COLOUR IMAGE PROCESSING - V   Sri MV Srikanth

Colour Image:-

Unit-4   ①

An image in which each and every pixel is included with colour information is refered as colour image.

Need for colour Image Processing:-

1. Usage of colour information makes the identification and extraction of objects easy

2. Human eye can perceive several thousands of shades of colours compared to limited shades of gray.

Types of colour Image Processing:-

Colour image processing is broadly classified into two types. They are

1. Full colour processing.
2. Pseudo colour processing (False colour Processing)

1. Full colour processing:- The process of acquiring an image using colour sensors is refered as full colour processing

Full colour images are natural colour images.

2. Pseudo Colour Processing:- The process of acquiring an image using achromatic sensor and then adding required colours to generate a colour image is srefered as pseudo colour processing.

Pseudo colour images are artificial colour images.

Quantities to describe quality of a colour:-

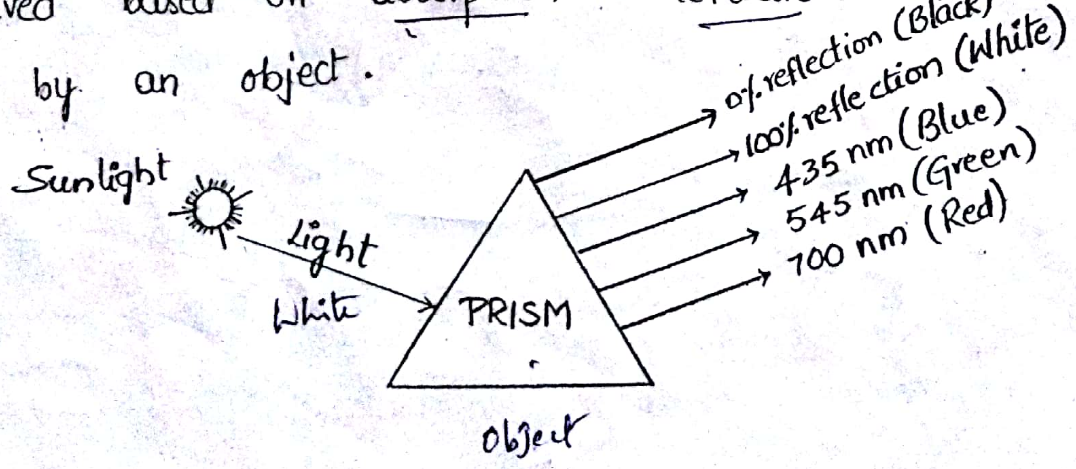
Radiance(R):- The amount of light radiated from a light source (Eg:- Sunlight) on an object is refered as radiance.

Luminence(L):- The amount of light ~~(absorb)~~ absorbed by the object out of total light falling on it is refered as luminance.

Brightness(B):- It is a subjective parameter that can be used to describe the intensity of light.

Colour detection Principle:-

The colour of an object can be perceived based on absorption & reflection capabilities of white light by an object.



In an electromagnetic spectrum, visible light ranges from 400nm - 700nm

If an object absorbs all the wavelengths of visible light falling on it (no wavelength is reflected by from the object), the object is perceived as the black (2i)

If an object reflects all the wavelengths of visible light falling on it (no wavelength is absorbed by the object) the object is perceived as white.

By appropriate combinations of absorption of certain wavelengths and the reflection of remaining, different shades of colours can be perceived.

Characteristics of colour :-

1. Hue (H)
2. Saturation (S)
3. Brightness (I)

1. Hue (H) :-

Hue is a measure of dominant colour in a colour object

2. Saturation (S) :-

Saturation is a measure of amount of whiteness mixed with the pure colour.

3. Brightness (I) :-

It is a subjective parameter that can be used to describe the intensity of light.

Types of Colours :- The retina of human eye mainly contains two ~~light sen~~ types of light sensing objects called rods & cones.

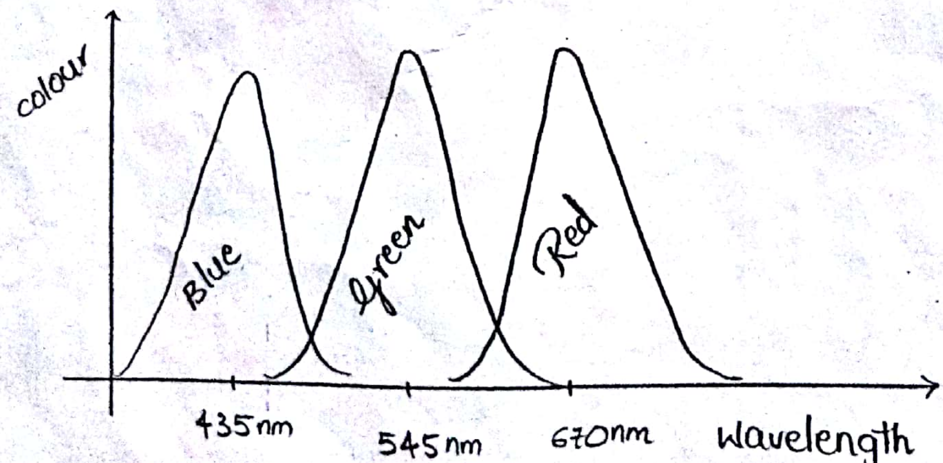
Cones are responsible for colour detection by the human eye and an eye approximately contains 6-7 millions of cones.

All these cones are sensitive to only three colours called Red, Green and Blue.

65% of cones are sensitive to Red and are called Large cones.

33% of cones are sensitive to Green and are called medium cones.

2% of cones are sensitive to Blue and are called Short cones.



Colours are basically classified into two types.

1. Primary
2. Secondary

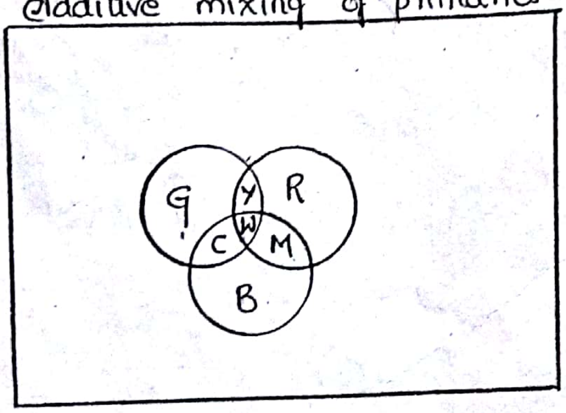
Primary colours :- (3)

Those colours which can be directly perceived by the cones of retina are refered as primary colours and hence Red, Green, Blue are refered as primary colours.

Appropriate mixing of primary colours can generate any other colour of visible spectrum.

Additive mixing of primary colours :-

Additive mixing of primaries



By Appropriate mixing of any two primaries will produce a secondary colour as follows

Red + Green	=	Yellow
Red + Blue	=	Magenta
Green + Blue	=	Cyan

Hence secondary colours can be generated by additive mixing of any two primaries.

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A colour pigment is refered as the property of absorbing one primary and reflecting the other two primaries. Hence, secondary colours Cyan, Magenta & Yellow are called pigments of primary colours.

NOTE:-

1. White colour can be produced by mixing all three primaries (or) by mixing a secondary with opposite primary as follows.

Red + Green + Blue = White

Red + Cyan = White

Green + Magenta = White

Blue + Yellow = White

2. $R + G + B = 1$ (White)

$R + C = 1$

$R = 1 - C$

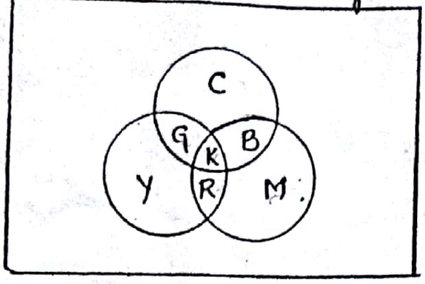
$C = 1 - R$

2. **Secondary Colours:-** Those colours which are produced by additive mixing of primary colours are refered as secondary colours.

Cyan, Magenta, Yellow are secondary colours for R, G, B primary colours.

Appropriate mixing of secondary colours (or) by subtracting a secondary colour from white produces a primary colour. Hence this type of mixing is called subtractive mixing. (4

Subtractive mixing



Combination of all three secondary colours produce blac

$C+M+Y=K$ ∵ (K = Black)

(or)

$C+M+Y=0$

$C+M=B$
$C+Y=G$
$M+Y=R$

Black can also be generated by mixing a primary with opposite secondary

Eg:- $B+Y=K$

NOTE :-

ADDITIVE MIXING	SUBTRACTIVE MIXING
1. An output colour is generated by removing "absorbed" light from the incident light output colour is the object colour.	1. An object colour is generated by removing the reflected light from the incident light.

Colour Models :- | Colour Space | Colour Systems :-

A model which provides information about different colours present in a colour-object and the relation between them is refered as a colour-model.

classification of colour models :-

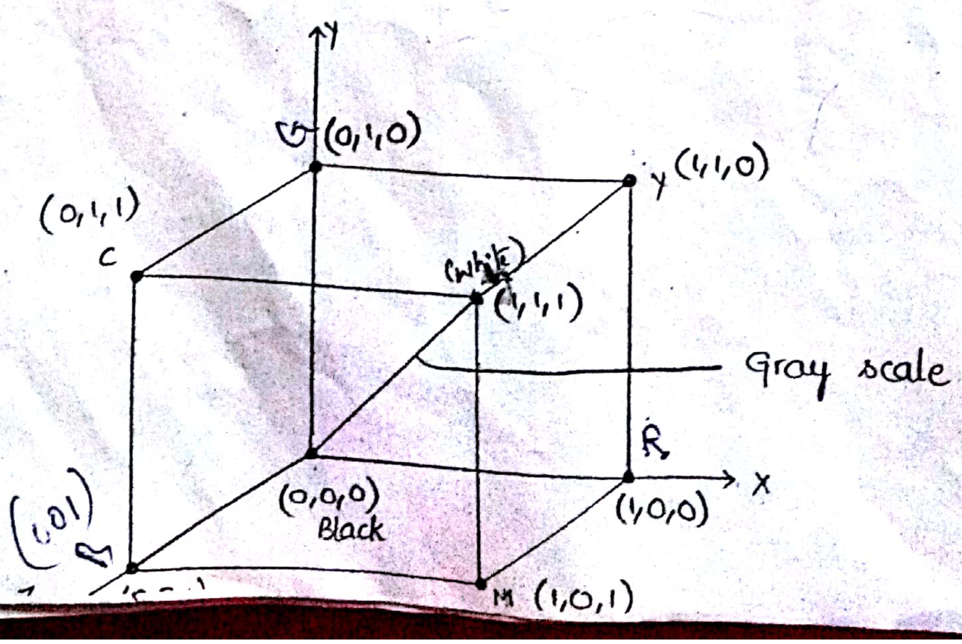
Based on the applications, colour models are classified into four types. They are:

1. RGB model
2. CMY|CMYK model
3. HSI model
4. YIQ model

1. RGB model :-

This is the basic model which finds application in hardware devices like colour cameras, colour monitors, scanners etc.

This model is represented in a cartesian co-ordinate system, where a unit distance cube is used to represent different colours as follows:



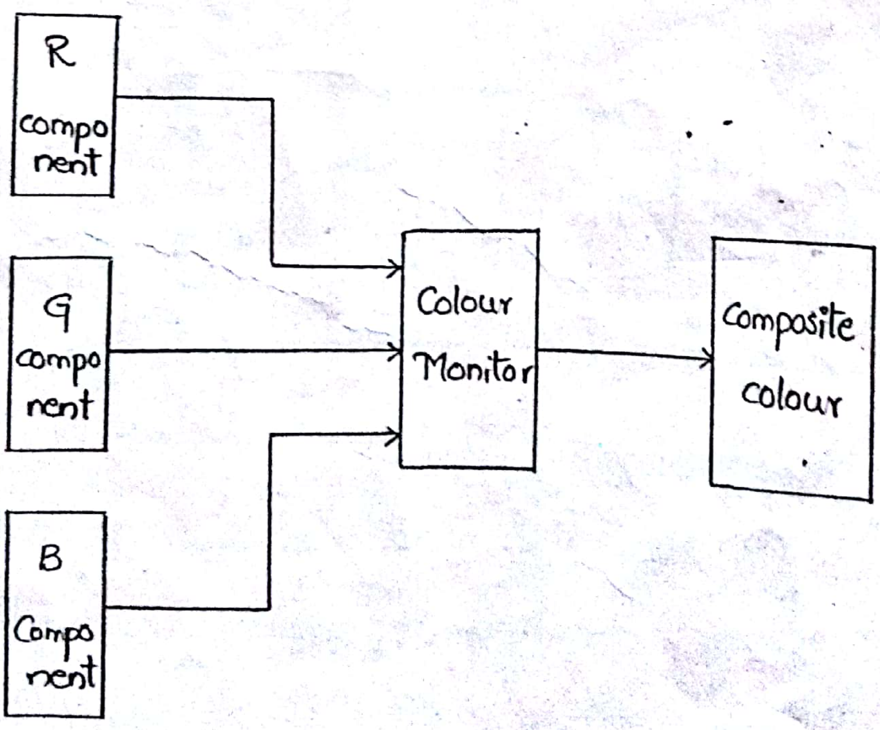
Here three primary colours form three corners of (5) cube & three secondary colours (C,M,Y) forms other three corners of cube.

Black occupies the origin and white is at the corner which is farthest distance from the origin.

Any other colour in RGB-model can be generated by mixing the colours either inside the cube (or) on the cube but not outside the cube.

In RGB model, each colour pixel occupies 24-bits (8-bit for red, 8-bits for Green, 8-bits for Blue) and hence each pixel can assume any colour out of 2^{24} colours.

Generation of RGB-image in colour monitors :-



CMY Model/CMYK Model:-

This model is based on secondary colours and finds applications in hardware components like colour printers, copiers etc where a hardcopy of colour object is obtained.

An object looking in cyan colour absorbs Red light from the incident light and Reflects the other colours. Similarly an object looking in Magenta absorbs Green light and Yellow absorbs Blue light from the incident light.

Hence

$$\text{Cyan}(C) = W - R$$

$$\text{Magenta}(M) = W - G$$

$$\text{Yellow}(Y) = W - B$$

Conversion of an RGB image to CMY:-

The Relation that can be used to convert an RGB image to CMY is

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

The appropriate combination of cyan, Magenta and yellow produces Black. The resulting black is not pure and Hence doesn't suit for printing application. In printing applications Black is a predominant colour, a pure black colour is included as fourth colour in the CMY Model and the Resulting model is called CMYK Model.

Scanned by CamScanner

HSI - Model:-

The RGB and CMYK models are suitable for hardware implementations on colour objects. They cannot be used for colour image processing applications. Hence HSI Model is introduced for processing of colour images and finds the applications in the areas of Computer graphics and animations.

In HSI Model,

H - Hue

S - Saturation

I - Intensity.

Hue:- This parameter gives information regarding the dominant colour present in a colour object

It is always Measured interms of angles (θ).

Hue for Primary colours:-

$H = 0^\circ$ for Red

$H = 120^\circ$ for green

$H = 240^\circ$ for Blue.

In Case of a 360° shape.

In case of hexagon, The hue of RG Sector (Varies from 0 to 120) is given by $H = H - 0$

In Case of GB sector (Varies from 120 to 240) is given by $H = H - 120$.

In Case of BR sector (Varies from 240 to 360) is given by $H = H - 240$.

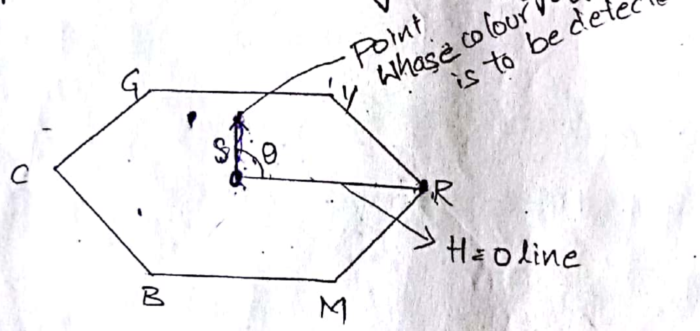
Saturation (Relative purity):-

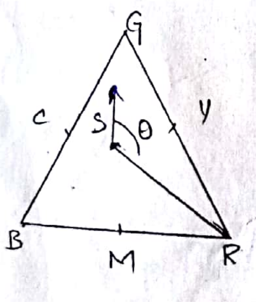
It is a measure of degree of diluteness of a pure colour with white colour.

It is a vector joining origin to the point for which the colour is to be detected. It varies in the interval [0,1].

Eg:- For a pure colour like red, saturation is 0. as saturation increases in red, it no longer exhibits red colour, but tends to exhibit pink. Hence saturation and purity are inversely related.

Calculation of H and S for a given object:-





Procedure:

step-1:- Draw a vector from origin to required point

step-2:- The length of the vector gives saturation.

step-3:- The angle made by vector with respect to reference line gives hue.

Intensity:-

Intensity of a colour object varies from [0,1] and can be calculated by moving a plane perpendicular to the intensity axis such that the required point is covered by the plane.

The intersection of the plane with the intensity axis gives the intensity of colour object.

Conversion from RGB to HSI:-

Step-1:- Given an RGB component, the hue can be calculated using the relation

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

$$\text{Where } \theta = \cos^{-1}\left\{ \frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}} \right\}$$

Step-2:- The saturation component is given by

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

Step-3:- Intensity component is given by

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

Conversion from HSI to RGB:-

Case-1:- RG Sector

When H is in this sector, the R,G,B components are given by following relations.

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

Where
$H = H - 0$
$= H.$

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

$$G = 3I-(R+B)$$

Case-2:-

$$G = I\left[1+\frac{S\cos H}{\cos(60^\circ-H)}\right]$$ Where $H = H-120^\circ$.

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

$$B = 3I-(G+R)$$

Case-3:-

$$B = I\left[1+\frac{S\cos H}{\cos(60^\circ-H)}\right]$$ Where $H = H-240^\circ$.

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

$$R = 3I-(G+R)$$

Pseudo Colour Processing:-

The process of converting a gray image into colour image by assigning colours to the gray image is referred as pseudo colour image processing.

Methods for Pseudo Colour processing:-

1. Intensity slicing
2. Gray to RGB transformation.

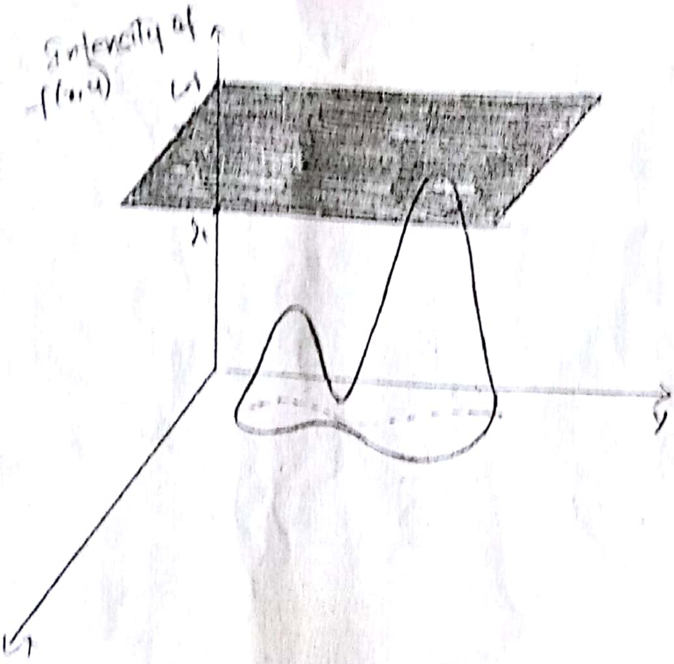
1, Intensity slicing:-

Here an image is represented in 3-Dimensions called (x, y, intensity). Where x,y are the spacial co-ordinates or Pixels of gray image f(x,y)

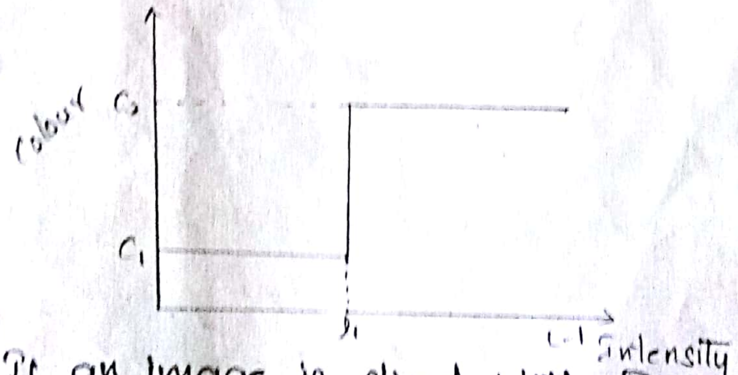
Take a plane and run it perpendicular to the intensity axis of the image.

This divides the image in two parts called image above the plane and image below the plane.

Assign one colour to the image above the plane and other colour to the image below the plane.



Intensity slicing can also be represented as follows.



If an image is sliced with P planes, its get divided into P+1 slices and each slice can be assigned different colour.

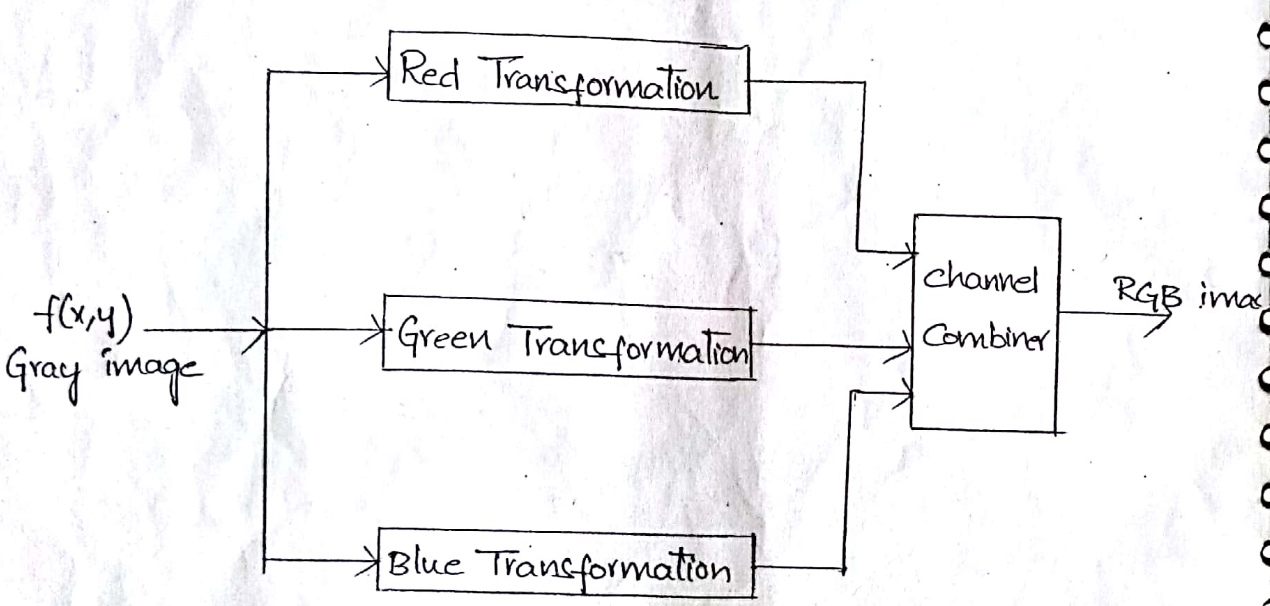
2. Gray to RGB Transformation:-

Any gray image $f(x,y)$ can be converted into a colour image using following procedure.

Step-1:- Perform Red transformation on gray image $f(x,y)$. Resultant image is denoted as $f_R(x,y)$

Perform Green transformation on gray image $f(x,y)$. Resultant image is denoted as $f_G(x,y)$

Perform Blue transformation on gray image $f(x,y)$. Resultant image is denoted as $f_B(x,y)$



The independent colour components f_R, f_G, f_B are then combined using a channel combiner to generate a composite RGB image

Note:-

Procedure to Convert a Colour Image to Gray image

Step-1:- Take R,G,B Triplet of a colour image and mix them according to following relation to produce a gray image

$$Gray = W_R \cdot R + W_G \cdot G + W_B \cdot B$$

where W_R, W_G, W_B are the weights (Ratios (or) percentages) of R,G,B respectively required to generate a gray image.

Case-1:- When $W_R = W_G = W_B = 1/3$ (Equal weights are used)

then, Gray image is given by

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

$$= \frac{R+G+B}{3}$$

Case-2:- When 60% of Green, 29% of Red and 11% of Blue is used then, the resultant Gray value is given by

$$Gray = 29R + 60G + 11B$$

Example:-

For a given R,G,B triplet 0.4, 0.6, 0.8, the resultant gray value for the above two cases is given by

$$\text{Gray value} = \frac{0.4+0.6+0.8}{3}$$

$$= \frac{1.8}{3} = 0.6 \text{ (using Case-1)}$$

$$\text{Gray value} = 29\times 0.4 + 60\times 0.6 + 11\times 0.8$$

$$= 11.6 + 36 + 8.8$$

$$= 56.4 \text{ (using Case-2)}$$

Problem:

RGB to HSV and HSV to RGB Conversion:-

Let R,G,B values of a point be 0.4, 0.6, 0.8 find HSV equivalent of RGB and also verify weather the original point can be obtained by converting HSV to RGB

Solution:-

Conversion of RGB to HSV

Step-1:- Calculate the maximum of R,G,B components and denote it by K_{max}.

∴ In the given problem $K_{max} = 0.8$

Step-2:-

Calculate The minimum of R,G,B Components and denote it by K_{min}

In this problem $\boxed{K_{min} = 0.4}$

Step-3:-

Calculate the range of K as

$$\boxed{\begin{aligned} K &= K_{max} - K_{min} \\ &= 0.8 - 0.4 \\ K &= 0.4 \end{aligned}}$$

Step-4:- Saturation Can be Calculated as follows

$$S = \begin{cases} \frac{K}{K_{max}} & \text{for } K_{max} > 0 \\ 0 & \text{elsewhere} \end{cases}$$

$K_{max} = 0.8 > 0$

$$\boxed{\therefore S = \frac{K}{K_{max}} = \frac{0.4}{0.8} = 0.5}$$

Step-5:- V can be Calculated as

$$V = K_{max} = 0.8$$

Step-6:- Normalized R,G,B Components are given by

$$\boxed{\begin{aligned} R' &= \frac{K_{max} - R}{K} = \frac{0.8 - 0.4}{0.4} = 1 \\ G' &= \frac{K_{max} - G}{K} = \frac{0.8 - 0.6}{0.4} = 0.5 \\ B' &= \frac{K_{max} - B}{K} = \frac{0.8 - 0.8}{0.4} = 0 \end{aligned}}$$

Step-7:- Normalized Hue Can be Calculated as

$$H' = \begin{cases} B' - G' & \text{if } R = K_{max} \\ R' - B' + 2 & \text{if } G = K_{max} \\ G' - R' + 4 & \text{if } B = K_{max} \end{cases}$$

In this problem

$$\boxed{B = 0.8 = K_{max}}$$

Hence
$$\boxed{\begin{aligned} H' &= G' - R' + 4 \\ &= 0.5 - 1 + 4 \\ &= 3.5 \end{aligned}}$$

Step-8:- Hue can be calculated as

$$H = \begin{cases} \frac{1}{6}(H'+6) & \text{if } H'<0 \\ \frac{H'}{6} & \text{if } H'>0 \end{cases}$$

Therefore
$$\boxed{H = \tfrac{1}{6}(H') = 3.6 \quad = 0.58}$$

Therefore the HSV equivalent of a given R,G,B triplet is

$$(H, S, V) = (0.58, 0.5, 0.8)$$

Procedure to Convert HSV to RGB

Calculate x, y, z values using the following relations

$$x = (1-s)V$$
$$= (1-0.5)0.8 = 0.4$$
$$y = \cancel{H'} \left(1 - s\left(H' - |H'|\right)\right)V$$
$$= \left(1 - 0.5(3.5-3)\right)0.8 \qquad \because |H'| = 3$$
$$= 0.6$$
$$z = \left[1 - s\left(1 - H' - |H'|\right)\right]V$$
$$= \left[1 - 0.5\left(1 - 3.5 - 3\right)\right]0.8$$
$$= (3.75)0.8$$
$$= 3.$$

When $|H'| = 3$, $R, G, B = x, y, v$

$\therefore R = x = 0.4$
$G = y = 0.6$
$B = V = 0.8$

Therefore original RGB is recovered by converting HSV to RGB.

* YIQ Model:-

This model is designed to make advantage of human visual system sensitivity to changes in luminense than hue and saturation

In this model, Y represents luminense.
I represents hue.
Q represents saturation.

Luminence (Y) carries the video information required by the television set. I and Q carries colour information.

In this model, more bandwidth is used for representin luminance & less bandwidth is used for representing hue and saturation.

This model finds application in commercial, television, broadcasting.

Conversion of RGB image to YIQ:-

The following relation can be used for converting RGB model to YIQ model.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

NOTE:-

In the above relation, sum of all co-efficients in 1st row is unity.

Sum of all co-efficients in 2nd or 3rd row is zero

Problem:-

For the following RGB triplets, find CMY and YIQ equivalents.

a) (1 0 1)

b) (1 1 1)

c) (1 0 0)

Sol:-

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

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

a) (1 0 1)

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.413 \\ 0.275 \\ 0.523 \end{bmatrix}$$

b) (1 1 1)

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

$$= \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

c) (100)

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 \\ 0.596 \\ 0.212 \end{bmatrix}$$

Colour Quantization:-

The process of representing a colour image with limited number of colours than originally present such that its appearance would not get affected is referec as colour quantization.

Eg:- If a colour image contains 'N' colours then colour quantisation refers to representing the same colour image using 'K' colours such that $K < N$

With respect to colour quantisation, colour space is defined as total no:of colours present in a colour image and colour map refers to the set of limit

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colours used to represent the same colour image without losing its appearance.

PHASES IN COLOUR QUANTISATION:-

1. Sampling the image to be Quantised.

2. Identification of colour space & colour map

3. Mapping colour space to colour map.

4. Redrawing the image using colour map.

Explanation:-

In sampling stage, the given colour image is partitioned to samples based on gray-levels.

For a given sample, identify the total no:of colours present and also identify the limited no:of colours that can be used to represent the same sample.

Once, colour space & colour map are identified for given sample, map colour space to the identified colour map.

Finally, redraw the sample using colour-map.

Repeat this process for each and every sample in the colour image and once all the samples are covered, the resultant image is refered as quantised colour image.

Eg:- In RGB colour model, each colour pixel occupies 24-bits and hence it can take any colour out of 2^{24} colours

If the same RGB image is to be represented with only 256 colours, then it can be done as follows

→ original RGB pixel contains 8-bits for RED (2^8 shades of Red)

8-bits for Green (2^8 shades of Green)

8-bits for Blue (2^8 shades of Blue)

Given colour-map = 256 colours

$= 2^8$.

Therefore, each colour pixel in RGB must be represented with only 8-bits. One possible way is assigning 3-bits for Red, 3-bits for Green, 2-bits for Blue.

Accordingly, the colour map contains only 8-shades of red, 8-shades of green and 4-shades of blue.

Quantisation refers to mapping the original 256 shades of Red to 8-shades, 256-shades of Green to 8-shades and 256 shades of Blue to 4-shades.

Types of Colour Quantisation:-

1. Uniform colour quantisation.
2. Non-uniform colour quantisation.

NOTE :- In colour quantisation, each R,G,B components are processed independently

Uniform Colour Quantisation:-
The type of quantisation in which the size of the segments used in a colour component are equal is refered as uniform colour quantisation.

Non-uniform Colour Quantisation:-
The type of quantisation where the size of segement for a colour component depends on concentration of colour is refered as non-uniform colour quantisation

FULL COLOUR PROCESSING:-

Full colour Images:- Those images which are directly acquired using a colour sensor are refered as full colour images. Full colour images can be processed using two methods

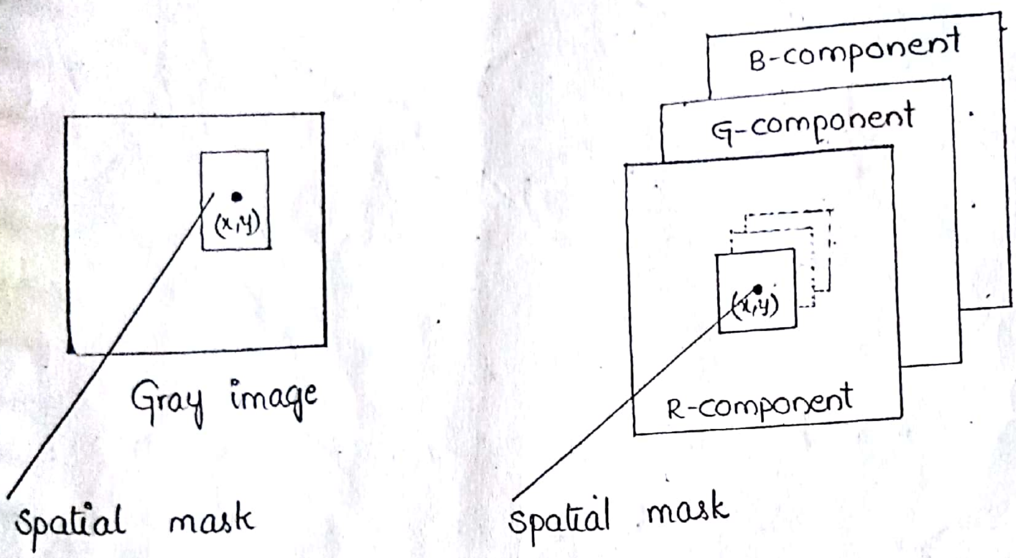
METHOD-I:- This method is analogous to intensity transformation on gray-images. In this method processing of a colour pixel is done by considering pixel alone.

Here each colour pixel is treated as a vector and the length of the vector is given by the distance between origin and required colour pixel.

Any vector $c(x,y)$, is given by

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

METHOD-II :- This method is analogous to spatial filtering of gray images. Hence, processing of a colour pixel is done by considering the neighbourhood of pixel along with required pixel.



Here, each colour component of a colour image is processed independently using a separate spatial mask and the independent results are then combined to produce processed colour image.

Application of full colour processing :-

1. Colour image enhancement
2. colour transformation
3. colour complement

1. Colour Image Enhancement :-

PROCEDURE

STEP 1 :- Read an input RGB image which is to be enhanced

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STEP 2 : Convert RGB to HSI model (since HSI provides provisi-
for processing colour ~~de~~ image.

STEP 3 :- Decouple the intensity component from Hue & Saturation

STEP 4 :- Apply any enhancement technique (Eg:- Histogram Equali-
-sation) on intensity image.

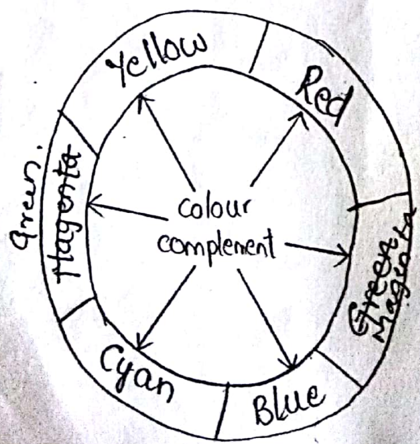
STEP 5 :- Couple enhanced intensity image to Hue & Saturation

STEP 6 :- Convert HSI image to RGB image to get enhanced
colour image in RGB system.

2. Colour complement :-

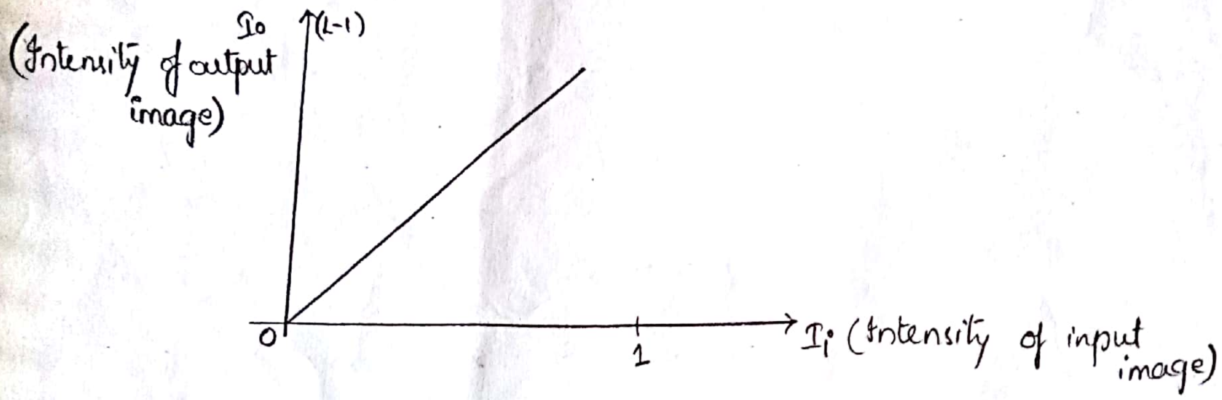
Like image negative operation on gray-scale images, colour complement can be used to generate the complements of primary & secondary colours as follows.

Primary colours	Complement colours
Red	Cyan
Green	Magenta
Blue	Yellow



3. Colour transformations on various colour models are (15) given as follows:

Input colour image :-



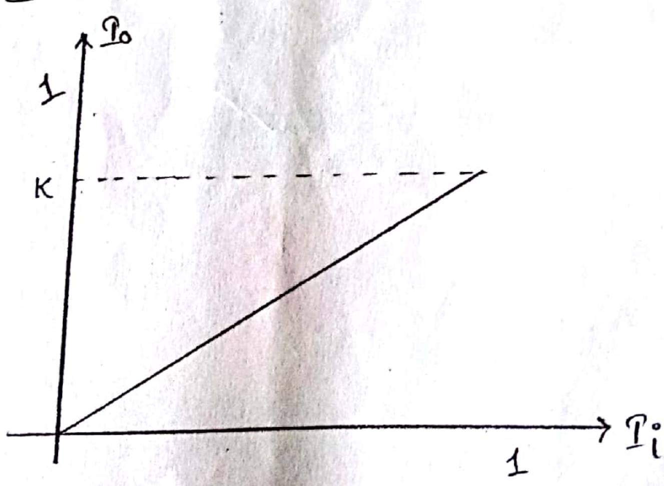
~~Case~~

In this figure, there is no change in intensity because of linear transformation with slope as 1.

Colour transformation refers to the process of transforming the intensity of an output image such that it has improved intensity than original.

~~Colour~~ t

Case i, RGB model :-



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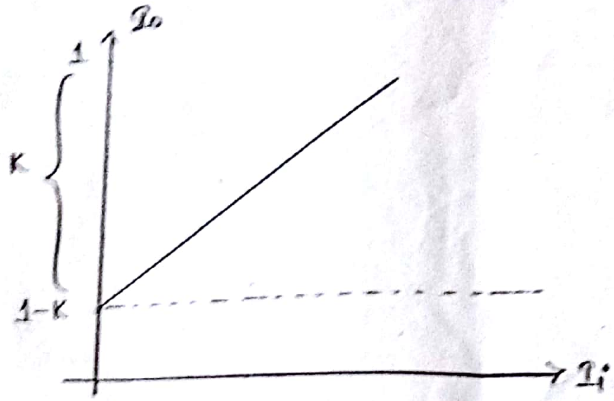
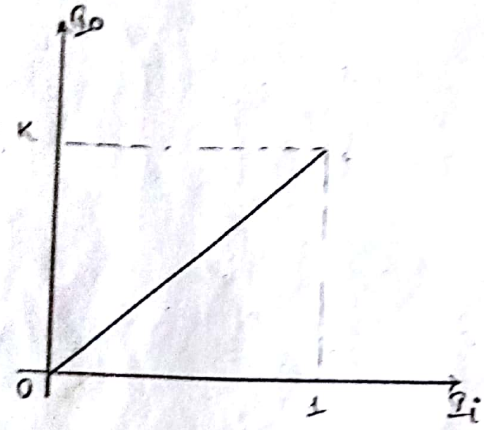
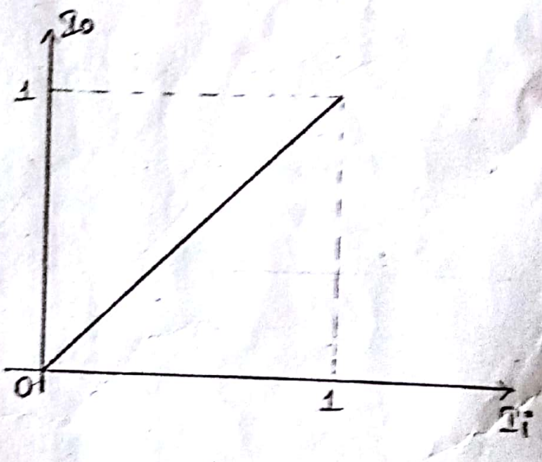
Case ii, CMYK model:-



Case iii HSI model:-



"HS"



"I"

Colour Segmentation:-

Colour segmentation is the process of ~~proc~~ partioning the image to various parts based on colour information.

Procedure:-

STEP 1 : Read an RGB image which is to be segmented based on colour.

STEP 2 : Since RGB does not support colour processing, convert RGB image to HSI.

STEP 3 : Separate hue image, saturation image, intensity imag from HSI image.

STEP 4 : Generate binary equivalent of saturation image.

STEP 5 : Mask the hue image with binary saturation image.

STEP 6 : Plot the histogram for the masked hue image

STEP 7 : Apply thresholding based on histogram information such that all the information below threshold is made '0' and above threshold is made 1.

COLOUR SMOOTHENING AND SHARPENING:-

Colour Smoothening:-

Smoothening is a spatial filtering operc-ion where, processing of a pixel is made by taking into account its neighbourhood.

In case of gray-scale smoothening, a mask is run over the image and in each run the original pixel is replaced with the average of the pixels contained in its neighbourhood.

The masks that are used for image smootheni contains all co-efficient values as '1' as follows.

3X3 Smoothening Mask

$\frac{1}{9} \times$

1	1	1
1	1	1
1	1	1

Scaling factor: $\frac{1}{9}$

5x5 Smoothening mask.

$\frac{1}{25} \times$

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

Scaling factor : $\frac{1}{25}$

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The colour smoothening is same as gray-scale smoothening with a principal difference that smoothening is done independently on each colour component of an RGB colour image as follows.

$$\text{Smoothened colour image } \bar{c}(x,y) = \frac{1}{K} \sum_{x,y \in S_{xy}} c(x,y)$$

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

where 'S_{xy}' is a set of neighbourhood pixels

The independent smoothened colour components are then combined to produce an overall smoothened colour image.

Colour Sharpening:-

Sharpening is the process of preserving the sharp variations in an image like edges & it can be implemented with the help of second order derivative called Laplacian.

For a grayscale image $f(x,y)$, laplacian is obtained by subtracting twice the current pixel from previous pixel and next pixel and is denoted by $\nabla^2 f$

The mask used for image sharpening is given as follows.

Laplacian Mask without diagonal details

0	-1	0
-1	4	-1
0	-1	0

Mask with diagonal details.

-1	-1	-1
-1	8	-1
-1	-1	-1

The colour sharpening is same as gray scale sharpening with a principal difference that sharpening is done independently on each colour component of an RGB colour image as follows

Sharpened colour image $\nabla^2 C(x,y) = \begin{bmatrix} \nabla^2 R(x,y) \\ \nabla^2 G(x,y) \\ \nabla^2 B(x,y) \end{bmatrix}$

The independent sharpened colour components are then combined to produce an overall sharpened colour image.

Optimal Thresholding :- (Unit - VII).

Let an image contain two different classes called background and object.

Optimal Thresholding refers to segmenting each pixel of an image into either background (or) an object such that segmentation results in minimum error.

Let P_1 - Probability of background in an image

P_2 - Probability of object in an image

$P_1(z)$ - Density function of background.

$P_2(z)$ - Density function of object.

In case of optimal thresholding, we need to calculate a threshold value at which segmentation results in minimum probability of error. The overall density function of an imag is given by

$$P(z) = P_1 P_1(z) + P_2 P_2(z)$$

If density functions are gaussian, then

$$P(z) = P_1 P_1(z) + P_2 P_2(z)$$

$$= P_1 \frac{1}{\sqrt{2\pi\sigma_1^2}} e^{-\frac{(z-\mu_1)^2}{2\sigma_1^2}} + P_2 \frac{1}{\sqrt{2\pi\sigma_2^2}} \cdot e^{-\frac{(z-\mu_2)^2}{2\sigma_2^2}}$$

Probability of error in classifying an object pixel as background pixel, is given by

$$E_1(T) = \int_{-\infty}^{T} P_2(z)\, dz$$

Similarly the probability of error in classifying background pixel as object pixel, is given by

$$E_2(T) = \int_{T}^{\infty} P_1(z)\, dz$$

$\because$ (since density function varies from $-\infty$ to ∞,

$-\infty$ to T : Background

T to ∞ : Object)

Overall error is given by

$$E(T) = P_1 E_2(T) + P_2 E_1(T)$$

To have a minimum error, differentiate $E(T)$ w.r.t and equate to '0', which results in

$$\Rightarrow P_1 \frac{1}{\sqrt{2\pi\sigma_1^2}} e^{-\frac{(T-\mu_1)^2}{2\sigma_1^2}} = P_2 \frac{1}{\sqrt{2\pi\sigma_2^2}} e^{-\frac{(T-\mu_2)^2}{2\sigma_2^2}}$$

$$\Rightarrow P_1 \frac{1}{\sigma_1} e^{-\frac{(T-\mu_1)^2}{2\sigma_1^2}} = P_2 \frac{1}{\sigma_2} e^{-\frac{(T-\mu_2)^2}{2\sigma_2^2}}$$

$$\frac{P_1}{P_2} \cdot \frac{\sigma_2}{\sigma_1} = \frac{e^{-\frac{(T-\mu_2)^2}{2\sigma_2^2}}}{e^{-\frac{(T-\mu_1)^2}{2\sigma_1^2}}}$$

$$\frac{\sigma_2 P_1}{\sigma_1 P_2} = e^{\left[-\frac{(T-\mu_1)^2}{2\sigma_2^2} + \frac{(T-\mu_1)^2}{2\sigma_1^2}\right]}$$

$$\frac{(T-\mu_1)^2}{2\sigma_2^2} - \frac{(T-\mu_2)^2}{2\sigma_1^2} = \ln\left(\frac{P_1\sigma_2}{P_2\sigma_1}\right)$$

let $\sigma_1 = \sigma_2 = \sigma$

$$\frac{(T-\mu_1)^2 - (T-\mu_2)^2}{2\sigma^2} = \ln\left(\frac{P_1}{P_2}\right)$$

$$\frac{\cancel{T^2} + \mu_1^2 - 2T\mu_1 - \cancel{T^2} - \mu_2^2 + 2T\mu_2}{2\sigma^2} = \ln\left(\frac{P_1}{P_2}\right)$$

$$(\mu_1^2 - \mu_2^2) + T(2\mu_2 - 2\mu_1) = 2\sigma^2 \ln\left(\frac{P_1}{P_2}\right)$$

$$T(2\mu_2 - 2\mu_1) = 2\sigma^2 \ln\left(\frac{P_1}{P_2}\right) - (\mu_1^2 - \mu_2^2)$$

$$2T(\mu_2 - \mu_1) = 2\sigma^2 \ln\left(\frac{P_1}{P_2}\right) + (\mu_2^2 - \mu_1^2)$$

$$T = \frac{2\sigma^2 \ln\left(\frac{P_1}{P_2}\right)}{2(\mu_2 - \mu_1)} + \frac{(\mu_2^2 - \mu_1^2)}{2(\mu_2 - \mu_1)}$$

$$\boxed{T = \frac{\sigma^2}{(\mu_2 - \mu_1)} \ln\left(\frac{P_1}{P_2}\right) + \left(\frac{\mu_1 + \mu_2}{2}\right)}$$

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Case i :-

If $P_1 = P_2$ then

$$\boxed{T = \left(\frac{\mu_1 + \mu_2}{2}\right)}$$

Case ii :- When variance is '0' (i.e. $\sigma^2 = 0$), then

$$\boxed{T = \left(\frac{\mu_1 + \mu_2}{2}\right)}$$

Hence in the above two cases, Thresholding is given by the average of Means.