Relationship between Pixels:

We consider several important relationships between pixels in a digital image.

NEIGHBORS OF A PIXEL

A pixel *p* at coordinates (*x*,*y*) has four *horizontal* and *vertical* neighbors whose coordinates are givenby:

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

	(x, y-1)	
(x-1, y)	*P (x,y)*	(x+1, y)
	(x, y+1)	

This set of pixels, called the 4-*neighbors* or *p*, is denoted by $N_4(p)$. Each pixel is one unit distance from (x,y) and some of the neighbors of p lie outside the digital image if (x,y) is on the border of the image. The four *diagonal* neighbors of *p* have coordinates and are denoted by $N_D(p)$.

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

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

These points, together with the 4-neighbors, are called the 8-neighbors of p, denoted by $N_8(p)$

(x-1, y+1)	(x, y-1)	(x+1, y-1)
(x-1, y)	*P (x,y)*	(x+1, y)
(x-1, y-1)	(x, y+1)	(x+1, y+1)

As before, some of the points in $N_D(p)$ and $N_8(p)$ fall outside the image if (x,y) is on the border of the image.

ADJACENCY AND CONNECTIVITY

Let v be the set of gray –level values used to define adjacency, in a binary image, v={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 – 255, *V* set can be any subset of these 256 values. if we are reference to adjacency of pixel with value.

Three types of adjacency

- 4- Adjacency – two pixel P and Q with value from V are 4 –adjacency if A is in the setN_4(P)
- 8- Adjacency – two pixel P and Q with value from V are 8 –adjacency if A is in the setN_8(P)
- M-adjacency –two pixel P and Q with value from V are m – adjacency if (i) Q is in N_4(p) or (ii) Q is in N_D(q) and the set $N_4(p) \cap N_4(q)$ has no pixel whose values are from V.
- Mixed adjacency is a modification of 8-adjacency. It is introduced to eliminate the ambiguities that often arise when 8-adjacency is used.
- Forexample:

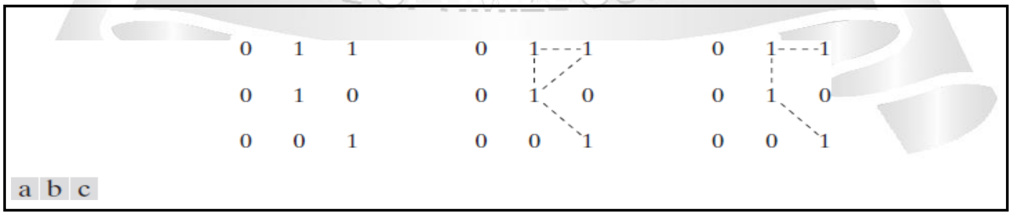

Fig:1.8(a) Arrangement of pixels; (b) pixels that are 8-adjacent (shown dashed) to the center pixel; (c) ***m***-adjacency.

Types of Adjacency:

- In this example, we can note that to connect between two pixels (finding a path between two pixels):

  -In 8-adjacency way, you can find multiple paths between twopixels

- While, in m-adjacency, you can find only one path between twopixels

- So, m-adjacency has eliminated the multiple path connection that has been generated by the8-adjacency.
- Two subsets $S_1$and $S_2$are adjacent, if some pixel in $S_1$is adjacent to some pixel in S_2.

A Digital Path:

- A digital path (or curve) from pixel p with coordinate (x,y) to pixel q with coordinate (s,t) is a sequence of distinct pixels with coordinates (x_0,y_0), (x_1,y_1), …, (x_n, y_n) where $(x_0,y_0) = (x,y)$ and $(x_n, y_n) = (s,t)$ and pixels (x_i, y_i) and (x_{i-1}, y_{i-1}) are adjacent for $1 \leq i \leq n$
- n is the length of the path
- If $(x_0,y_0) = (x_n, y_n)$, the path is closed.

  We can specify 4-, 8- or m-paths depending on the type of adjacency specified.

  - Return to the previous example:

Fig:1.8 (a) Arrangement of pixels; (b) pixels that are 8-adjacent(shown dashed) to the center pixel; (c) m-adjacency.

In figure (b) the paths between the top right and bottom right pixels are 8-paths. And the path between the same 2 pixels in figure (c) is m-path

Connectivity:

- Let S represent a subset of pixels in an image, two pixels$p$ and q are said to be connected in *S* if there exists a path between them consisting entirely of pixels in *S*

- For any pixel *p* in *S*, the set of pixels that are connected to it in *S* is called a *connected component* of *S*. If it only has one connected component, then set *S* is called a *connected set*.

Region and Boundary:

- REGION: Let *R* be a subset of pixels in an image, we call *R* a region of the image if *R* is a connected set.
- BOUNDARY: The *boundary* (also called *border* or *contour*) of a region *R* is the set of pixels in the region that have one or more neighbors that are not in*R*.

If *R* happens to be an entire image, then its boundary is defined as the set of pixels in the first and last rows and columns in the image. This extra definition is required because an image has no neighbors beyond its borders. Normally, when we refer to a region, we are referring to subset of an image, and any pixels in the boundary of the region that happen to coincide with the border of the image are included implicitly as part of the region boundary.

COLOR IMAGE FUNDAMENTALS

According to the theory of the human eye, all colors are seen as variable combinations of the three so-called primary colors red (*R*), green (*G*), and blue (*B*). The following specific wavelength values to the primary colors:

Blue(B) = 435.8 nm

Green (*G*)= 546.1 nm

Red (*R*) = 700.0 nm

The primary colors can be added to produce the secondary colors

Magenta (red + blue), **cyan** (green + blue), and **yellow** (red + green), see Figure

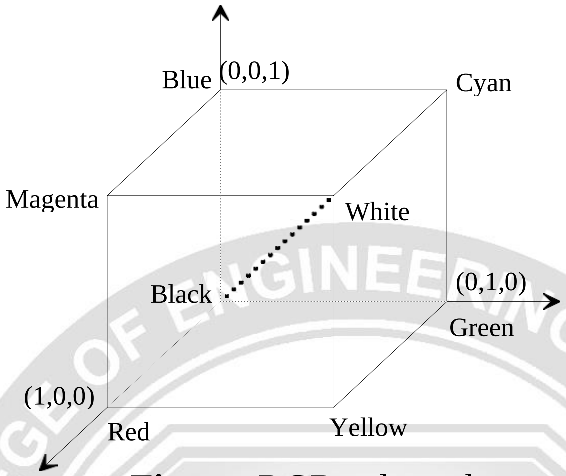

Figure -RGB color cube

(Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010- Page no-402)

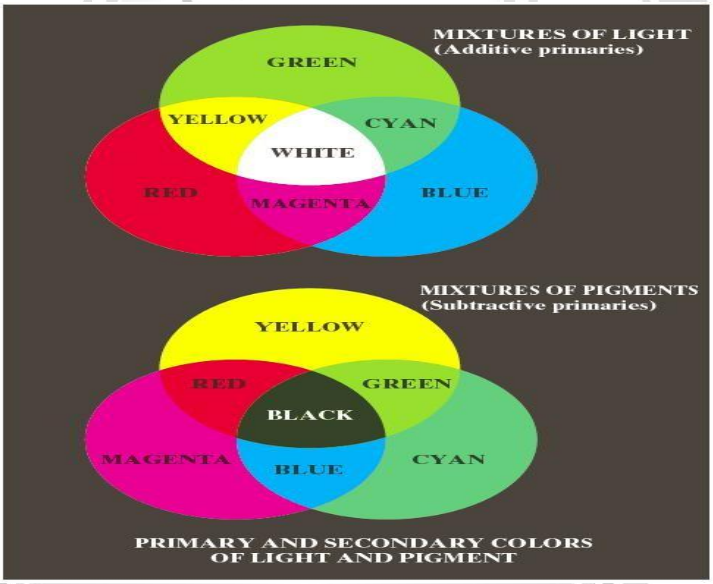

Fig: RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity

(Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010. – Page no. -403)

Mixing all three primary colors results in white. Color television reception is based on this three color system with the additive nature of light.

There are several useful color models: RGB, CMY, YUV, YIQ, and HSI.

1. RGB color model

The colors of the RGB model can be described as a triple (*R*, *G*, *B*), so that *R*, *G*, *B* .The RGB color space can be considered as a three-dimensional unit cube, in which each axis represents one of the primary colors, see Figure. Colors are points inside the cube defined by its coordinates. The primary colors thus are red=(1,0,0), green=(0,1,0), and blue=(0,0,1). The secondary colors of RGB are cyan=(0,1,1), magenta=(1,0,1) and yellow=(1,1,0).

The nature of the RGB color system is additive in the sense how adding colors makes the image brighter. **Black is at the origin, and white is at the corner** where *R*=*G*=*B*=1. The gray scale extends from black to white along the line joining these two points. Thus a shade of gray can be described by (*x*,*x*,*x*) starting from black=(0,0,0) to white=(1,1,1).

The colors are often normalized as given in equation .

This normalization guarantees that $r+g+b=1$.

ADDITIVE COLOUR MIXING

In order to generate suitable colour signals it is necessary to know definite ratios in which red, green and blue combine form new colours. Since R,G and B can be mixed to create any colour including white, these are called primary colours.

R + G + B = White colour
R – G – B = Black colour
The primary colours R, G and B combine to form new colours
R + G = Y
R + B = Magenta (purplish)
G + B = Cyan (greenish blue)

HSI COLOR MODEL

The HSI model consists of *hue* (*H*), *saturation* (*S*), and *intensity* (*I*).

Intensity corresponds to the luminance component (*Y*) of the YUV and YIQ models.

Hue is an attribute associated with the dominant wavelength in a mixture of light waves, i.e. the dominant color as perceived by an observer.

Saturation refers to relative purity of the amount of white light mixed with hue. The advantages of HSI are:

The intensity is separated from the color information (the same holds for the YUV and YIQ models though).

The hue and saturation components are intimately related to the way in which human beings perceive color.