Image Representation and Printing

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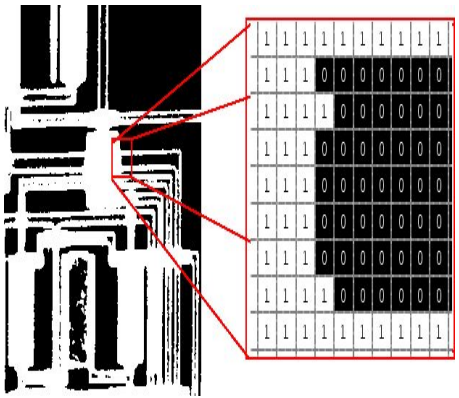
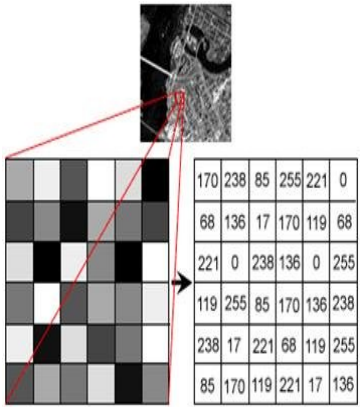
Outline

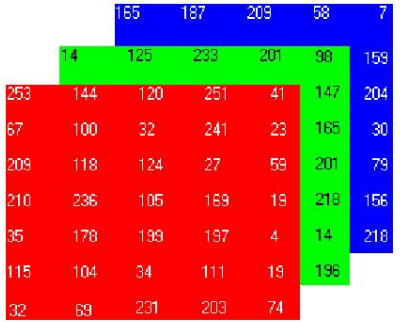
- Definition of Digital Image
- Representation of Colour Pixel values
  - RGB –for monitors
  - CMY -for printers
- Image file
- Printers
  - Halftone, Approximation of Halftone, Dither matrix based Halftone

Definition of Digital Image

- **Gray Scale Digital image** is a 2D array of integers from 0 to L-1
- **Binary Image** is a gray scale image when L=2
- L is called as number of **gray levels**
- **Colour Image** is a sequence of three 2D arrays –each one for one of R,G,B



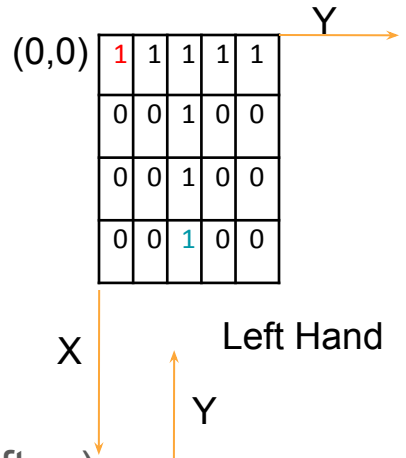


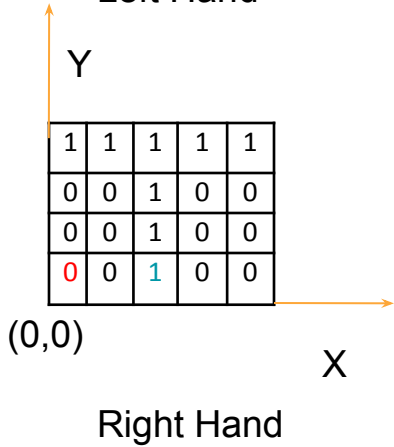


X

2D Coordinate System

- **Co-ordinate system**: (origin, axes)
- **2D-Left Hand co-ordinate system**: (Used in DIP often)
  - Top-left cell of the image is origin (0,0)
  - +ve X axis is towards bottom from origin
  - +ve Y axis is towards right from origin
- **2D-Right Hand co-ordinate system**: Used in Graphics often)
  - Bottom-left cell of the image is origin (0,0)
  - +ve X axis is towards right from origin
  - +ve Y axis is towards top from origin

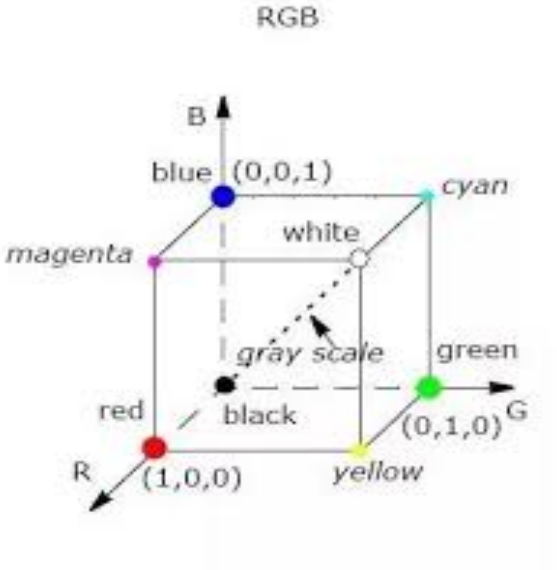


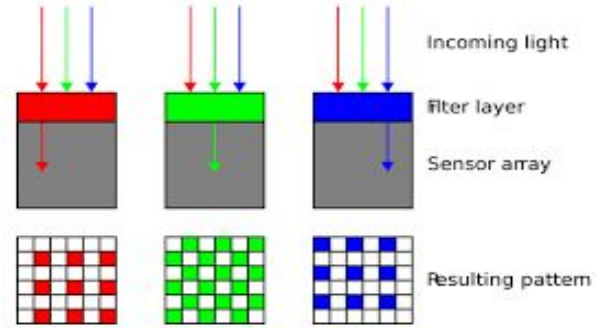


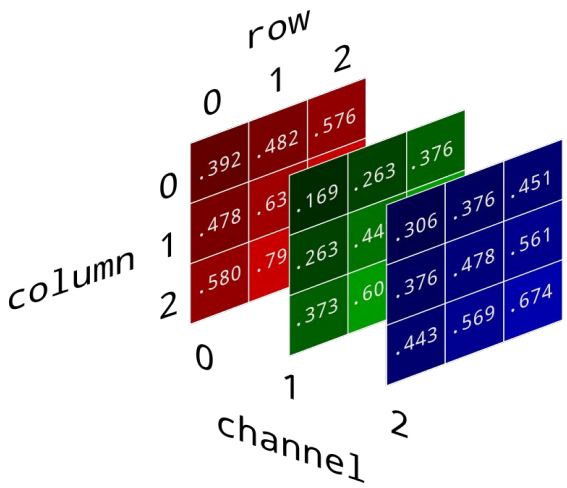
RGB to CMY Conversion

- Printer scans image using RGB, but prints using CMY
- In normalized colour image Values of R, G, B are in [0,1]
- **CMY Colour Model**:

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







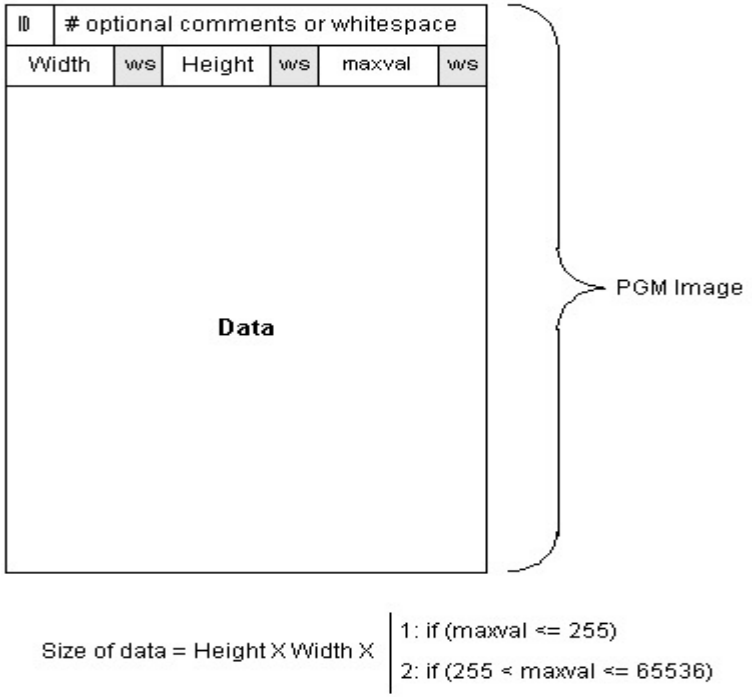
How to Represent Colour

- Colour can be represented in any colour model such RGB or CMY etc.
- Colour Representation using **Direct coding** : R: 0 to L1-1; G: 0 to L2-1; G: 0 to L3-1.
    - Total number of colours is L1xL2XL3
    - Our eye can not distinguish all colours when L1, L2 and L3 are large number
- Colour representation using **Lookup table**:
    - Colour image is represented by single matrix M,
        - Where M[i][j] is an index of table entry
    - Image Storage will be less as only index is to be stored(8 bits instead of 24 bits per pixel)

Color Index (8 bits)	Color (24 bits)		
	Red (8 bits)	Green (8 bits)	Blue (8 bits)
0	0	0	0
1	0	128	0
2	128	255	128
...	...	...	...
255	255	255	0

File Format

- **File format:** The layout of image file in storage/transmission -Header, Data
- **Different File format** means different compression scheme
- The Header portion will have all info required for de-compression
- Data portion will have compressed data
- Eg. Run Length Coding:
  - Input: 4 4 4 4 4 4 11 11 11 5 5 5 5
  - Compressed Image: (4,6), (11,3), (5,4)
- Size of image file = size of data + size of header

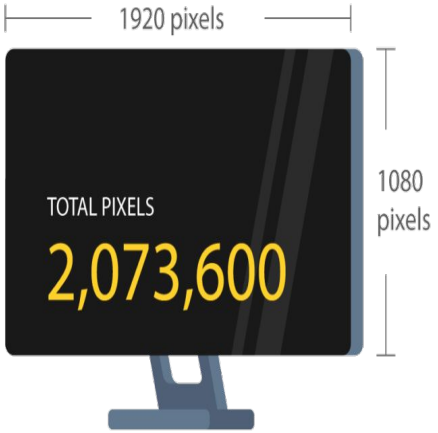


Some Properties of Image

- **Size of gray scale image**: The size of the 2D array that represents the image
  ie. No. of rows X No. of columns
- **Size of gray scale image in storage**: No of rows X No of columns X No of bits required to represent one pixel
- **Size of gray scale image in display:** M X N sqrinch
- **Size of Colour Image**:
  - When Direct Coding is used: 3X No of rows X No of columns X No of bits required to store one pixel
  - When Lookup table is used: No of rows X No of columns X No of bits required to store index
- **Resolution of Image at display**: No. of pixels per inch. - row and column directions

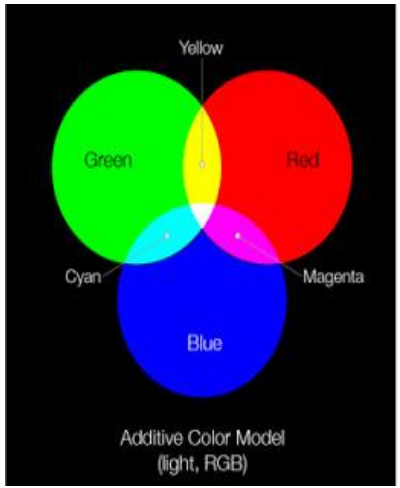
Some Properties of Image

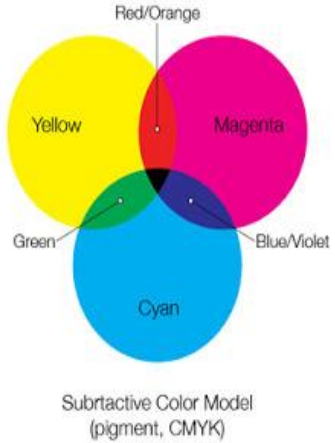
- **Resolution of Image when image is captured**: No. of pixels captured per inch captured by camera - row and column directions
- When the same No. of pixels displayed on larger area, the resolution will become less



How image is displayed by Printers

- Printers use CMYK colour model; K stands for black pigment
- Printer Deposits colour pigments(CMYK) onto print media
- When the light gets reflected from the pigments, we see colour
- For Binary, only Black pigment is used
- 60-80 dots per inch is used in News paper
- 120-200 dots per inch is used in Magazine





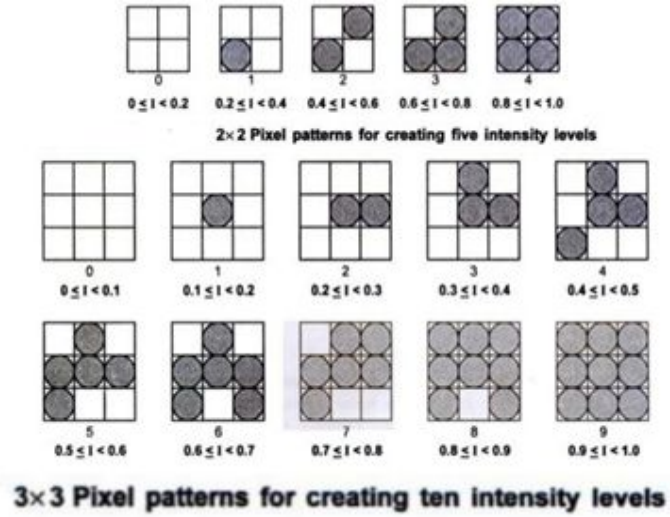
Halftone

- Fulltone(printing continuously on medium) Vs Halftone(printing discrete dots)
- **To print gray scale image**, only black pigment is used by employing Halftone technique
- **Halftone** is a technique used by printers: Various tones of grey or colour are produced by variously sized dots of pigments**.**
- **To print darker shade: print** larger dots using black ink
- **To print lighter shade**: print smaller dots using black ink
- **Issue:** Producing dots different size is a challenging task

-Image with 256 level needs dots of 256 sizes

Halftone Approximation

- Instead of changing dot size, halftone can be **approximated** using **pixel-grid pattern**
- More the black dots, darker the pattern
- Shades of gray is produced by the patterns
- Instead of displaying larger dot in Halftone method, display darker pattern in halftone approximation method
- When an image If(x,y) is to be printed, print lighter pattern when I(x,y) is low
- Issue: Resolution will decrease as display area increases:
    - if nXn image is displayed in aXb sqrinch using Halftone, then this halftone approximation will take 2aX2b sqrinch



Dithering

- Dithering is a technique to approximate halftones, without reducing resolution
- Dithering is done using a matrix called Dithering matrix
- Let D_n be the Dithering matrix of size nXn
- For every pixel, (x,y) in image f, find i= x mod n; j= y mod n
- Display dot (Using black pigment) at (x,y) if f(x,y)>D(i,j)
- Note that more the value of f(x,y), darker the pixel will be
    - Printer uses C=M=Y for gray, C=M=Y=1 means R=G=B=0
- Halftone approximation can be done for colour images by using the same technique for each matrix

How is Dithering matrix used in printing

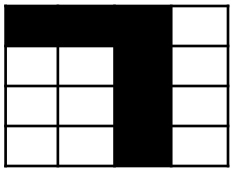
Image to be printed

.9	.9	.9	0
0	0	.9	0
0	0	.9	0
0	0	.9	0

Dither Matrix

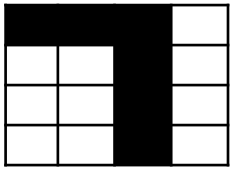
0	.5
.75	.25

Printed Image



.9	.9	.9	.1
.1	0	.9	0
0	0	.9	0
0	.2	.9	.2

0	.5
.75	.25



Floyd-Steinberg Error Diffusion Algorithm

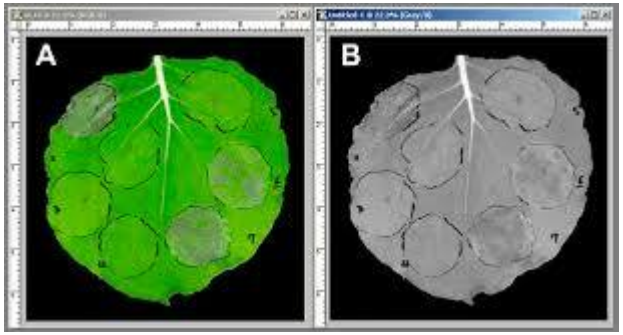
- i/p: Gray scale image f(x,y) to be printed, and Set of shades available with printing device
- o/p: modified image f ’(x,y) with the property that the difference between f(x,y) and printed shade at (x,y) is distributed to the neighbouring pixels
- S1) Copy f to f ’
- S2) for each pixel (x,y),
    - e= f ’(x,y)-P(x,y), where P(x,y) is the value(shade) printed at (x,y) (P(x,y) is the nearest input shade to f ’(x,y))
    - find f ’(x+1, y) =f ’(x+1,y) +ae ; find f ’(x+1, y+1) =f ’(x+1,y+1) +be
    - find f ’(x, y+1) =f ’(x, y+1) +ce ; where a=c=3/8 and b=2/8 (Origin is top-left pixel of array)
- Note: Different neighbourhood and also different values for weights are allowed

How Colour Printer Works

- For each pixel (i,j), Colour value in CMY model will be available in memory
- One display medium, to print each pixel (i,j), three closely spaced dots with C,M,Y ink will be applied
    - As those three dots are very close, when the light reflected from those dots, we will see a single colour
- To print each of C, M, Y, the same technique followed for gray scale image is used
    - Such as halftone, approximation to halftone etc.

Conversion from Colour to Gray

- Suppose colour image is available in memory, and the printer that attempts to print is gray scale printer -colour to gray conversion is required



- Let colour image f(x,y)=(r(x,y), g(x,y), b(x,y))

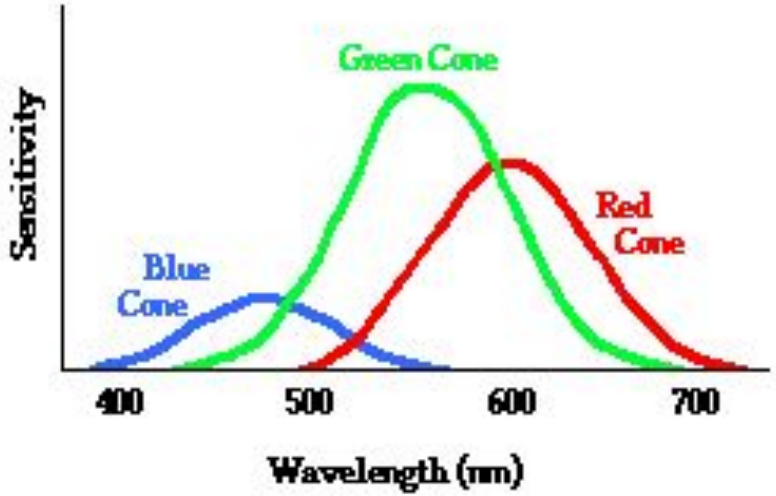
- The corresponding gray scale image
  f ’(x,y)=(r(x,y)+g(x,y)+b(x,y))/3

Or

f ’(x,y) = 0.299 r(x,y) + 0.587 g(x,y) + 0.114 b(x,y)

Why Green Colour is given more importance

- Eye is more sensitive to Green, less sensitive to Red, least sensitive to Blue



Some Problems

- What is the resolution of 2 X 2 inch image that has 512 X 512 pixel
  Ans: 512 pixels per inch
- If an image has a height of 2 inches and an aspect ratio of 1.5 , find its width
  Ans: 3 inches
- If we use 2 byte pixel values in a 24-bit lookup table representation, how many bytes does the lookup table occupy?
  Ans: 2^16 X 24/8
- HW: 1) Given a pixel p at the location (x,y) of image with M X N pixels using left handed system, find the coordinates of p, say (x', y') in right handed system
- 2) If we use direct coding for RGB values with 10 bits per primary colour, how many possible colours do we have for each pixel?