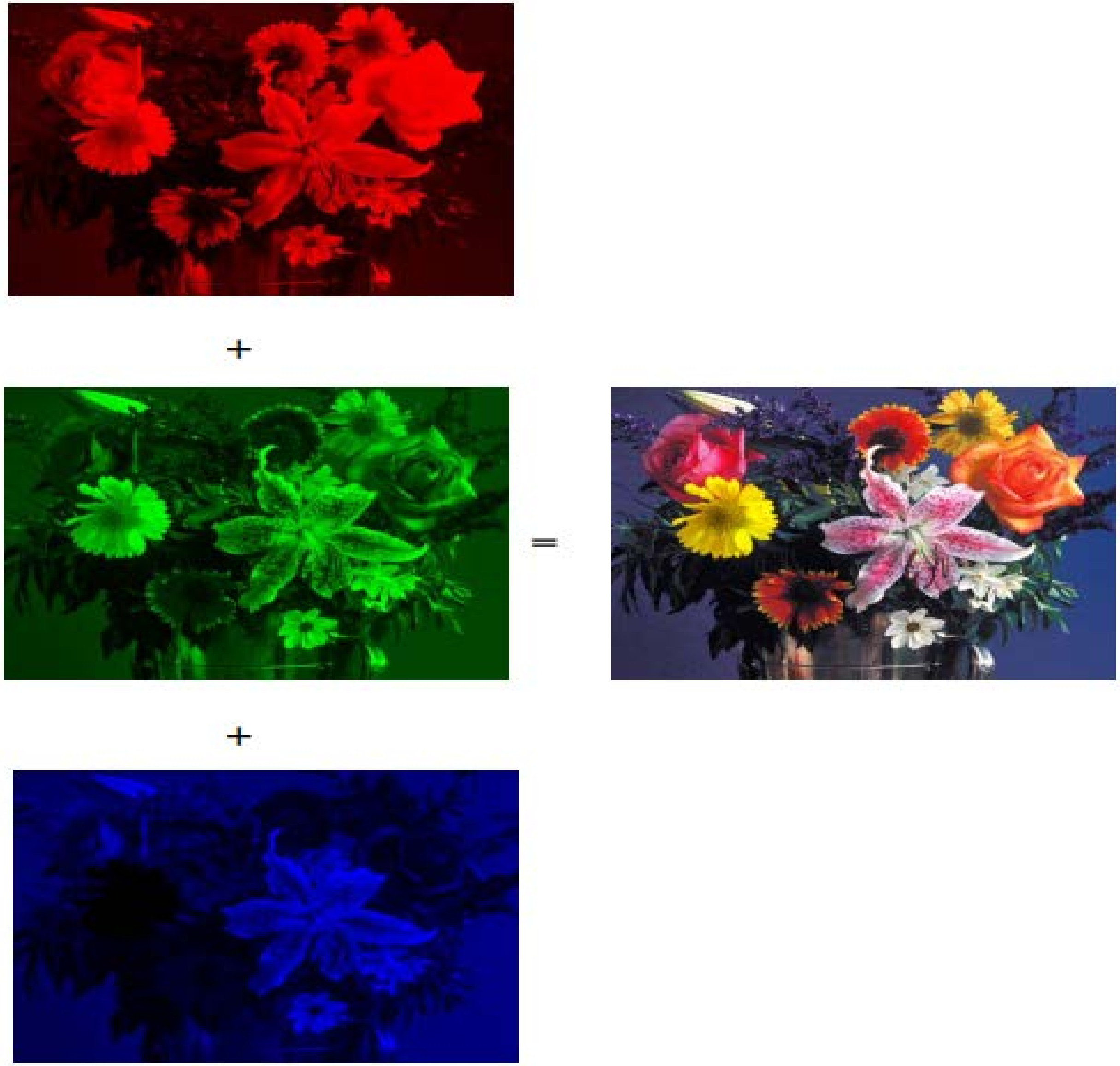
- For example, if eight bits are used to represent each of the primary components, each RGB color pixel would have a depth of 24 bits. This is usually referred to as a full color image.

- There are 16,777,216 unique colors possible in this system.

# Color Image Processing



# Color Image Processing



# Color Image Processing

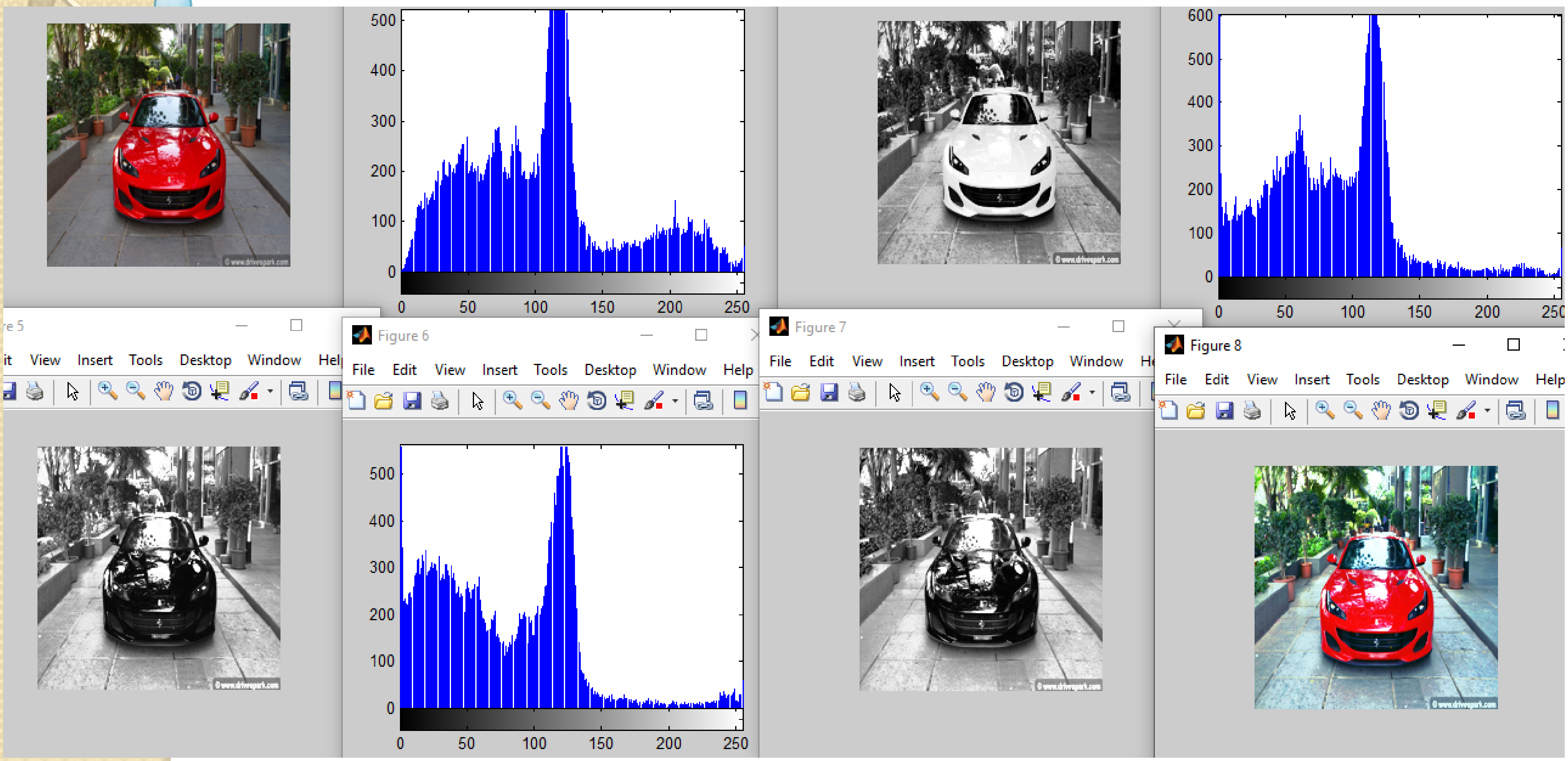
```
I = imread('D:/Matlab_Folder/car.jpg');
figure, imshow(I);
figure, imshow(I);
R = I(:,:,1);
imhist(R);
figure, imshow(R);
figure, imshow(R);
G = I(:,:,2);
imhist(G);
figure, imshow(G);
figure, imshow(G);
B = I(:,:,3);
imhist(B);
figure, imshow(B);
```

# Color Image Processing

```
I = imread('D:/Matlab_Folder/car.jpg');
figure, imshow(I);
figure, imshow(I);
R = I(:,:,1);
imhist(R);
R = histeq(R);
figure, imshow(R);
figure, imshow(R);
G = I(:,:,2);
imhist(G);
G = histeq(G);
figure, imshow(G);
figure, imshow(G);
B = I(:,:,3);
imhist(B);
B = histeq(B);
figure, imshow(B);
J = cat(3,R,G,B);
figure, imshow(J);
```

# Color Image Processing

# Color Image Processing



# Color Image Processing

**Why does blue paint plus yellow paint give green?**

As all schoolchildren know, the way to make green paint is to mix blue paint with yellow. But how does this work? If blue paint absorbs all but blue light, and yellow absorbs blue only, when combined no light should be reflected and black paint result.

However, what actually happens is that imperfections in the paint are exploited. In practice, blue paint reflects not only blue, but also some green. Since the yellow paint also reflects green (since yellow = green + red), some green is reflected by both pigments, and all other colors are absorbed, resulting in green paint.

# Color Image Processing

## RGB and CMY models

- Ideally suited for hardware implementation.

- RGB and CMY not suitable for describing colors for human interpretation.

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

# Color Image Processing

## HSI color model

- Hue,
- Saturation,
- Intensity

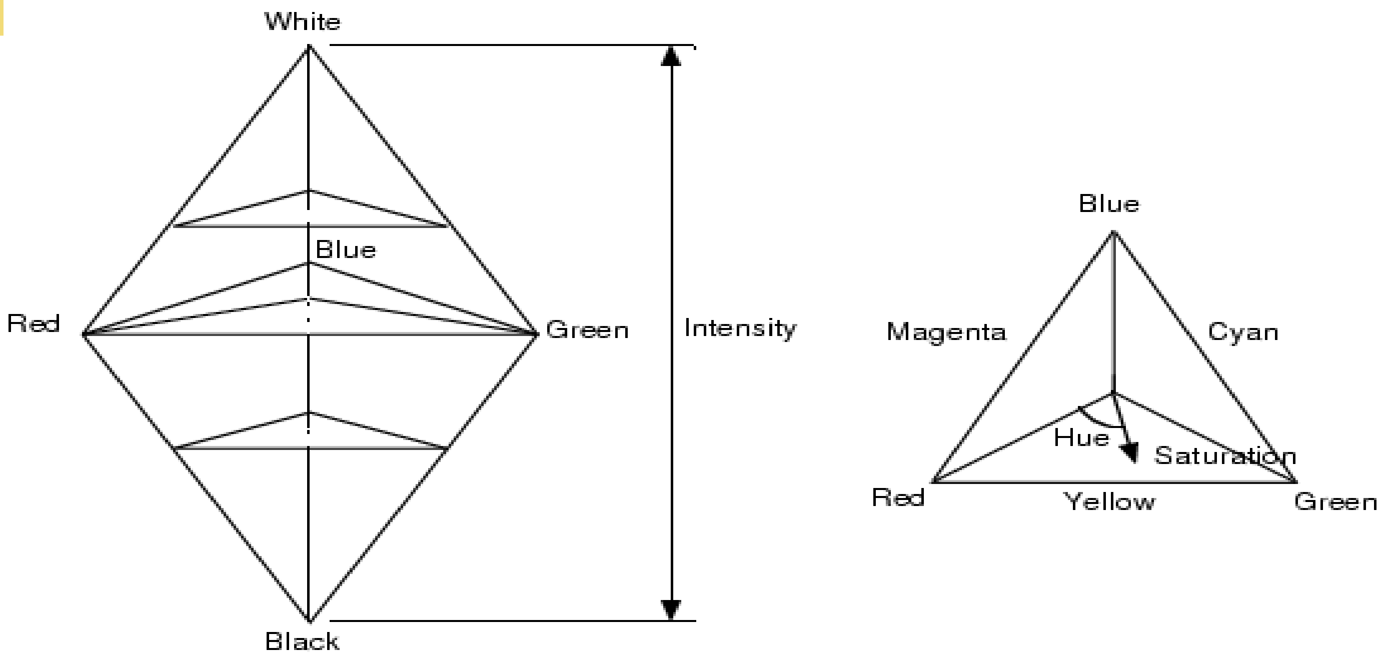
Human description of images/colors

∗ In terms of hue, saturation, and brightness

# Color Image Processing

- HSI model is an ideal tool for developing image processing algorithms
- Natural and intuitive to humans

# Color Image Processing




The HSI model, showing the HSI solid on the left, and the HSI triangle on the right, formed by taking a horizontal slice through the HSI solid at a particular intensity. Hue is measured from red, and saturation is given by distance from the axis. Colours on the surface of the solid are fully saturated, i.e. pure colours, and the greyscale spectrum is on the axis of the solid. For these colours, hue is undefined.

# Color Image Processing

- Converting colors from RGB to HSI
  - Consider RGB values normalized to the range $[0, 1]$
  - Given an RGB value, $H$ is obtained as follows:

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

    * It should be normalized to the range $[0, 1]$ by dividing the quantity computed above by 360
  - $\theta$ is given by

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

    * $\theta$ is measured with respect to red axis of HSI space
  - Saturation is given by

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

  - Intensity component is given by

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

# Color Image Processing

```
close all;
I = imread('D:/Matlab_Folder/car.jpg');
figure, imshow(I);

%Represent the RGB image in [0 1] range
I=double(I)/255;

R=I(:,:,1);
G=I(:,:,2);
B=I(:,:,3);
```

# Color Image Processing

```
%Hue
N=1/2*((R-G)+(R-B));
D=((R-G).^2+((R-B).*(G-B))).^0.5;

%To avoid divide by zero exception add a small number
H=acosd(N./(D+0.000001));

%If B>G then H= 360-Theta
H(B>G)=360-H(B>G);

%Normalize to the range [0 1]
H=H/360;
```

# Color Image Processing

```
%Saturation
S=1- (3./(sum(I,3)+0.000001)).*min(I,[],3);


%Intensity
I=sum(I,3)./3;


%HSI
HSI = cat(3,H,S,I);

figure,imshow(HSI);
title('HSI Image');
```

# Color Image Processing

- Converting colors from HSI to RGB
  - Consider the values of HSI in the interval $[0, 1]$
  - $H$ should be multiplied by 360 (or $2\pi$) to recover the angle; further computation is based on the value of $H$
  - RG sector – $0^\circ \leq H < 120^\circ$

$$\begin{aligned} B &= I(1-S) \\ R &= I\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right] \\ G &= 3I - (R+B) \end{aligned}$$

  - GB sector – $120^\circ \leq H < 240^\circ$

$$\begin{aligned} H' &= H - 120^\circ \\ R &= I(1-S) \\ G &= I\left[1 + \frac{S\cos H'}{\cos(60^\circ - H')}\right] \\ B &= 3I - (R+G) \end{aligned}$$

  - BR sector – $0^\circ \leq H < 360^\circ$

$$\begin{aligned} H' &= H - 240^\circ \\ G &= I(1-S) \\ B &= I\left[1 + \frac{S\cos H'}{\cos(60^\circ - H')}\right] \\ R &= 3I - (G+B) \end{aligned}$$

# Color Image Processing

```
%Obtain the Hue, Saturation and Intensity components
 H1=HSI(:,:,1);
 S1=HSI(:,:,2);
 I1=HSI(:,:,3);

 %Multiply Hue by 360 to represent in the range [0 360]
 H1=H1*360;

%Pre-allocate the R,G and B components
 R1=zeros(size(H1));
 G1=zeros(size(H1));
 B1=zeros(size(H1));
 RGB1=zeros([size(H1),3]);
```

# Color Image Processing

```
%RG Sector(0<=H<120)
 %When H is in the above sector, the RGB components equations are


 B1(H1<120)=I1(H1<120).*(1-S1(H1<120));
 R1(H1<120)=I1(H1<120).*(1+((S1(H1<120).*cosd(H1(H1<120)))./cosd(60-
H1(H1<120))));
 G1(H1<120)=3.*I1(H1<120)-(R1(H1<120)+B1(H1<120));



 %GB Sector(120<=H<240)
 %When H is in the above sector, the RGB components equations are
```

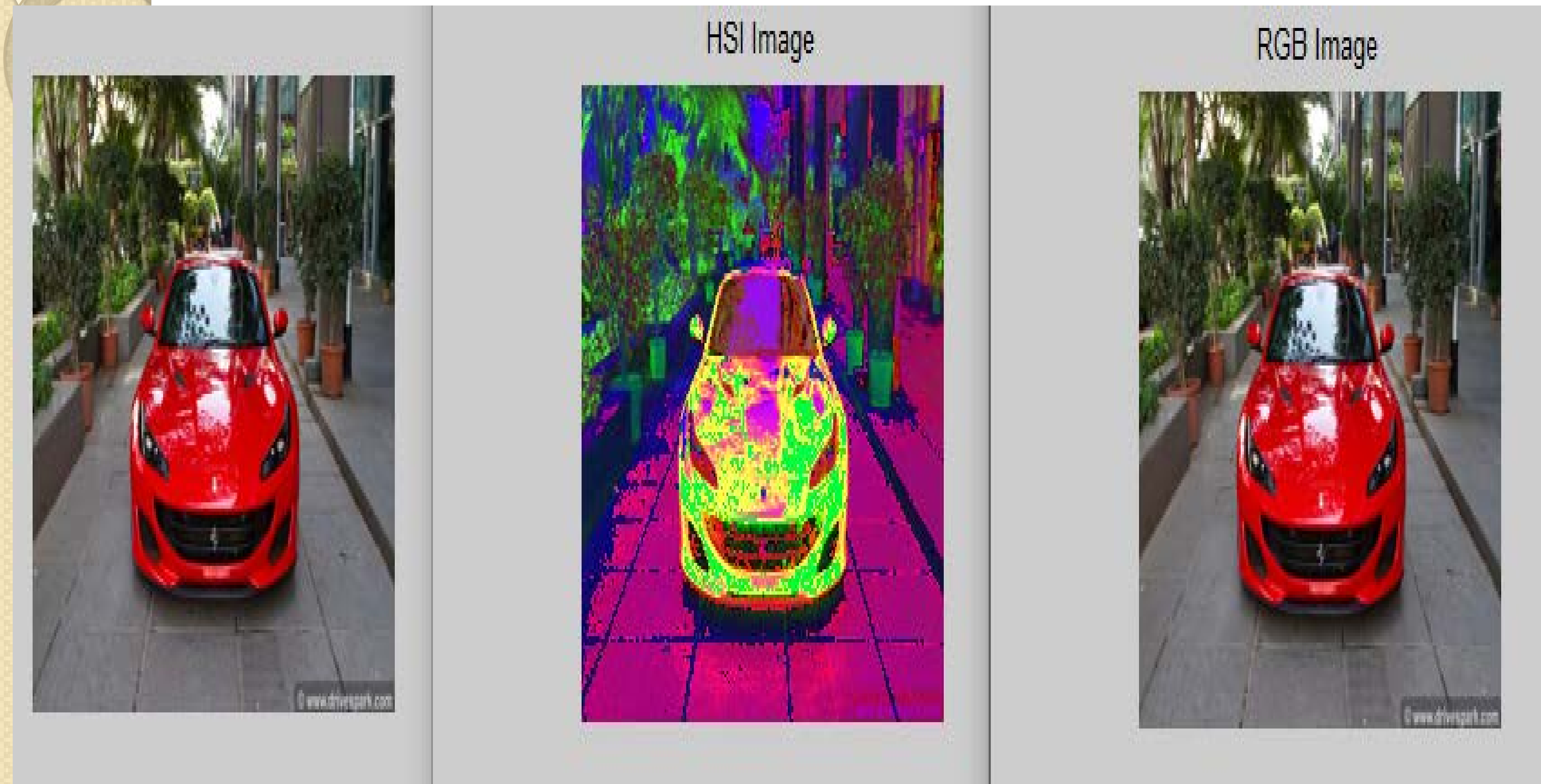
# Color Image Processing

```
%Subtract 120 from Hue
 H2=H1-120;


 R1(H1>=120&H1<240)=I1(H1>=120&H1<240).*(1-
S1(H1>=120&H1<240));

G1(H1>=120&H1<240)=I1(H1>=120&H1<240).*(1+((S1(H1>=120&H
1<240).*cosd(H2(H1>=120&H1<240)))./cosd(60-
H2(H1>=120&H1<240))));
 B1(H1>=120&H1<240)=3.*I1(H1>=120&H1<240)-
(R1(H1>=120&H1<240)+G1(H1>=120&H1<240));


 %BR Sector(240<=H<=360)
 %When H is in the above sector, the RGB components equations are
```

# Color Image Processing

```
%Subtract 240 from Hue
 H2=H1-240;

 G1(H1>=240&H1<=360)=I1(H1>=240&H1<=360).*(1-S1(H1>=240&H1<=360));

B1(H1>=240&H1<=360)=I1(H1>=240&H1<=360).*(1+((S1(H1>=240&H1<=360).*cosd(H2(H1>=240&H1<=360)))./cosd(60-H2(H1>=240&H1<=360))));
 R1(H1>=240&H1<=360)=3.*I1(H1>=240&H1<=360)-(G1(H1>=240&H1<=360)+B1(H1>=240&H1<=360));

 %Form RGB Image
 RGB1(:,:,1)=R1;
 RGB1(:,:,2)=G1;
 RGB1(:,:,3)=B1;

   %Represent the image in the range [0 255]
 RGB1=im2uint8(RGB1);
 figure,imshow(RGB1);title('RGB Image');
```

# Color Image Processing



# Color Image Processing

## HSV color space

- Projects the RGB color cube onto a non-linear

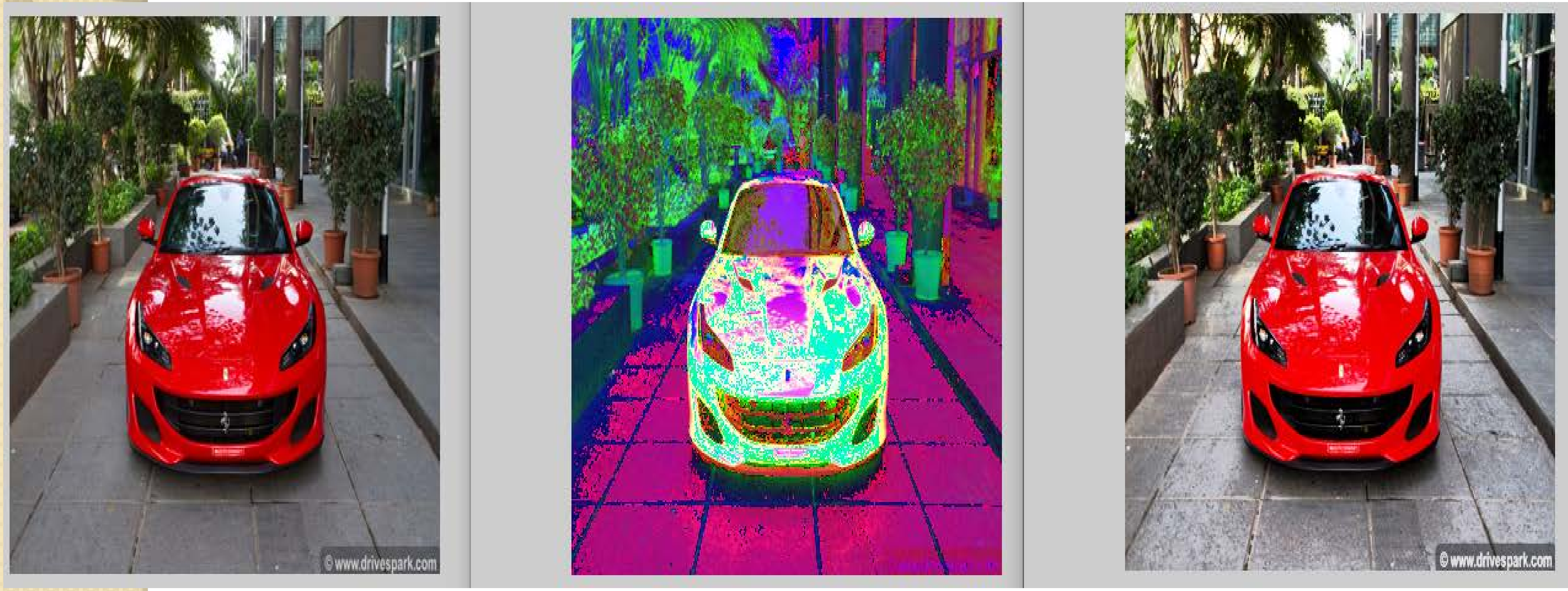
1. chroma angle (H),
2. a radial saturation percentage (S), and
3. a luminance inspired value (V)

- Similar to HSI color space

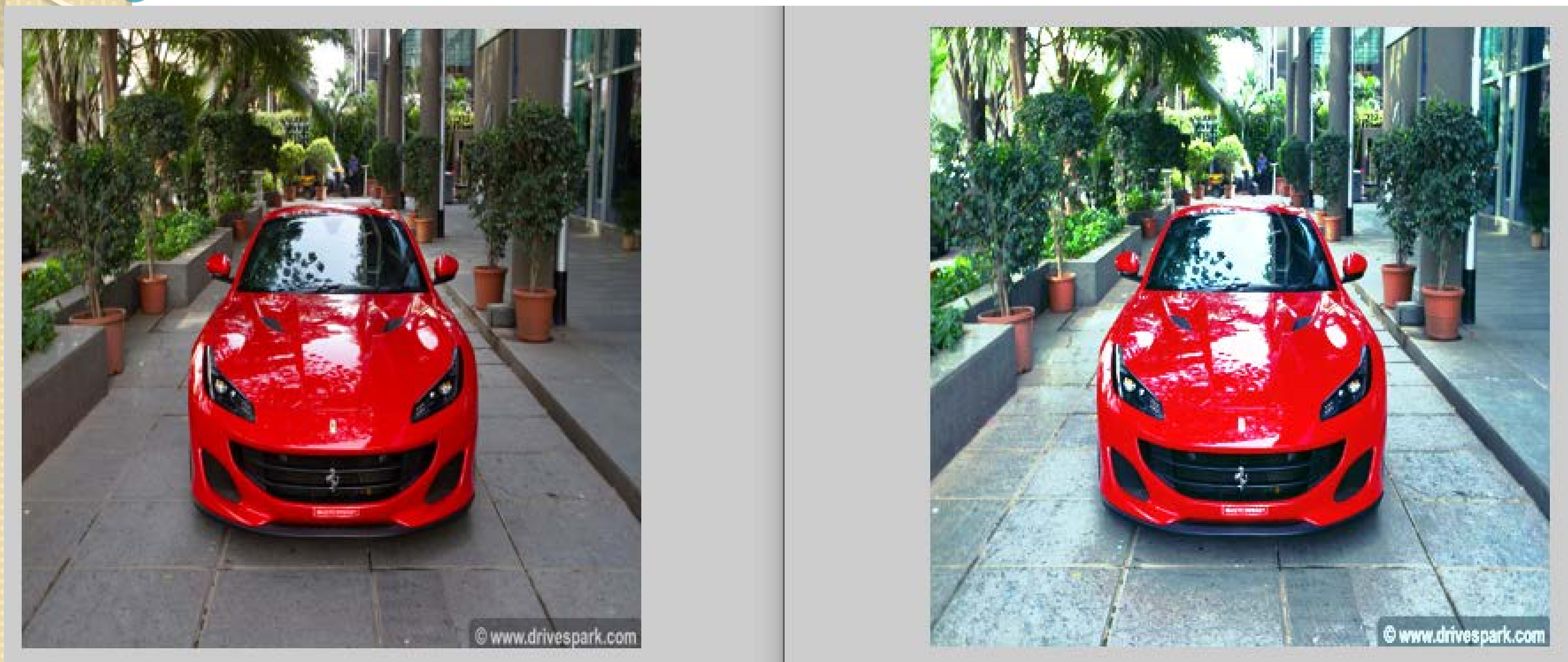
# Color Image Processing

```
close all;
I = imread('D:/Matlab_Folder/car.jpg');
figure, imshow(I);
figure, imshow(I);
R = I(:,:,1);
imhist(R);
R = histeq(R);
figure, imshow(R);
figure, imshow(R);
G = I(:,:,2);
imhist(G);
G = histeq(G);
figure, imshow(G);
figure, imshow(G);
B = I(:,:,3);
imhist(B);
B = histeq(B);
figure, imshow(B);
J = cat(3,R,G,B);
figure, imshow(J);
```

# Color Image Processing

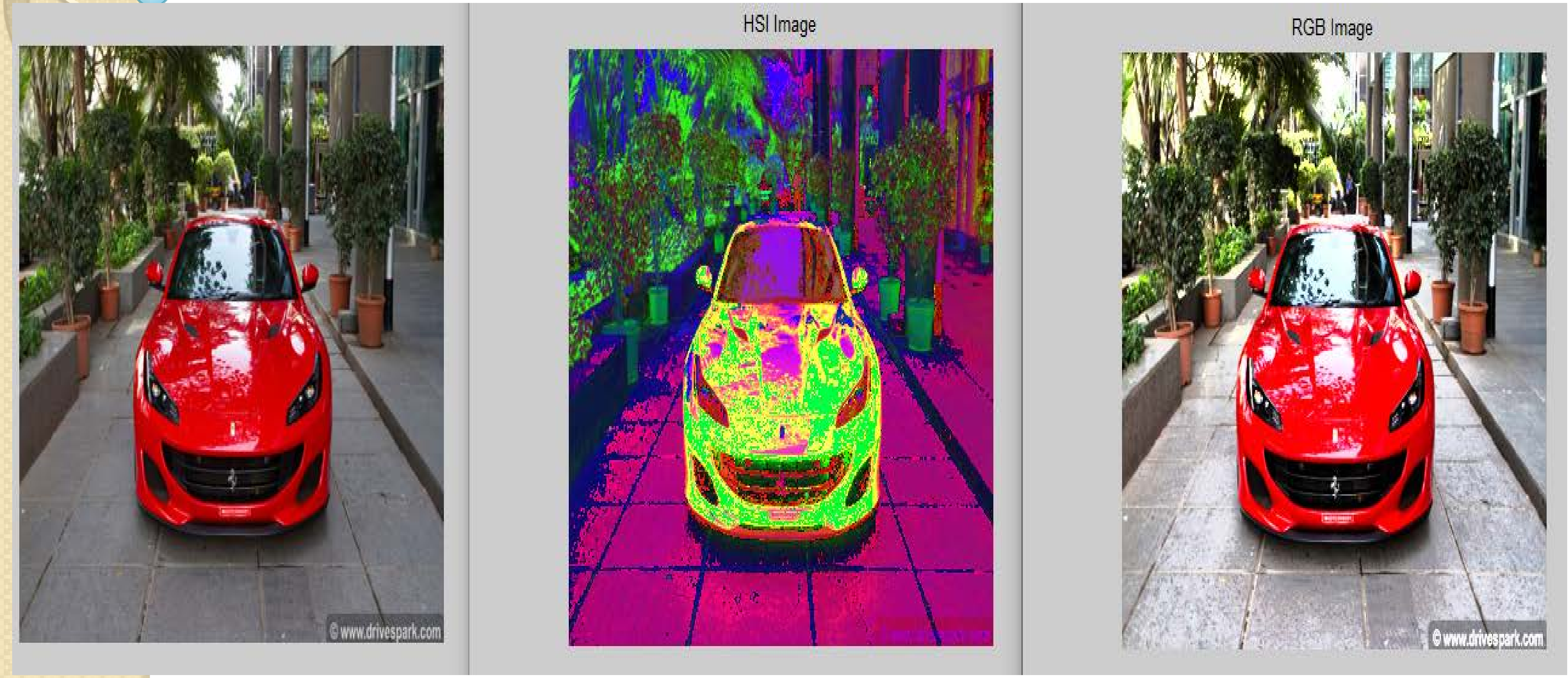


# Color Image Processing




Histogram Equalization on RGB Color model

# Color Image Processing




Histogram Equalization on HSI Color model

# Color Image Processing


Histogram Equalization on HSV Color model

# Color Image Processing


RGB Image


Enhancement on HSV color model


Enhancement on RGB color model


Enhancement on HSI coloe model

**Thanks !!!**