# CHAPTER 9

# COLOUR IMAGE PROCESSING

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# Colour Image Processing

- Colour Image Processing
- Primary and Secondary Colour
- Colour Characteristics
- Chromaticity Diagram and Its Use
- Colour Model
  - Conversion from one model to another model
- Pseudo Colour Image Processing
- Full Colour Image Processing

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# Colour Image Processing

- Human eye can distinguishes about thousand numbers of colour shade whether in gray scale we only distinguishes roughly 2 dozens of shade
- Colour is very powerful descriptor
- We can use colour to identify objects

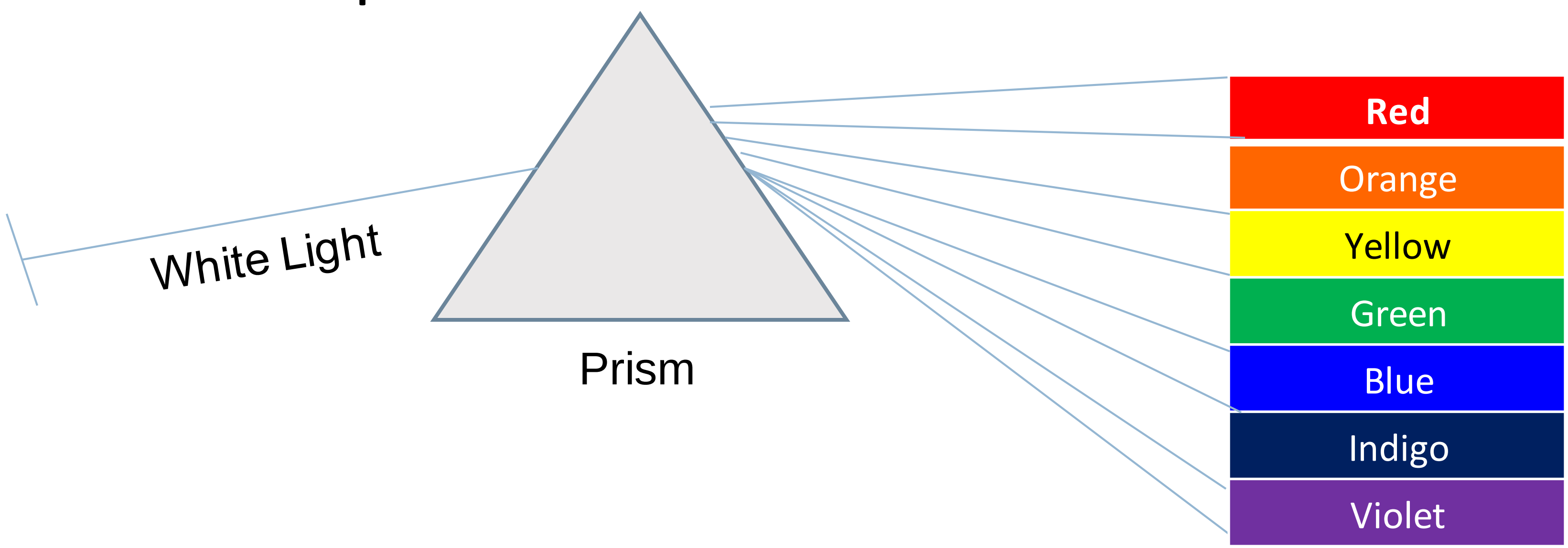
- Full colour processing
  - In full colour processing we take all the colour considered in the image

# Pseudo colour processing

- Pseudo Colour Processing
  - Here we try to assign certain colour to gray level image.
  - 0 – 255 divided in different range
  - We can divide range 0 – 255 into range 0 – 50, 50 – 100, 100 – 150 and so on.
  - And we assign different colour to different range of intensity value into gray scale image.
  - Say 0 – 50 is colour A
  - We can extract information from gray level image

# Colour Fundamental

- We till dose not know how human intercept colour but we have some standard like Newton (1666) use optical prism.
- When a white light passes through  prism we get 7 colour spectrum “ V I B G Y O R “

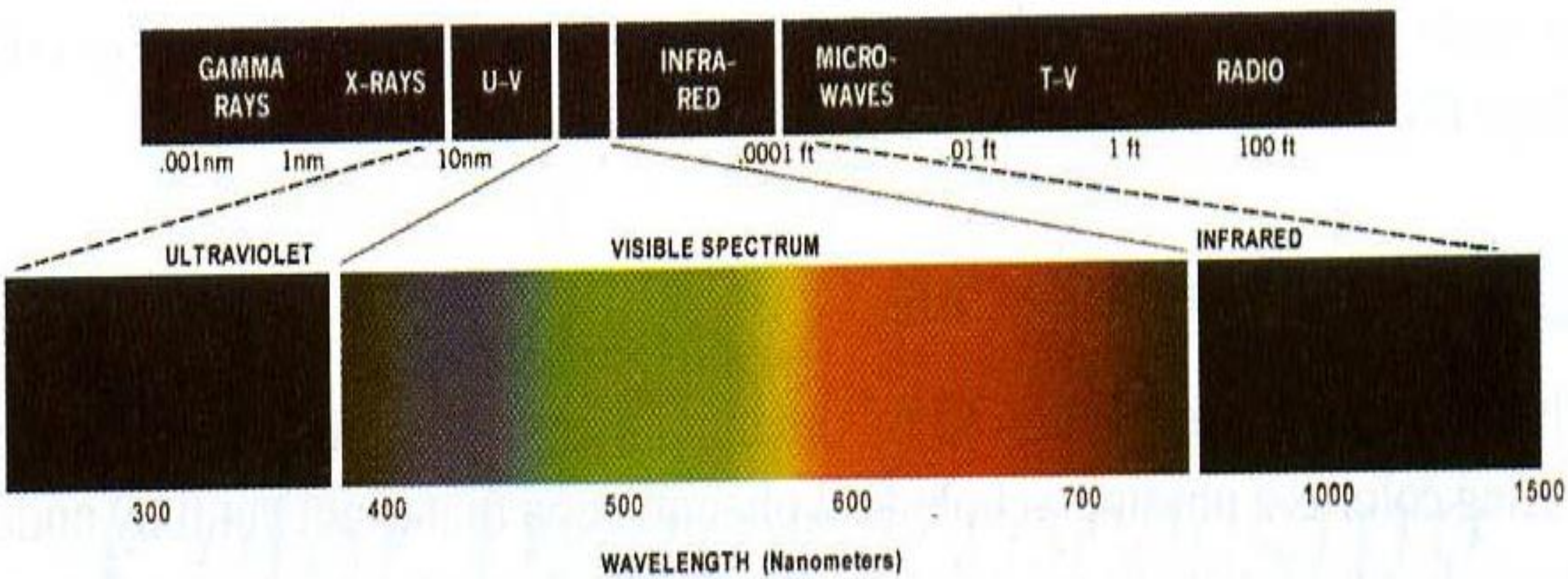


# Attributes of Colour

- Achromatic light
  - Intensity of light matters
  - Achromatic lights what viewers see on black and white Television set.
  - Gray level refers to scalar measure to intensity that range fro black to white
- Chromatic light
  - Wavelength of lights matters
  - The chromatic light spans the electromagnetic spectrum from 400nm to 700nm

# Electromagnetic Spectrum

- Electromagnetic Spectrum



# Quality of Light

- Radiance
  - It is the total amount of energy coming out of light source
  - Its measuring unit is watt
- Luminance
  - It is the amount of energy perceive by object
  - Its measuring unit is lumens
- Brightness
  - It is only the practical observation
  - We can not measure it

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# Primary Colours

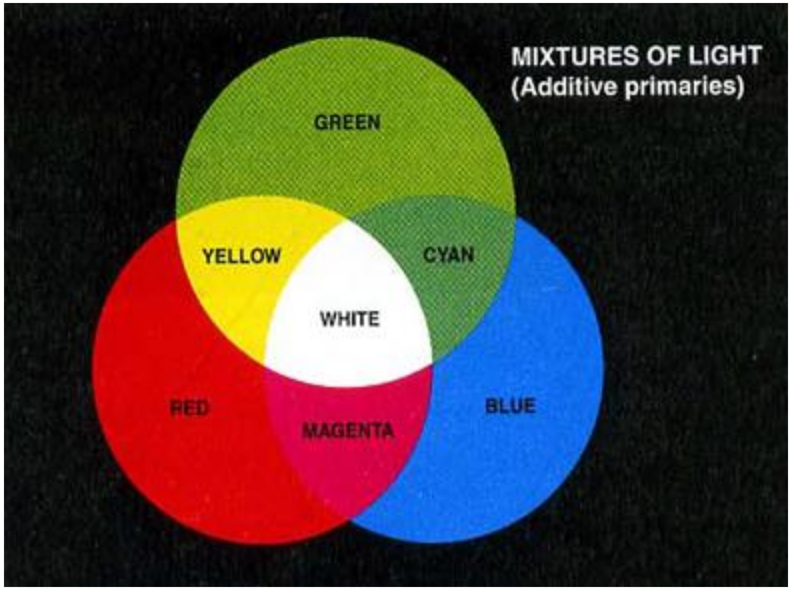
- There are three Primary Colours

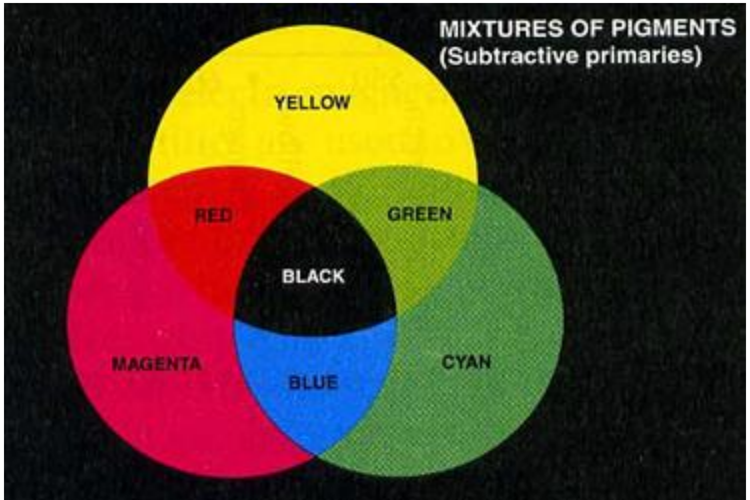
Red Green Blue

- By mixing these colours in different proportions we can generate different colours
- Why choosing RGB as primary color
  - There are around 6 to 7 million cone cells in our eye for sensing colours among then
  - 65% of cone cell sense Red
  - 33% of cone cell sense Green
  - 2%   of cone cell sense Blue

# Secondary Colour

- Primary colours combined to form secondary colour
- Red + Blue = Magenta
- Green + Blue = Cyan
- Red + Green = Yellow



PRIMARY AND SECONDARY COLORS
OF LIGHT AND PIGMENT

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# Colour Characteristics

- Brightness
  - It is nothing but chromatic notion of intensity
  - It gives the sensation
- Hue
  - It represent the dominant (colour) wavelength in a mixture of colour
- Saturation
  - What is the purity of the colour or the amount of white colour mixed with Hue
  - Pink = White colour mixed with red colour
- Hue & Saturation together represents chromaticity

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# Tristiumulas

- The amount of red, gree and blue needed to form any particular colour is known as tristimulas value and it is denoted as X, Y and Z
- A colour is then specified by its tri-chromatic coefficient and is defined as

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

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

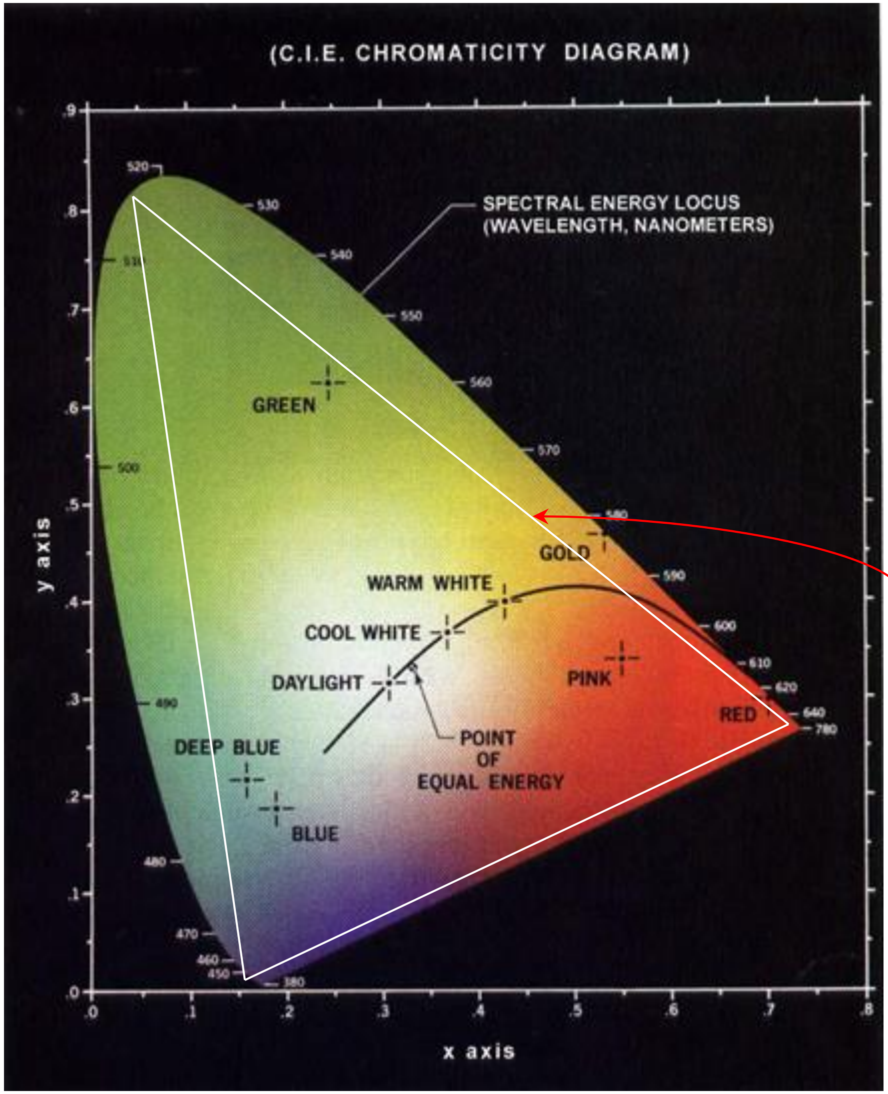
And

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

Sum of chromatic coefficient is $x + y + z = 1$

Colour can be specified by chromatic coefficient or chromatic diagram

# Chromatic Diagram




Using the chromatic diagram we can obtain any colour

A straight line joining any two point in the chromatic diagram define different colours along that line

To determine the range of colour that can be obtained from any three point in the chromatic diagram is found by simply joining those three colour points to form triangle.

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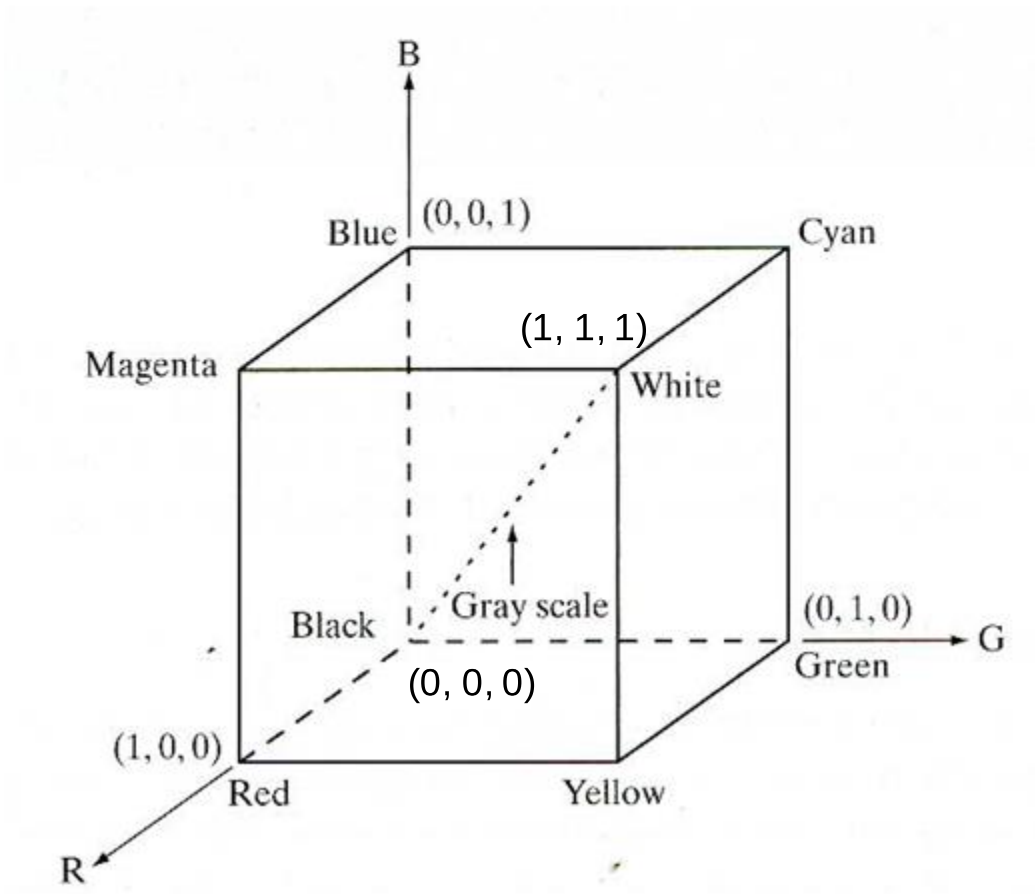
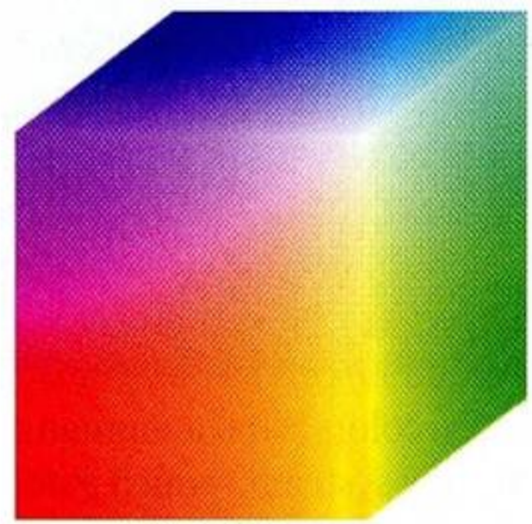
# Color Model

- RGB (Red – Green – Blue) model
  - Used in Monitor
- CMY (Cyan – Magenta – Yellow) model
  - Used in Printers
- CMYK (Cyan – Magenta – Yellow – Black) model
  - Used in Printers
- HSI (Hue – Saturation – Intensity ) model

# RGB Model



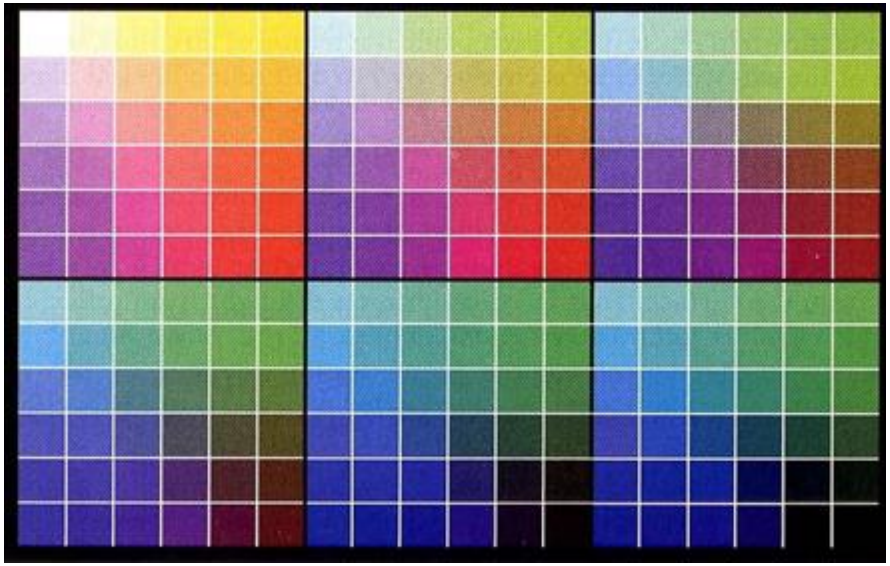

Three colour mix in appropriate proportion to form different colours



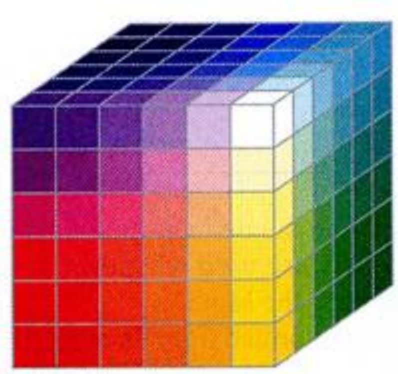
RGB 24 bit colour Model

# RGB Model

- There are $(2^8)3$ = 16,777,216 colour can be possible using 8 bit of red, 8 bit of green and 8 bit of blue.
- 256 is the minimum number of colour that can be reproduce faithfully and among them 40 colours are processed differently by the operation system. So only 216 colors remains in the safe.



12 row and 18 columns represents the RGB safe colour



RGB safe colour Cube

# CMY & CMYK Model

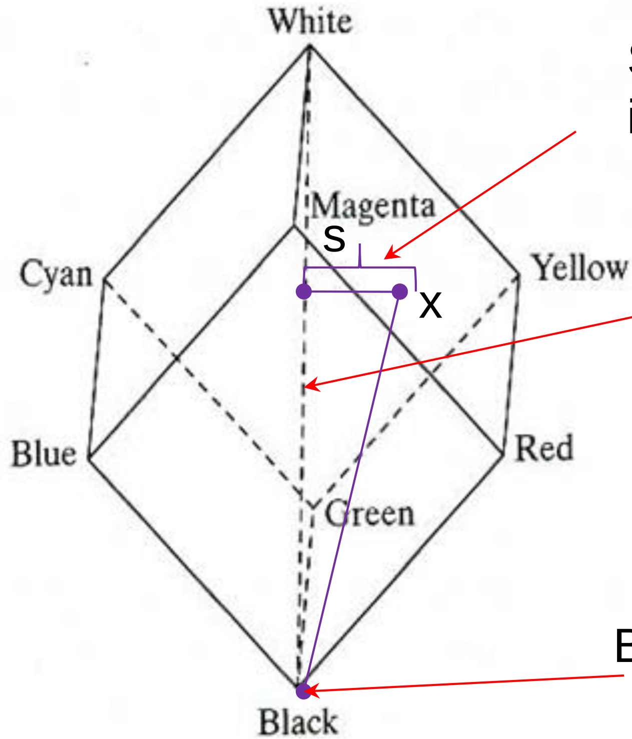
- The CMY color model is simply obtained from the RBG color model
- Assuming that all colour are normalized in the range [0 1]. If so the CMY model is as follows

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

- Here Cyan is subtracted Red colour from white colour. Similarly Magenta is subtracted green from white and Yellow is subtracted blue from white.
- CMYK is a CMY model where an additional pigment colour is black

# HSI model

- HSI model is useful for human interpretation
- Hue & Saturation gives Chromaticity information
- Intensity gives brightness (Intensity) information
- RGB to HIS Conversion



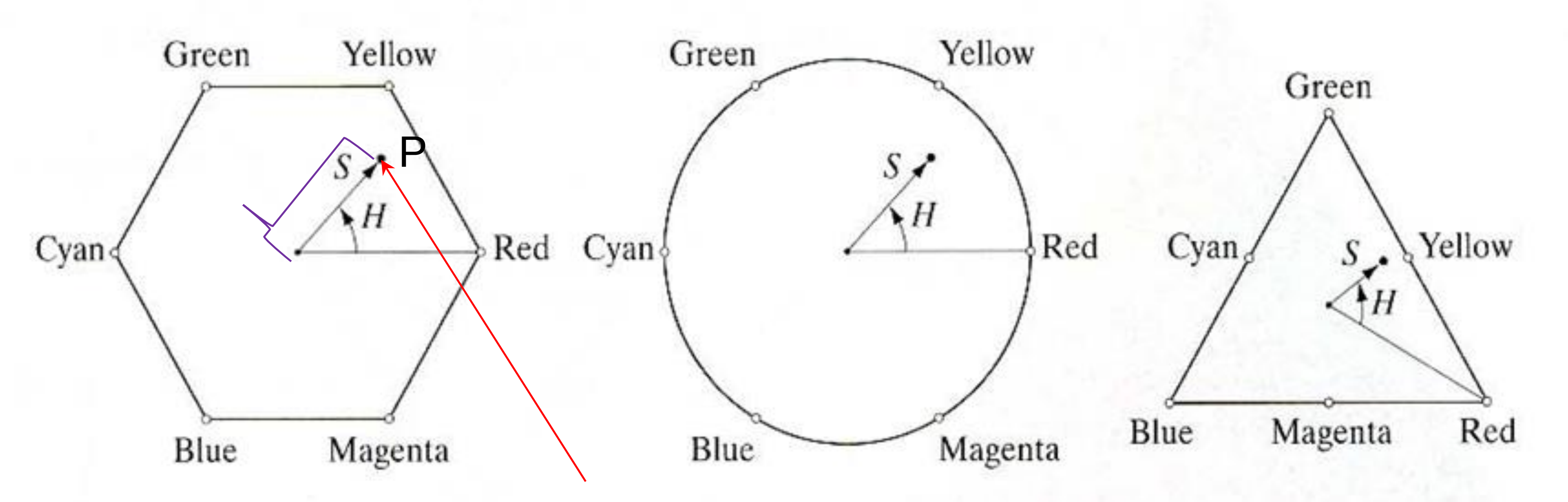

Saturation at intensity axis is zero and the saturation increases as it move away from intensity axis

Intensity axis

Intensity at black is 0 and at white is 1
Black contain no colour component and white contain all colour component

# HSI Model Cont..

To have a concept about the Hue & Saturation we de projection to plane perpendicular to Intensity axis




Point whose Hue & Saturation needs to be determined

**Hue:** It is the angle between the red axis and the line headed to the point ‘P’
**Saturation:** It is defined as the distance (length of the line from origin to point p) from origin to the point P

# RGB to HSI Conversion

Assuming that RGB is normalized in the range [0, 1] and θ is measured from the red axis in the HSI colour space.
Hue(H), Saturation(S) and Intensity(I) in terms of RGB is given as

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

Where θ is

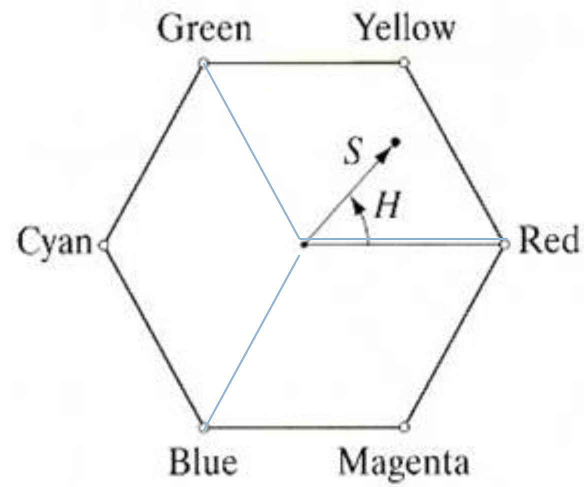
$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-G)^2+(R-B)(G-B)\right]^{1/2}} \right\}$$

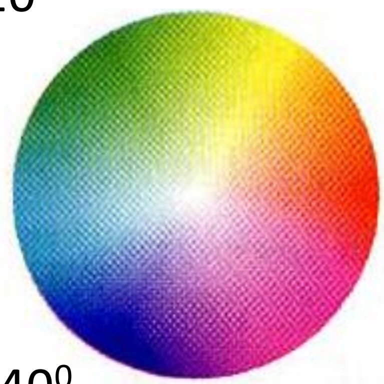
$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R, G, B)\right]$$

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

# HSI to RGB conversion

- RG Region ($0^0 \leq H < 120^0$)
  - $B = I(1 - S)$
  - $R = I[1 + S\cos H/\cos(60^0 - H)]$
  - $G = 1 - (R + B)$
- GB Region ($120^0 \leq H < 240^0$)
  - $R = I(1 - S)$
  - $G = I[1 + S\cos H'/\cos(60^0 - H)]$ where $H' = H - 120^0$
  - $B = 1 - (R + G)$
- BR Region ($240^0 \leq H < 360^0$)
  - $R = 1 - (G + B)$
  - $G = I(1 - S)$
  - $B = I[1 + S\cos H'/\cos(60^0 - H)]$ where $H' = H - 240^0$



# Colour Perception in HSI Model

- Keeping H & I fixed (Saturation reduction means: image becoming milky)
- H = 0
- I = 128

S = 255 200 100 50

- Keeping H & S Fixed (Intensity reduction means: image becoming darker)
- H = 0
- S = 255

I = 128 100 74 50

- Keeping S & I fixed (Hue increasing means: Change in colour of image)
- S = 255
- I = 128

H = 0 50 100 150

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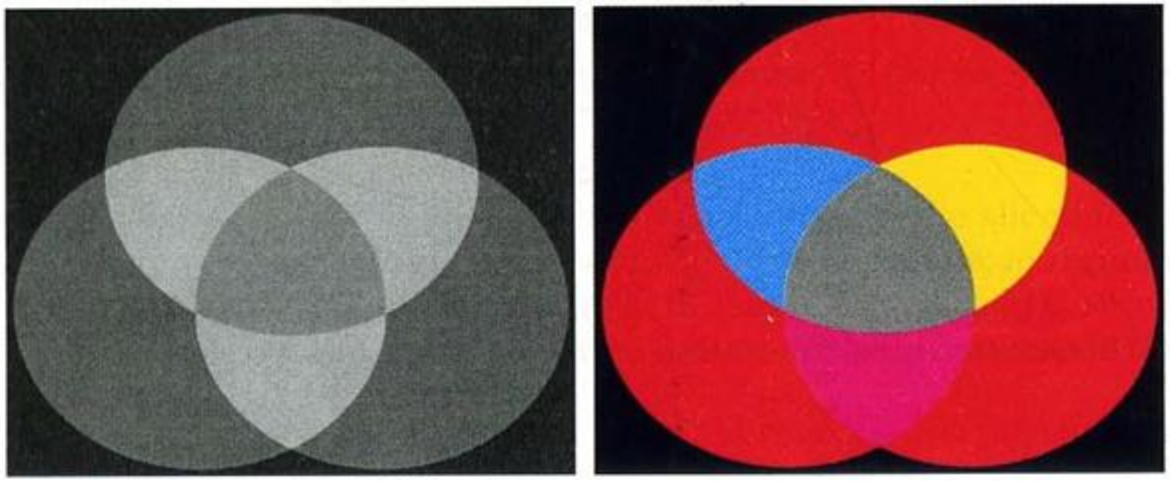
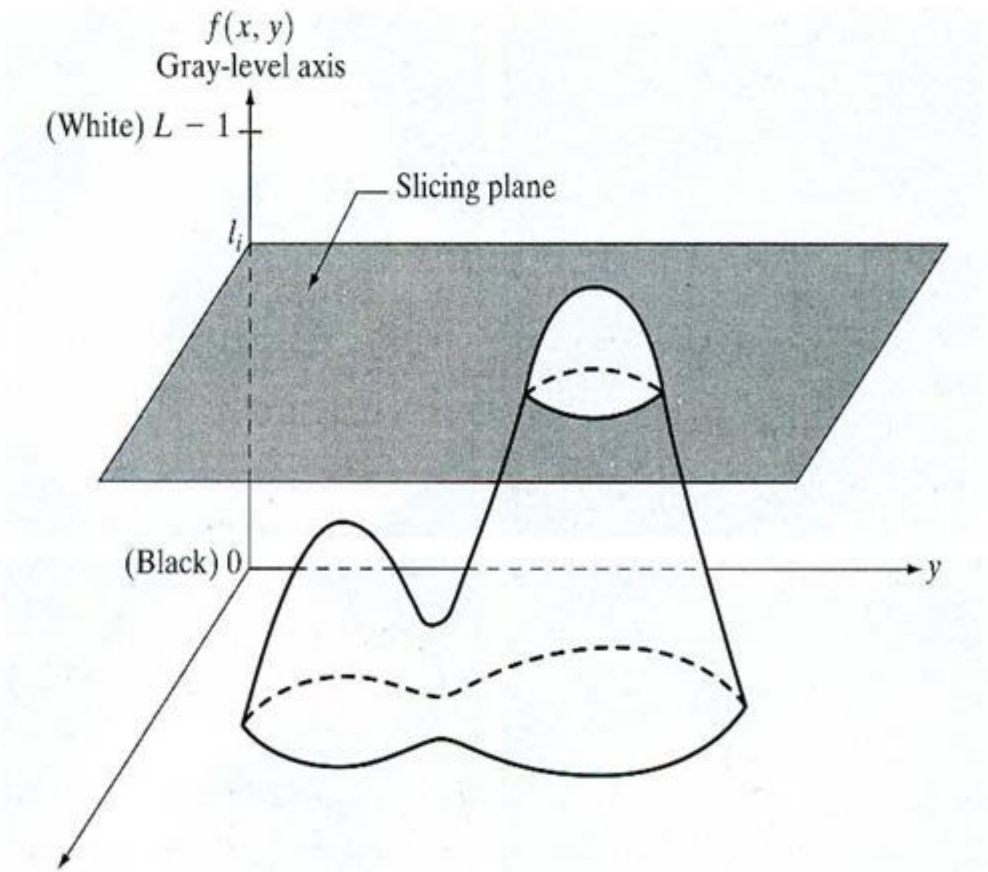
# Pseudo Colour Image Processing

- The process of assigning colours to gray level range is known as pseudocolour image processing
  - Intensity Slicing
  - Gray level to Colour Transmission



Gray scale image to RGB colour Image

# Intensity Slicing




If the geay scale image is sliced into two components or intensity levels using a slicing plane. Now we can assign colours to the sliced components/area of the image.

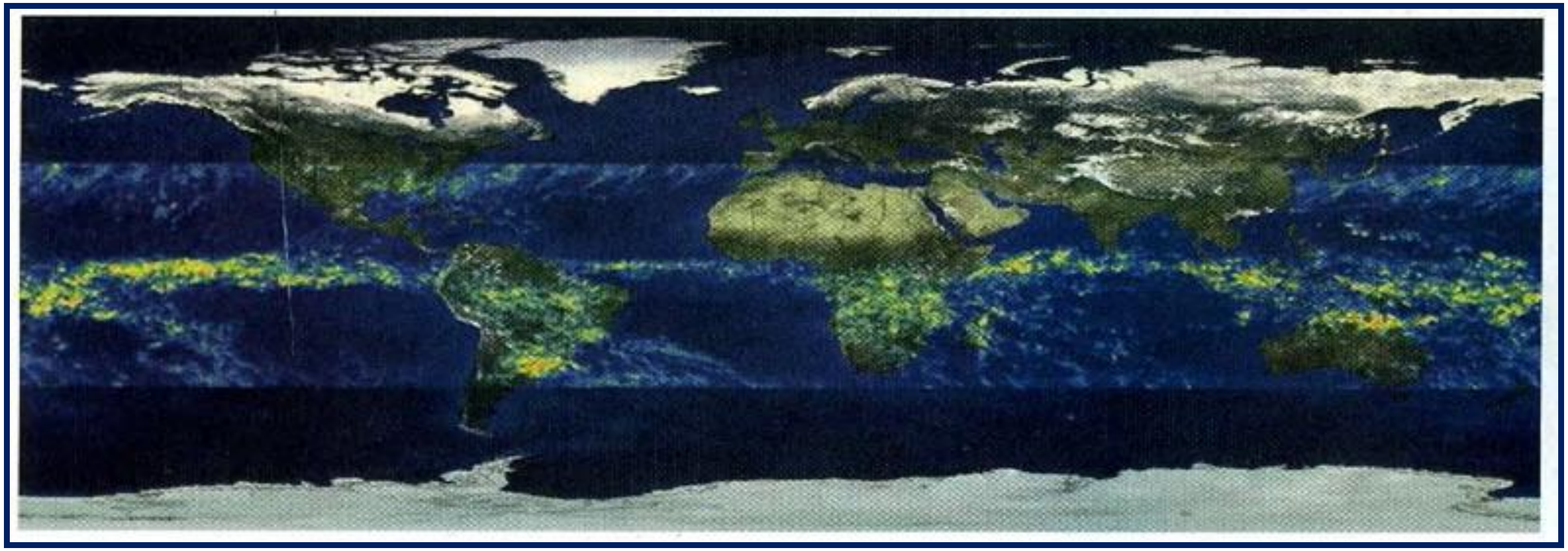
Here slicing plane cut the image in two parts so we can assign two different colour to two different area or intensity range

# Intensity Slicing

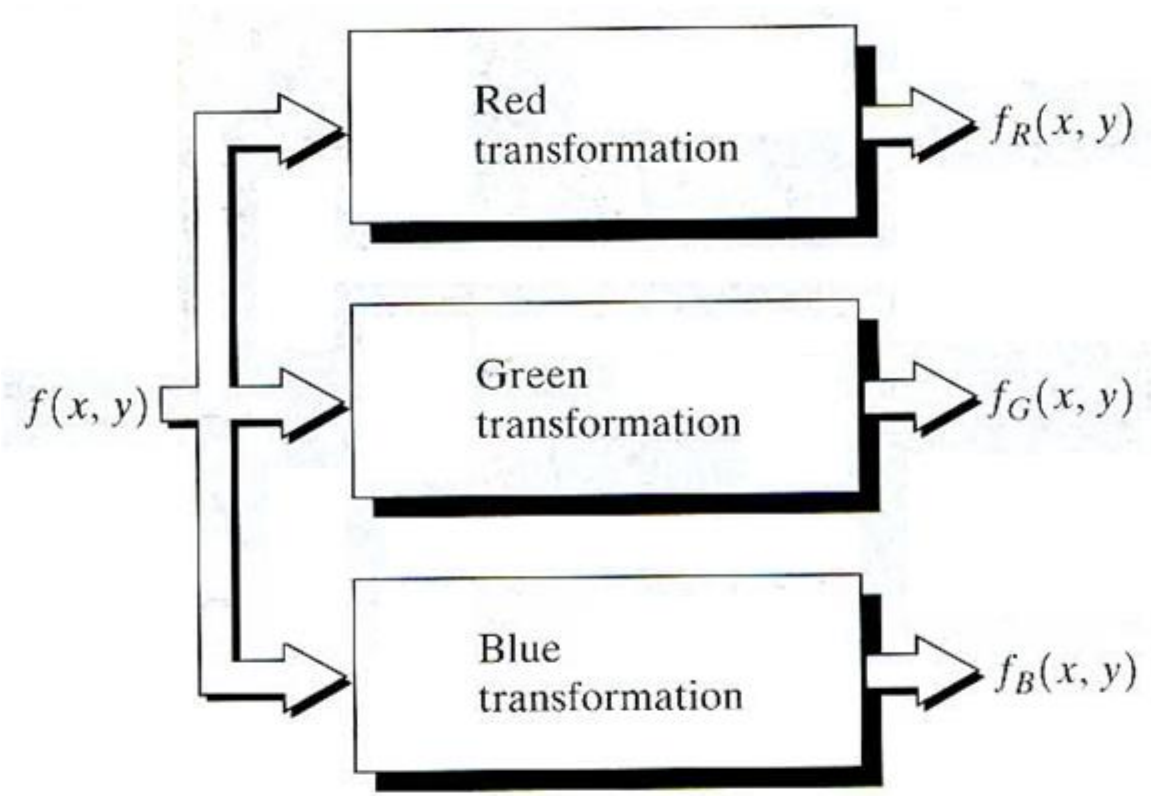
- Let an image have intensity level [ 0 – L -1 ] where L total no. of intensity value
- Assume
  - $L_0 \rightarrow$ black [f(x,y) = 0] & $L_{L-1} \rightarrow$ white[f(x,y) = L – 1]
  - P $\rightarrow$ no. of planes perpendicular to intensity axis i.e. parallel to image plane
  - $l_1, l_2, \ldots \ldots, l_P$ are the plane perpendicular to intensity axis
  - $0 < P < L - 1$ and this divide intensity range into P+1 intervals
- Colour assign to local (x,y) is
  - $h(x,y) = C_k$

    If $f(x,y) \in V_k$
  - Where $V_k$ is the intensity range defined by location $(l_k, l_{k+1})$ and P no. of ranges/intervals are $V_1, V_2, V_3, \ldots, V_k$

# Intensity Slicing



# Gray To Colour Transmission



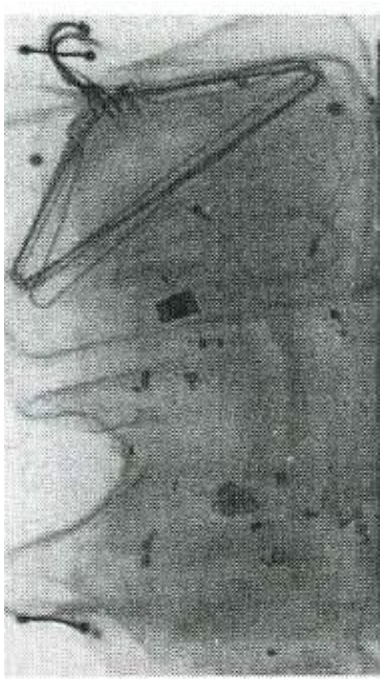

Red, Green & Blue combined together to form a colour image, the colour image form is pseudo colour image as it does not match with the real perception. Here we only colour different intensity value with different colour value.

# Gray To Colour Transmission

- Pseudo colour is appear more radish if we scale as
  - $f_R(x,y) = f(x,y)$
  - $f_G(x,y) = 0.33f(x,y)$ (scale down)
  - $f_B(x,y) = 0.11f(x,y)$ (scale down)
- Pseudo colour is appear more greenish if we scale as
  - $f_R(x,y) = 0.33f(x,y)$ (scale down)
  - $f_G(x,y) = f(x,y)$
  - $f_B(x,y) = 0.11f(x,y)$ (scale down)
- Pseudo colour is appear more bluish if we scale as
  - $f_R(x,y) = 0.11f(x,y)$ (scale down)
  - $f_G(x,y) = 0.33f(x,y)$ (scale down)
  - $f_B(x,y) = f(x,y)$

# Gray To Colour Transmission

# Gray To Colour Transmission



Gray to colour transmission

It is advantageous to represent image in colour rather in gray scale because we can distinguish more object in colour image in respect to gray image

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# Full Colour Image Processing

- Full Colour Image Processing
  - Colour Transformation
    - Intensity modifivcation
    - Colour Complement
    - Colour Slicing
    - Tone and Colour Correction
  - Colour Image Smoothening
  - Colour Image Sharpening

# Full Colour Image Processing

- Full colour image processing is divided in two category
  - Per-Colour-Plane Processing:
    - We process every individual colour component of colour image and then we combine these processed component to get processed colour image processing
  - Vectors Based Processing:
    - Every colour image is specified using three colour i.e, one colour among Red, Green & Blue
    - Colour Red, Green & Blue can be considered as vector

$$\mathbf{c}(x, y) = \begin{bmatrix} c_R(x, y) \\ c_G(x, y) \\ c_B(x, y) \end{bmatrix} = \begin{bmatrix} R(x, y) \\ G(x, y) \\ B(x, y) \end{bmatrix}$$

# Colour Transformation

$$S = T(r) \quad ; \text{T is the transfer function}$$

- Where r is the intensity value in the image f(x,y) and s is the corresponding intensity value in the transferred/proceed image g(x,y)
- Extending this concept to colour image processing

$$S_i = T_i\,(r_1, r_2, \ldots\ldots\ldots, r_n) \text{ for } i = 1,2,\ldots,n$$

- Wher n is the no. of component and
- Ti = $\{T_1, T_2, \ldots\ldots., T_n\}$ is the set of colour transformation function.
- For RGB/ HSI model n = 3

# Application of Colour Transformation

- Intensity Modification
  - Increasing image intensity value of → Increasing colour value of R G B
  - For i/p image f(x,y) the modified image g(x,y) is

$$g(x,y) = kf(x,y)$$

  - Where k is the scaling factor
  - In RGB space

$$s_i = kr_i \quad i = 1(R),2(G),3(B)$$

  - In HSI space

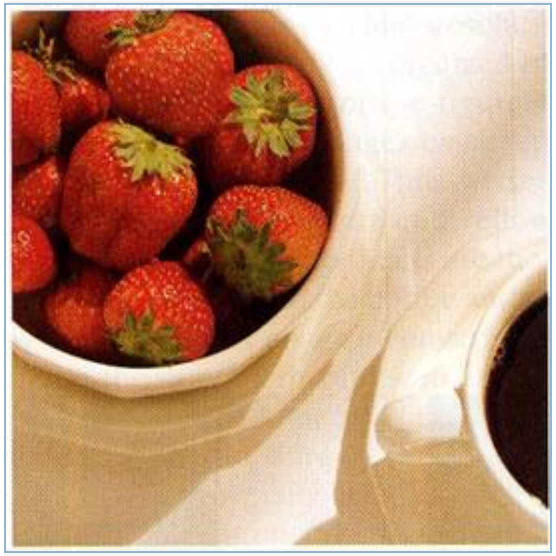
$$s_3 = kr_3 \quad \text{(Intensity scaled by factor k)}$$

$$s_1 = r_1 \quad \text{(Hue remains unchanged)}$$

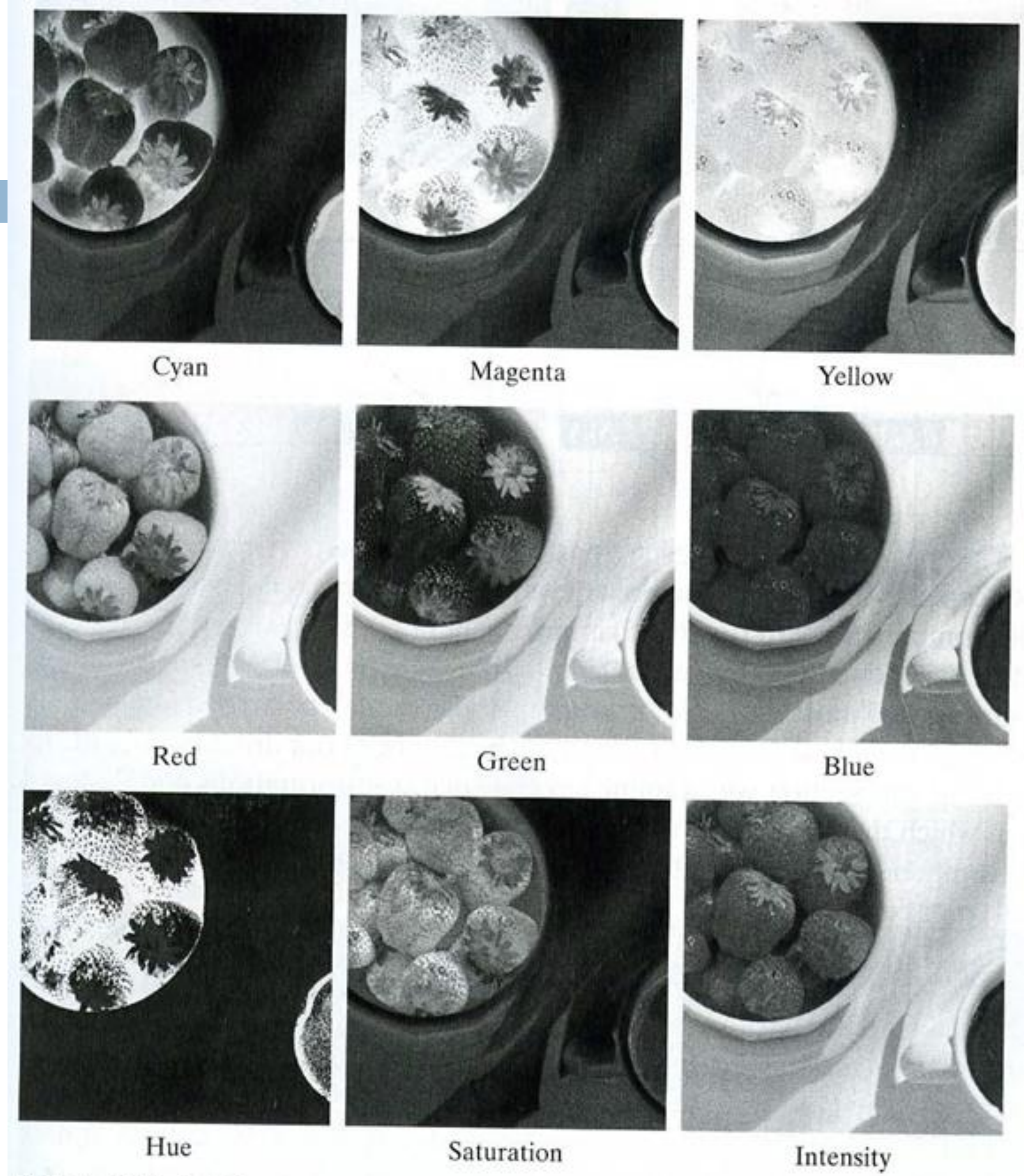
$$s_2 = r_2 \quad \text{(Saturation remains unchanged)}$$

  - In CMY Space

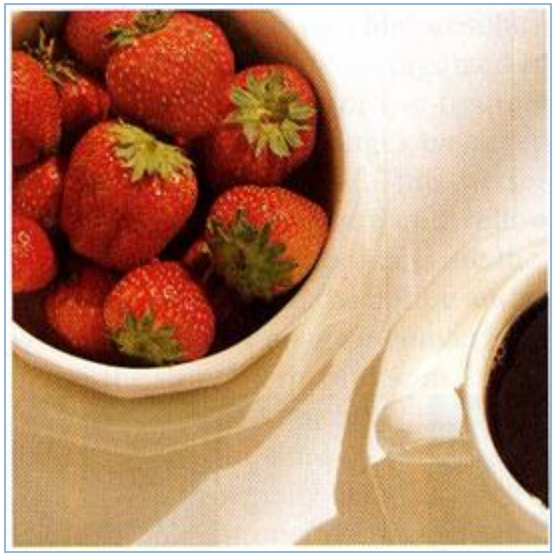
$$s_i = kr_i + (i - k) \quad i = 1(C),2(M),3(Y)$$

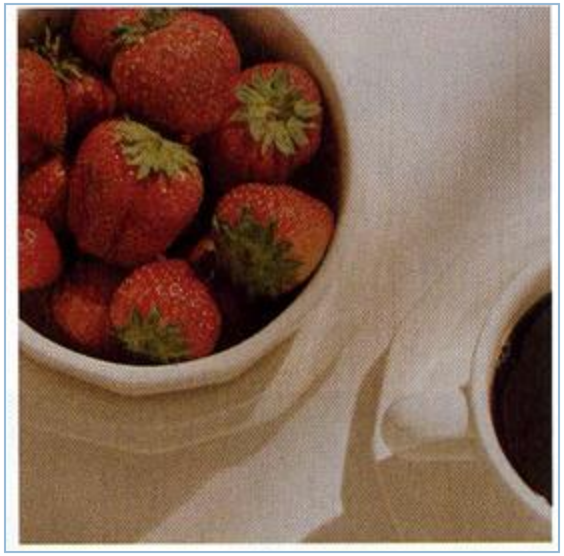


Full Colour Image



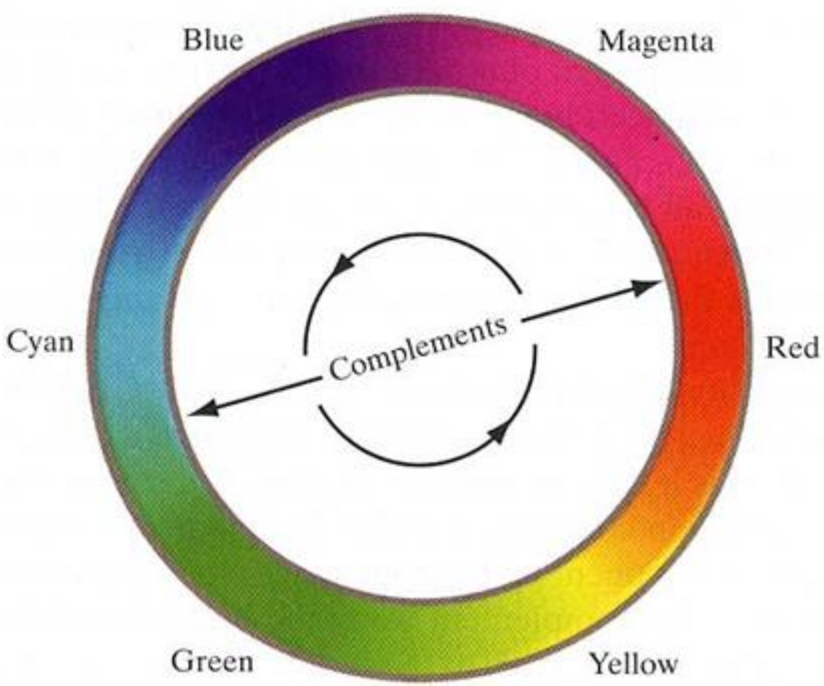
# Intensity modification Result





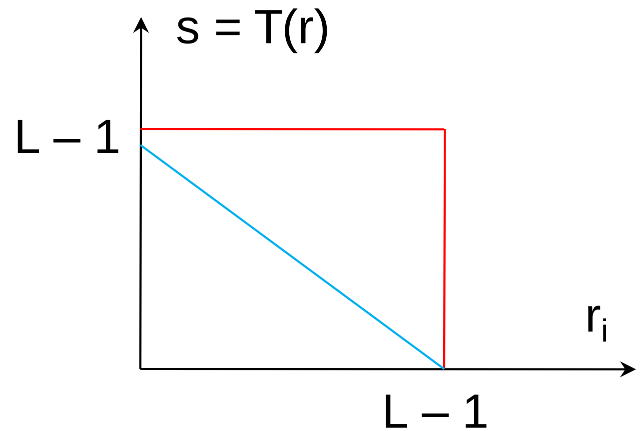
# Colour Complement

- Colour complement is analogues to negetive operation in gray scale
- Complement of red is cyan

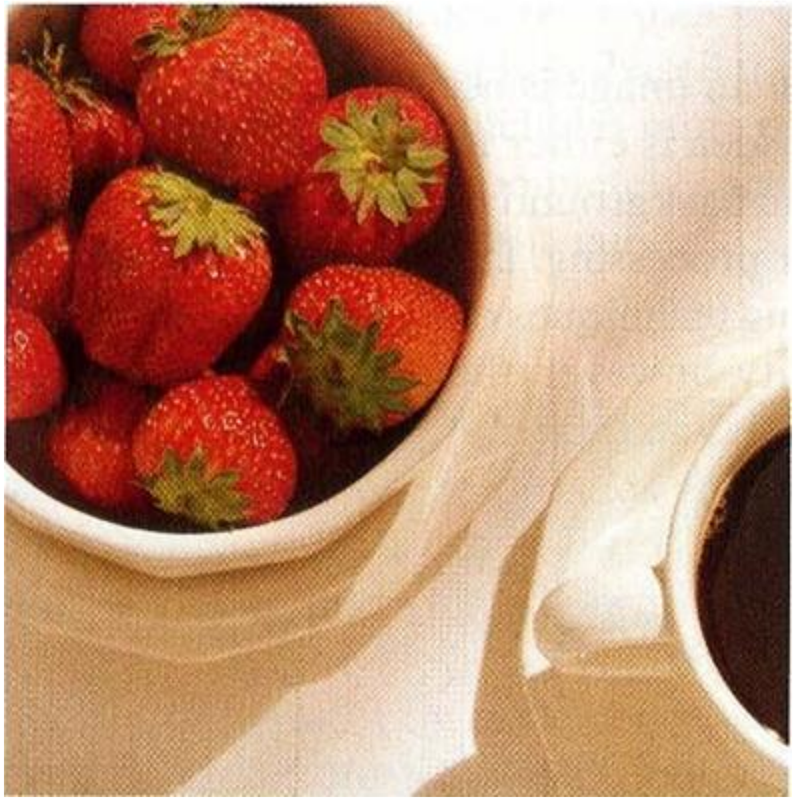


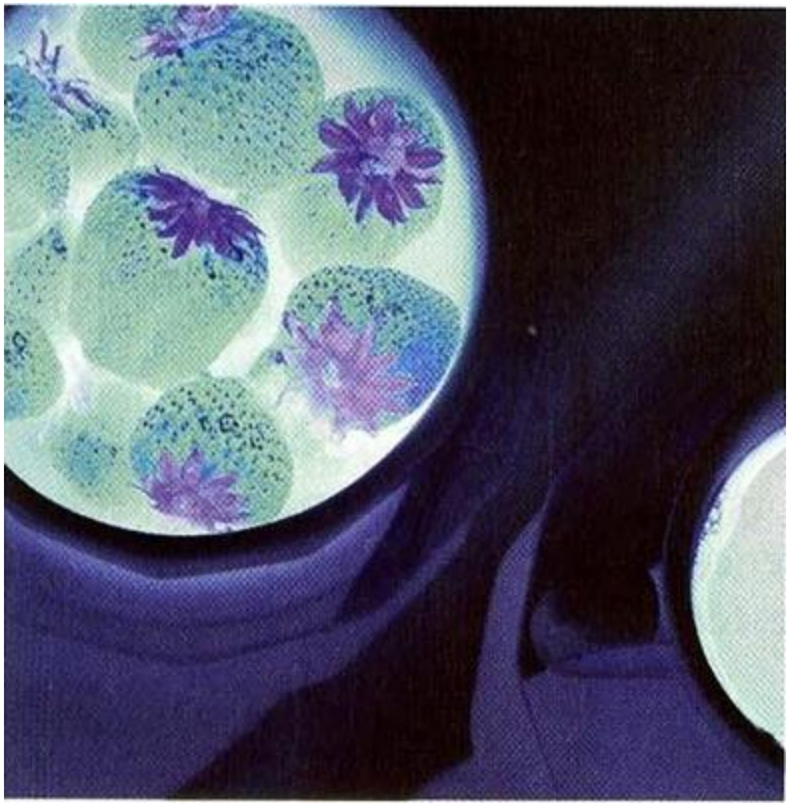

$$= T(r_i) = L - 1 - r_i$$

$$i = 1(R), 2(G), 3(B)$$



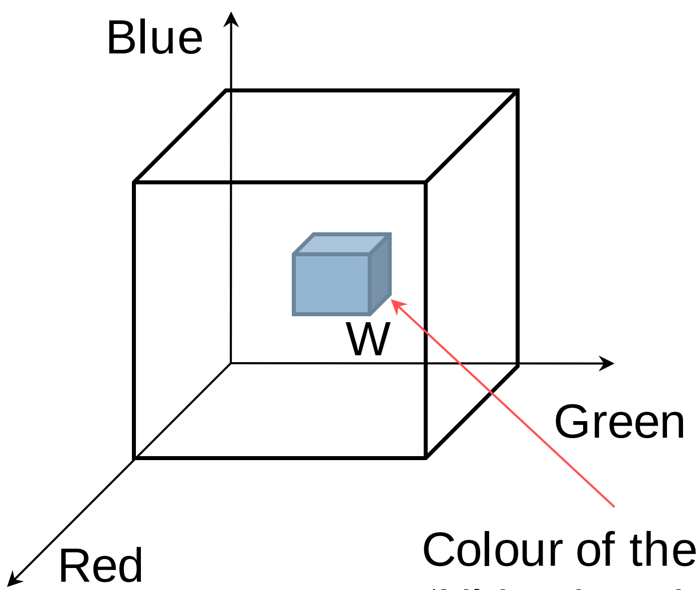
# Colour Complement Result





# Clour Slicing

- Colour Slicing operation is used to highlight certain colour range
- It is useful in identifying object of certain colour in an image (object only having colour red)

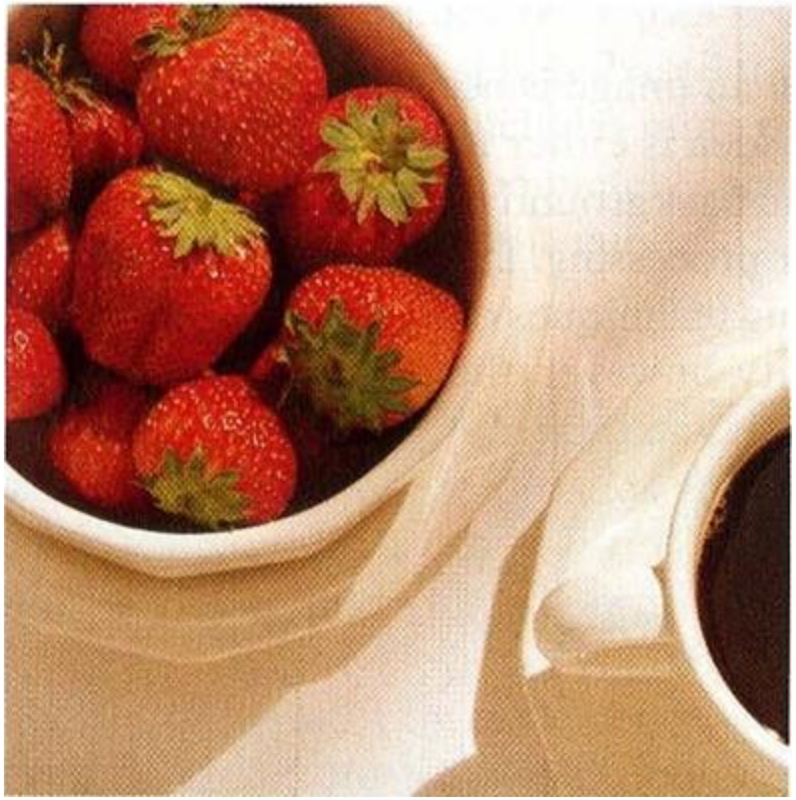


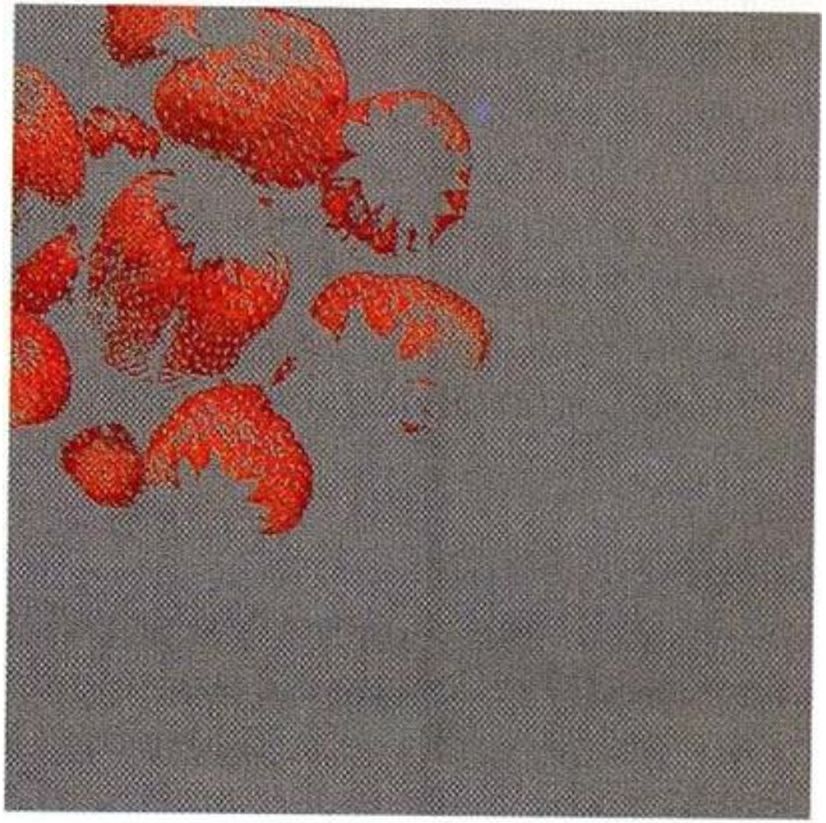

Colour of the inner cube 'N' is given by $(a_1,a_2,a_3)$

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

For i = 1,2,3, . …n

# Colour Slicing Result





# Tone Correction

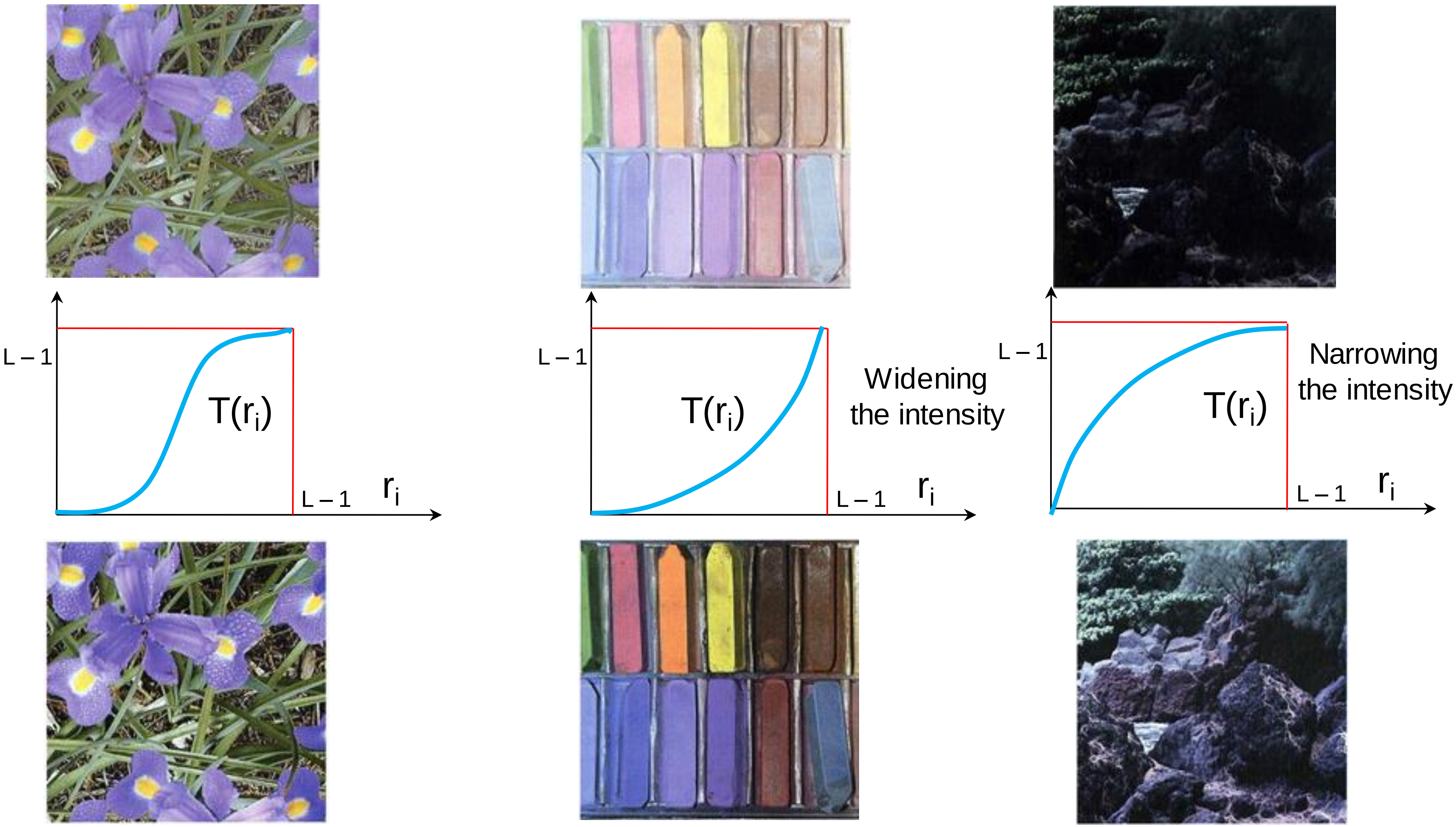
- Tone : It is the distribution of intensity value of different RGB component in the image
- Tone are: Flat Tone, Light Tone & Dark Tone

Flat Tone

Light Tone

Dark Tone

# Tone Correction



# Smoothening

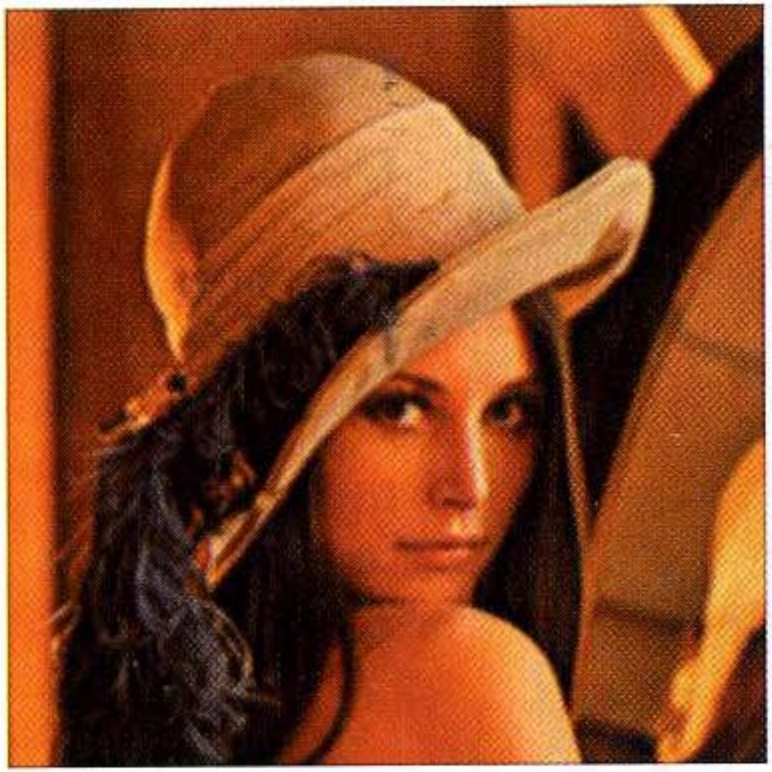
Smoothening in colour image processing is averaging of different RGB component in the colour image

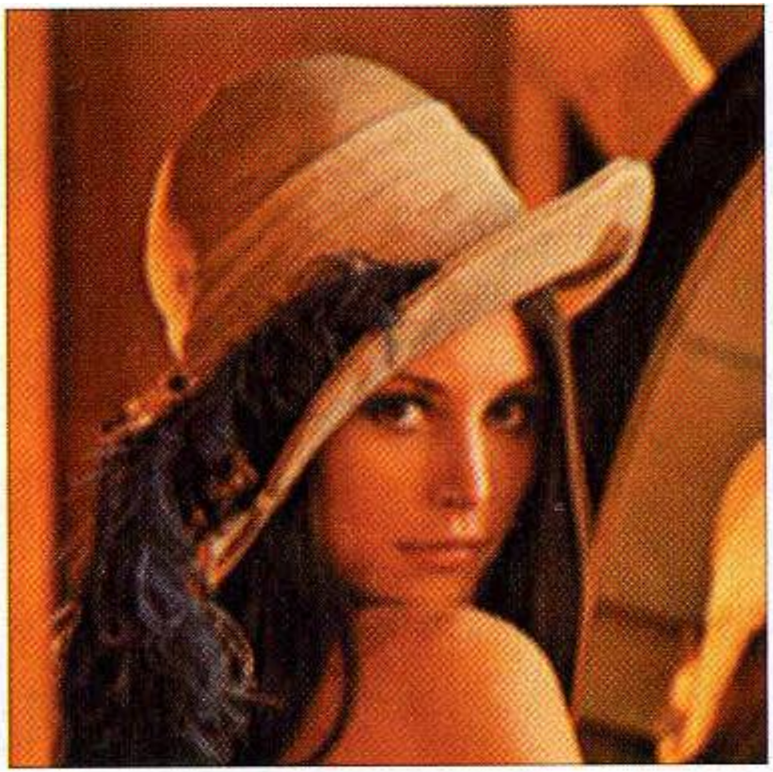
Let $S_{xy}$ is set of coordinate defining neighbourhood centered at point (x,y). The average of RGB component in this neighbourhood is define as

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

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

# Averaging Result



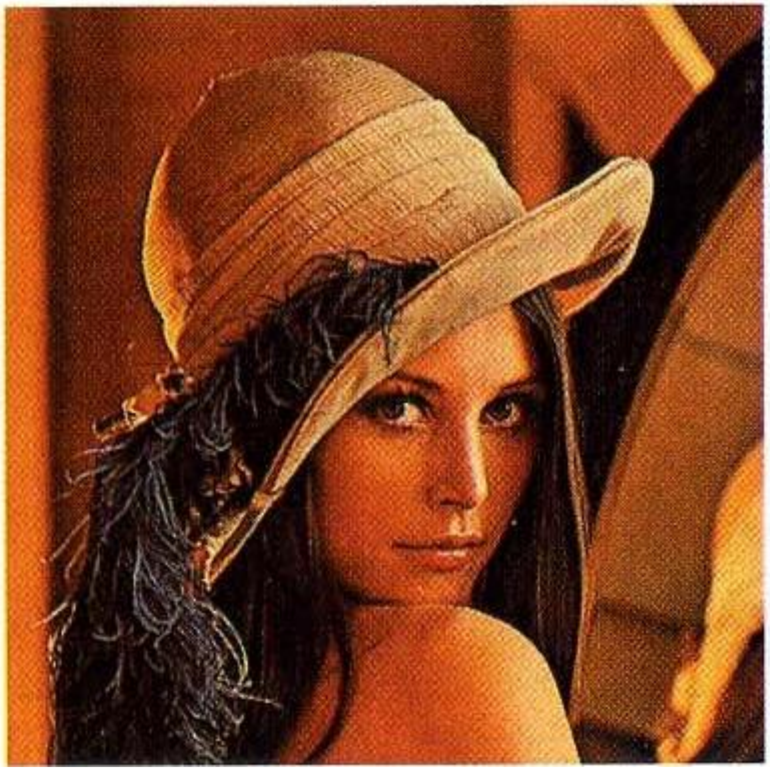


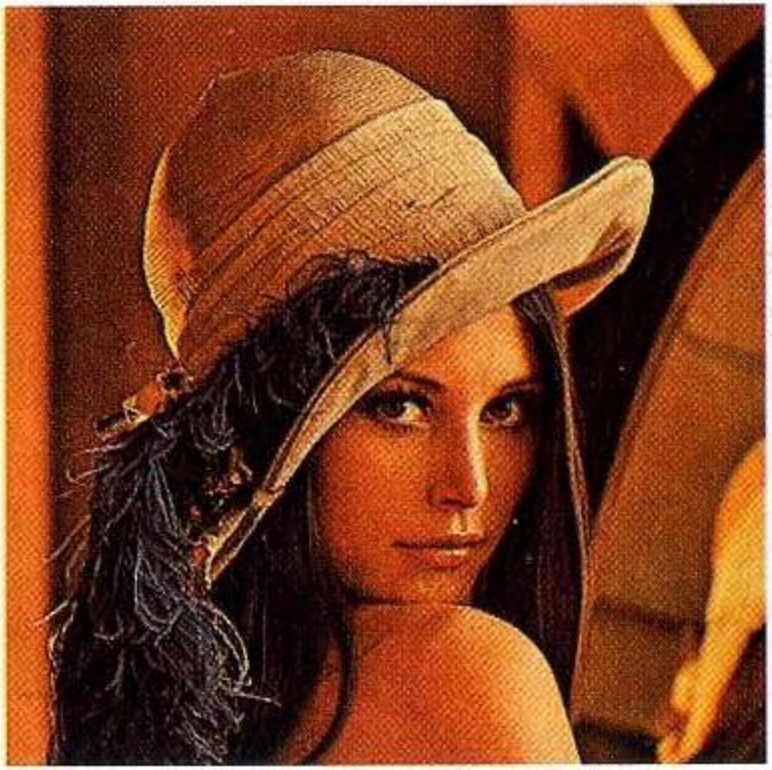
# Sharpening

- Laplacian Operation is used for sharpening an image henc the laplacian vector in case of color image processing is defined as

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

# Sharpening Result





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