Chapter Four

Color images formats (RGB, HSV and YCbCr)

4.1 RGB Color Model

Any color that can be represented on a computer monitor is specified by means of the three basic colors- Red, Green and Blue called the RGB colors. By mixing appropriate percentages of these basic colors, one can design almost any color one ever imagines.

The model of designing colors based on the intensities of their RGB components is called the RGB model, and it's a fundamental concept in computer graphics. Each color, therefore, is represented by a triplet (Red, Green, and Blue), in which red, green and blue three bytes are that represent the basic color components. The smallest value, 0, indicates the absence of color. The largest value, 255, indicates full intensity or saturation. The triplet (0, 0, 0) is black, because all colors are missing, and the triplet (255, 255, 255) is white. Other colors have various combinations:

(255,0,0) is pure red, (0,255,255) is a pure cyan (what one gets when green and blue are mixed), and (0,128,128) is a mid-cyan (a mix of mid-green and mid-blue tones). The possible combinations of the three basic color components are 256x256x256, or 16,777,216 colors. Figure (4.1) shows Color specification of the RGB Color Cube.

The process of generating colors with three basic components is based on the RGB Color cube as shown in the figure (4.1). The three dimensions of the color cube correspond to the three basic colors.

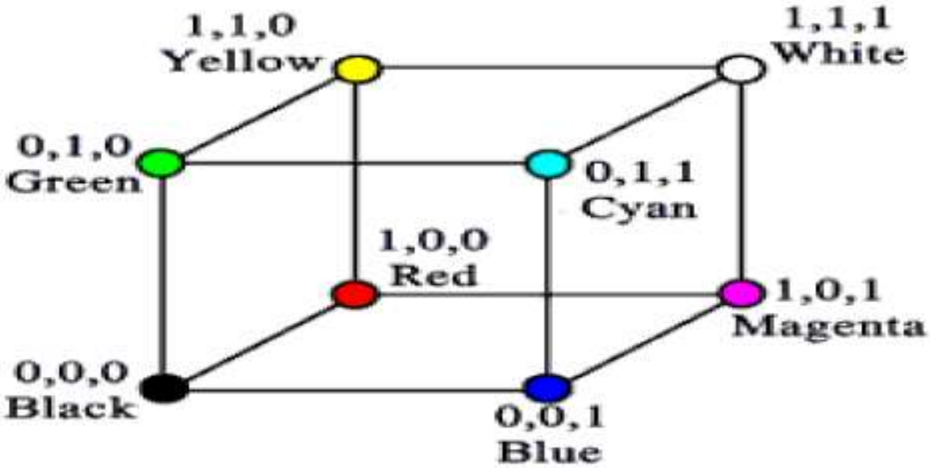

Figure (4.1): Color specification of the RGB Color Cube

The cube's corners are assigned each of the three primary colors, their complements, and the colors black and white. **<u>Complementary colors are easily calculated by subtracting the Color values from 255. For example, the color (0, 0,255) is a pure blue tone</u>**.

Its complementary color is (255-0,255-0,255-255), or (255, 255, 0), which is a pure yellow tone see Figure (4.2). Blue and Yellow are complementary colors, and they are mapped to opposite corners of the cube. The same is true for red and cyan, green and magenta, and black and white.

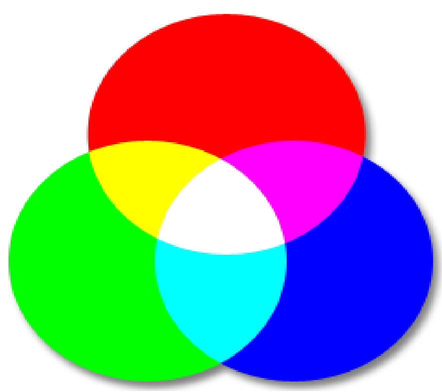

Figure (4.2): RGB Color Model

- Adding a color to its complement gives white.
- It is noticed that the components of the colors at the corners of the cube have either zero or full intensity.
- As we move from one corner to another along the same edge of the cube, only one of its components changes value. For example, as we move from the Green to the Yellow corner, the Red component changes from 0 to 255.
- Although we can specify more than 16 million colors, we can't have more than 256 shades of Gray. **The reason** is that a gray tone, including the two extremes (black and white), is made up of equal values of all the three primary colors. This is seen from the RGB cube as well. Gray shades lie on the cube's diagonal that goes from black to white. As we move along this path, all three basic components change value, but they are always equal. The value (128,128,128) is a mid-gray tone
- That's why it is wasteful to store grayscale pictures using 16-million color True Color file formats.
- **Once an image is known in grayscale, we needn't store all three bytes per pixel. One value is adequate (the other two components have the same value).**

4.2 HSV color Model

- HSL and HSV are two related representations of points in an RGB color space, which attempt to describe perceptual color relationships more accurately than RGB, while remaining computationally simple.
- **HSL stands for hue, saturation, lightness, while HSV stands for hue, saturation, value.**

Hue: the color type (such as red, blue, or yellow). a blue car reflects blue hue. The hue which is essentially the chromatic component of our perception may again be considered as weak hue or strong hue.

Saturation: The colorfulness of a color is described by the saturation component. For example, the color from a single monochromatic source of light, which produce colors of a single wavelength only , is highly saturated , while the colors comprising hues of different wavelengths have little Chroma and have less saturation.

The gray colors do not have any hue and hence they have less saturation or unsaturated. Saturation is thus a measure of colorfulness or whiteness in the color perceived.

The lightness (L) or intensity (I) or value (V) : essentially provides a measure of the brightness of colors. This gives a measure of how much light is reflected from the object or how much light is emitted from a region.

The HSV model is commonly used in computer graphics applications. The HSV color space is compatible with human color perception

The HSV image may be computed from RGB image using different transformation. Some of them are as follows:

- The simplest form of HSV transformation is :

H= tan [3(G-B)/(R-G) +(R-B)]

S= 1-(min(R, G, B)/V)

V= (R+G+B/3)

However, the hue (H) becomes undefined when saturation S=0

- The most popular form of HSV transformation is shown next, where the r,g,b values are first obtained by normalizing each pixel such that

  r=(R/(R+G+B)), g=(G/(R+G+B)), b=(B/(R+G+B))
- Accordingly the H, S and V value can be computed as:

  V = max (r, g, b),

$$S = \begin{cases} 0, & if\ V = 0 \\ V - \min(r, g, b)/V, & if\ V > 0 \end{cases}$$

$$H = \begin{cases} 0, & if\ S = 0 \\ 60 * [(g-b)/S * V] & if\ V = r \\ 60\,[2 + ((b-r)/S * V)] & if\ V = g \\ 60[4 + ((r-g)/S * V)] & if\ V = b \end{cases}$$

H = H+360 if H<0

4.3 YCbCr Color Format

Another color space in which luminance and chrominance are separately represented is the YC_bC_r. The **Y** component takes values from 16 to 235, while Cb and Cr take values from 16 to 240. They are obtained from gamma-corrected R, G, B values as follows:

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

4.4 Basic Relationships between Pixels

In this section, several important relationships between pixels in a digital image are considered. As mentioned before, an image is denoted by f(x, y).When referring in this section to a particular pixel.

1. <u>**Neighbors of a Pixel**</u>

   a. **N4(p) : four neighbors of pixel P.**

   - Any pixel p(x, y) has two vertical and two horizontal neighbors, given by: (x+1,y), (x-1, y), (x, y+1), (x, y-1)
   - This set of pixels are called the 4-neighbors of P, and is denoted by N4(P)
   - Each of them is at a unit distance from P., and some of the neighbors of p lie outside the digital image if (x, y) is on the border of the image.

   b. **ND(p) : four diagonal neighbors of pixel P**, denoted by ND(p).

   - have coordinates :(x+1, y+1), (x+1, y-1), (x-1, y+1), (x-1, y-1).
   - Each of them are at Euclidean distance of 1.414 from P.

   c. **N8(p) These points, together with the 4-neighbors, are called the 8-neighbors of p, denoted by N8 (p).**

- As before, some of the points in ND(p) and N8(p) fall outside the image if (x, y) is on the border of the image.

F(x-1, y-1)	F(x-1, y)	F(x-1, y+1)
F(x, y-1)	F(x,y)	F(x, y+1)
F(x+1, y-1)	F(x+1, y)	F(x+1, y+1)

N_8 (p)

2. Adjacency

- Two pixels are connected if they are neighbors and their gray levels satisfy some specified criterion of similarity.
- For example, in a binary image two pixels are connected if they are 4-neighbors and have same value (0/1)
- Let v: a set of intensity values used to define adjacency and connectivity.
- In a binary Image v={1}, if we are referring to adjacency of pixels with value 1.
- In a Gray scale image, the idea is the same, but v typically contains more elements,for example v= {180, 181, 182,....,200}.
- If the possible intensity values 0 to 255, v set could be any subset of these 256 values.

Chapter Five

Image Compression

5.1 Introduction

In general, data compression is defined as the process of encoding data using a representation that reduces the overall size of data. This reduction is possible when the original dataset contains some type of redundancy. Digital image compression is a field that studies methods for reducing the total number of bits required to represent an image. Image compression involves reducing the size of image data file, while is retaining necessary information, the reduced file is called the compressed file and is used to reconstruct the image, resulting in the decompressed image. The original image, before any compression is performed, is called the uncompressed image file. The ratio of the original, uncompressed image file and the compressed file is referred to as the compression ratio.

$$1.\ \ \textit{Compression Ratio} = \frac{\text{Uncompressed File Size}}{\textit{Cmpressed File Size}} = \frac{\textit{Size}\ \ u}{\textit{Size}\ \ c}$$

It is often written as Size u: Size c

Compression techniques are used to reduce the redundant information in the image data in order to facilitate the storage, transmission and distribution of images (e.g. GIF, TIFF, PNG, JPEG).

<u>Example:</u> An original image Image 256X256 pixels, 256 level gray scale can be compressed with file size 6554 byte. Find the compression ratio.

Original Image Size = 256X256 (pixels) * 1 (byte/pixel)

= 65536 bytes

Compression ratio = $\frac{65536}{\mathbf{6554}} \approx \mathbf{10}$

this can be written as: **10:1**

2. $$Bits\ per\ Pixel = \frac{Number\,of\ \ Bits}{Number\,of\ \ Pixels}$$

Example: An original image 256X256 pixels, 256 level gray scale can be compressed file size 6554 byte.

Original Image Size = 256X256 (pixels) * 1 (byte/pixel)

= 65536 bytes

Compressed file = 6554 (bytes) * 8 (bits/pixel)

= 52432 bits

Bit per Pixel = $\frac{52432}{\mathbf{65536}}$ = 0.8 bit / pixel

Q: Why we want to compress?

To transmit a digitized color scanned at 3,000×2,000 pixels, and 24 bits, at 28.8(kilobits/second), it would take about:

$$\frac{3000 * \ 2000\ (pixels) * 24\ (bits/pixels)}{28.8 * 1024\ \ (bits\ /\ second)} = 4883\ Second$$
$$= 81\ minutes$$

Q: What is the key of compression??

- Reducing Data but Retaining Information,
- DATA are used to convey information

For digital images, data refer to pixel gray-level values which correspond to the brightness of a pixel at a point in space. Information is interpretation of the data in a meaningful way. Data are used to convey information, much like the way the alphabet is used to convey information via words. Information is an elusive concept, it can be application specific. For example, in a binary image that contains text only, the necessary information may only involve the text being readable, whereas for a medical image the necessary information may be every minute detail in the original image.

5.2 Compression System Model

The compression system model consists of two parts: Compressor and Decompressor.

Compressor: consists of preprocessing stage and encoding stage.

Decompressor: consists of decoding stage followed by a post processing stage

Figure 5.3 depicts a general data compression scheme, in which **compression is performed by an encoder and decompression is performed by a decoder.**

We call the output of the encoder codes or codewords. The intermediate medium could either be data storage or a communication/computer network. If the compression and decompression processes induce no information loss, the compression scheme is lossless; otherwise, it is lossy.

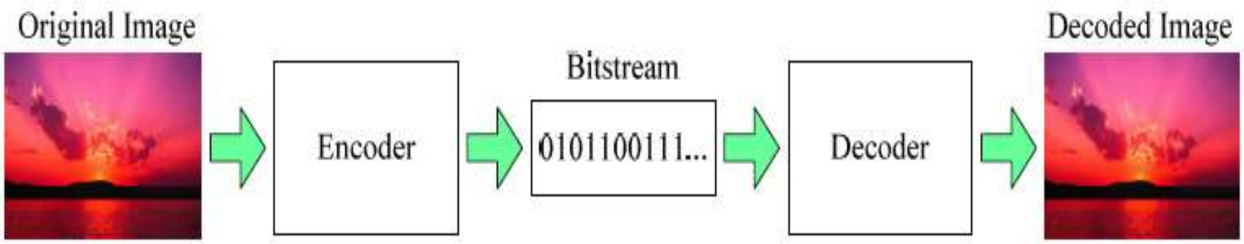

Figure (5.1): Compression System Model

5.3 Lossy Compression

These compression methods are called Lossy because they allow a loss because they allow a loss in actual image data, so original uncompressed image can not be created exactly from the compressed file. For complex images these techniques can achieve compression ratios of 100 0r 200 and still retain in high – quality visual information. For simple image or lower-quality results compression ratios as high as 100 to 200 can be attained. Lossy compression yields a much higher compression ratio than that of loss-less compression. Table (5.1) shows differences between lossy and lossless compression

Table (5.1) : the comparison between Lossy and Lossless compression

Lossless Compression	Lossy Compression
1. All original data can be recovered when the file is uncompressed every single bit of data that was originally in the file remains after the file is uncompressed. **2.** All of the information is completely restored **3.** This is generally the technique of choice for text or spreadsheet files, where losing words or financial data could pose a problem **4.** The Graphics Interchange File (GIF) is an image format used on the Web that provides lossless compression.	**1.** Reduces a file by permanently eliminating certain information, especially redundant information **2.** When the file is uncompressed, only a part of the original information is still there (although the user may not notice it) **3.** Lossy compression is generally used for video and sound where a certain amount of information loss will not be detected by most users **4.** The JPEG image file, commonly used for photographs and other complex still images on the Web, is an image that has lossy compression.

5.4 Lossless Compression

Lossless compression methods are necessary in some imaging applications. All of the information is completely restored (no data are lost). This is generally the technique of choice for text or spreadsheet files, where losing words or financial data could pose a problem. In addition, with medical image, the law requires that any archived medical images are stored without any data loss. Lossless compressors (Figure 5.2) are usually two step algorithms. **The first step** transforms the original image to some other format in which the inter -pixel redundancy is reduced. **The second step** uses an entropy encoder to remove the coding redundancy. The lossless decompressor is a perfect inverse process of the lossless compressor.

Typically, medical images can be compressed losslessly to about 50% of their original size

An important concepts here is the ides of measuring the average information in an image, referred to as entropy. The entropy for N×N image can be calculated by equation 5.3.

$$Entropy = -\sum_{i=0}^{L-1} P_i \log_2(P_i) \qquad \text{(in bits per pixel)} \qquad \text{----- -------- (5.3)}$$

Where:

P_i = The probability of the ith gray level $\frac{n_k}{N^2}$

n_k = the total number of pixels with gray value k.

L = the total number of gray levels (e.g. 256 for 8-bits)

Not : The compression ratio for image data using lossless compression techniques is low when the image histogram is relatively flat.

Example :

Example

Let L=8, meaning that there are 3 bits/ pixel in the original image. Let that number of pixel at each gray level value is equal (they have the same probability) that is:

8

1

0 1 2 7 $P1 = P2 = P3 = \cdots\cdots = P7 = 1/8$

Now, we can calculate the entropy as follows:

Now, we can calculate the entropy as follows:

$Entropy$=-$\sum P\log(P$

$= - = \sum_{=} 1/8 \log(1/8)=3$

5.6 Distortion Measures

In order to evaluate the performance of the image compression coding, it is necessary to define a measurement that can estimate the difference between the original image and the decoded image. Two common used measure ements are the **Mean Square Error (MSE)** and the **Peak Signal to Noise Ratio (PSNR)** , which are defined in (5.1) and (5.2), respectively, where x_n is the pixel value of the original image, and y_n the pixel value of the decoded image and N is the length of original image. **Most image compression systems are designed to minimize the MSE and maximize the PSNR**.

Mean Square Error (MSE) σ2, $\sigma^2 = \frac{1}{N}\sum_{n=1}^{N}(x_n - y_n)^2$ ----- -------- (5.1)

$$PSNR = 20\log_{10}\frac{255}{MSE}$$ ------ -------- (5.2)