DIGITAL IMAGE PROCESSING-1

Unit 3: Lecture 29-30

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Unit 3: Image Enhancement

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Last Session

- Introduction to Image Enhancement
- Point Operations

Today's Session

- Point Operations cont..
  - Histogram Processing

- Objective:
    - To process an image so that the result is more suitable than the original image for a *specific* application
    - Techniques are problem/image dependent
    - One of the most interesting and '***visually appealing'*** areas of image processing

Bit Plane Slicing

- Here, we find the contribution made by each bit to the final image
- Consider a 256 x 256 image with 256 gray levels i.e. 8-bit representation for each pixel. E.g. BLACK is represented as 00000000 & WHITE by 11111111.
- Consider LSB value of each pixel & plot image. Continue till MSB is reached.
- All 8 images will be binary.

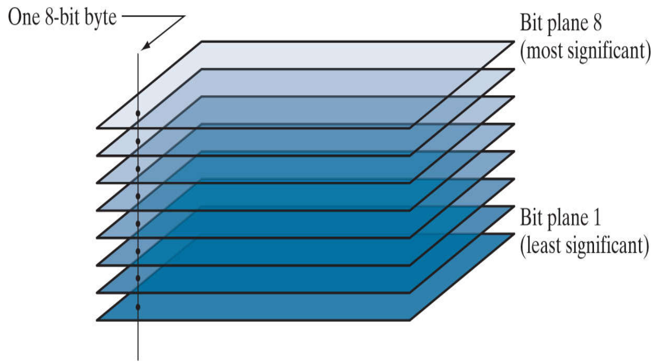
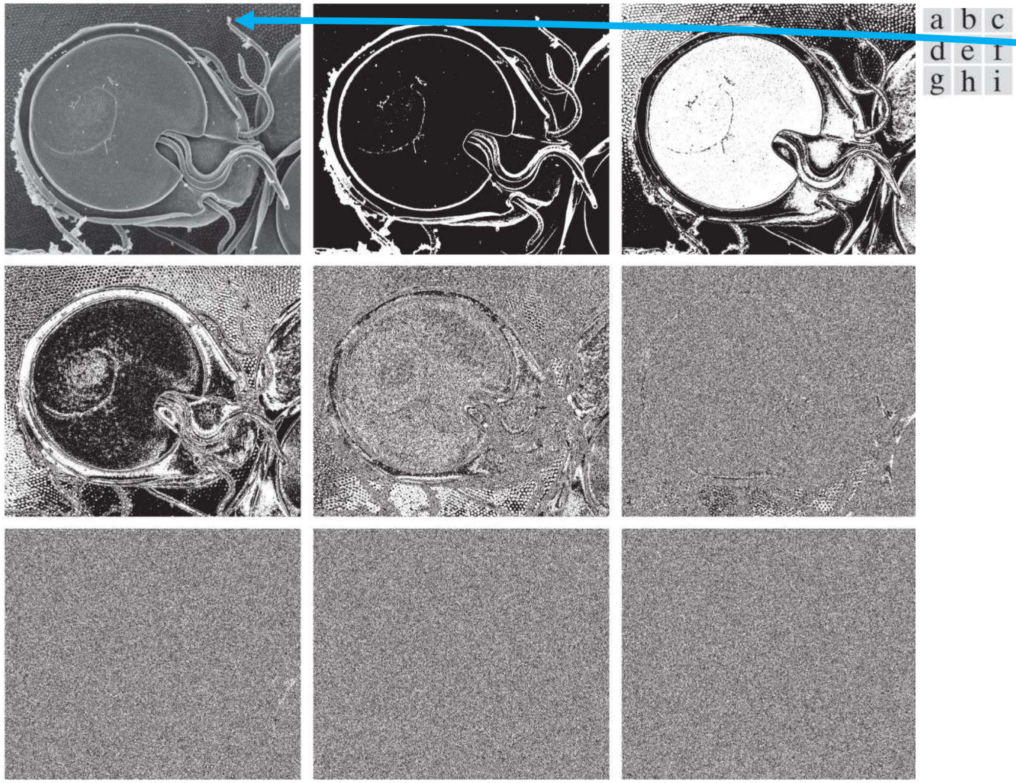


FIGURE 3.13
Bit-planes of an 8-bit image.

Bit Plane Slicing



(a) An 8-bit gray-scale image of size 837 × 988 pixels. (b) through (i) Bit planes 8 through 1, respectively, where plane 1 contains the least significant bit. Each bit plane is a binary image

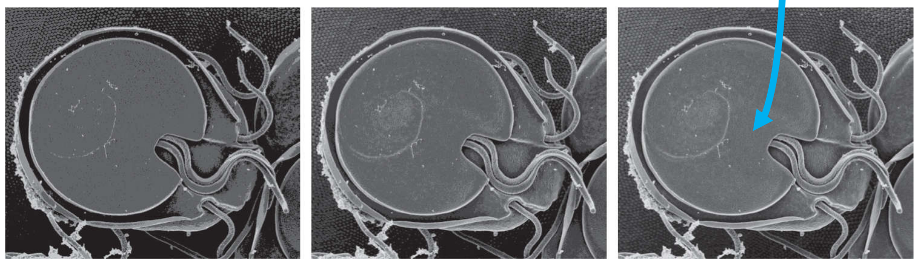


Image reconstructed from bit planes: (a) 8 and 7; (b) 8, 7, and 6; (c) 8, 7, 6, and 5.

Types of Enhancement Techniques

Image Enhancement

Point Operations

- Contrast Stretching
- Noise Clipping
- Window Slicing
- Histogram Modeling

Spatial Operations

- Noise Smoothing
- Median Filtering
- Unsharp Masking
- LP,HP,BP filtering
- Zooming

Transform Operations

- Linear filtering
- Root Filtering
- Homomorphic Filtering

Pseudocoloring

- False Coloring
- Pseudocoloring

Spatial Domain

Point Processing

- Brightness modification
- Contrast Modification
- Digital Negative
- Dynamic range compression
- Thresholding (noise clipping)
- Intensity level slicing
- Bit plane slicing
- **Histogram modeling**

Histogram

- Histogram: It is a plot of number of occurrences of gray levels in the image against the gray level values
- It provides convenient summary of the intensities in an image, but does not convey any information regarding spatial relationships between pixels
- Provides more insight about contrast and brightness

- Histogram of images provide a global description of their appearance
- Enormous information is obtained
- Represents relative frequency of occurrence of various levels
- Histogram can be plotted in two ways

Histogram Processing: First Method

- It is a plot of frequency of occurrence of an event
- x - axis has gray levels and y - axis has number of pixels in each gray level

Gray Level	No. of Pixels (n_k)
0	40
1	20
2	10
3	15
4	10
5	3
6	2

Histogram Processing: Second Method

- x-axis has gray levels and y-axis has probability of occurrence of gray levels

$P(\mu_k) = n_k / n$; where, μ_k – gray level

n_k – no. of pixels in k^{th} gray level

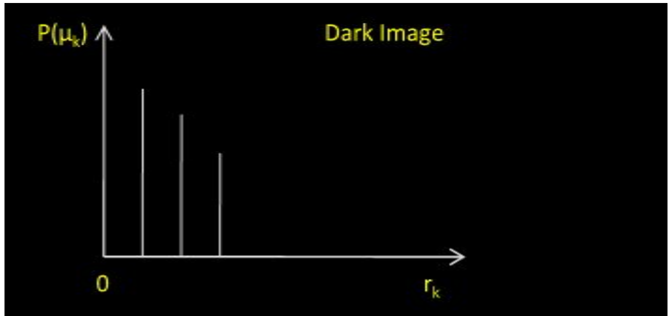
n – total number of pixels in an image

Prob. Of Occurrence

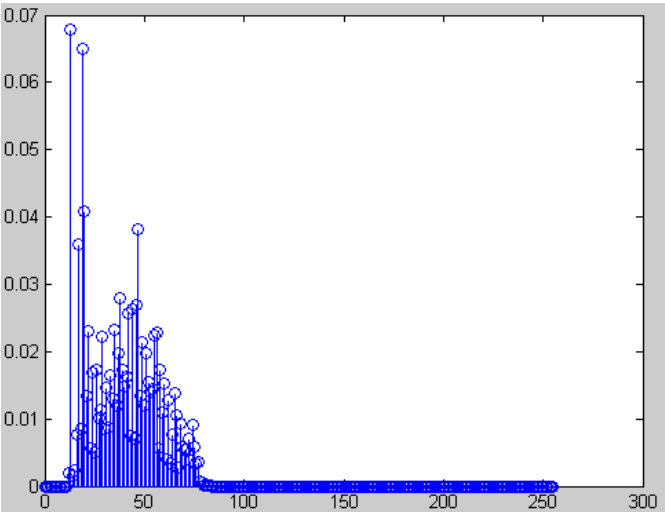
Gray Level	No. of Pixels (n_k)	$P(\mu_k)$
0	40	0.4
1	20	0.2
2	10	0.1
3	15	0.15
4	10	0.1
5	3	0.03
6	2	0.02
	n = 100	1

Advantage of using Probability

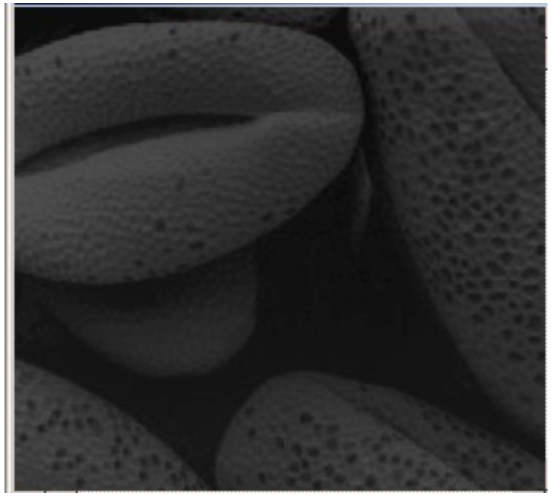
- Maximum value plotted will always be 1
- White: 1, Black: 0
- Types:



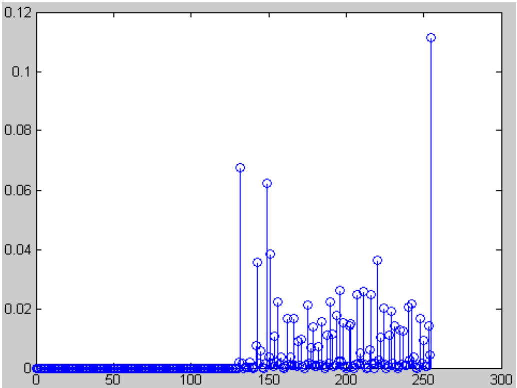
Example

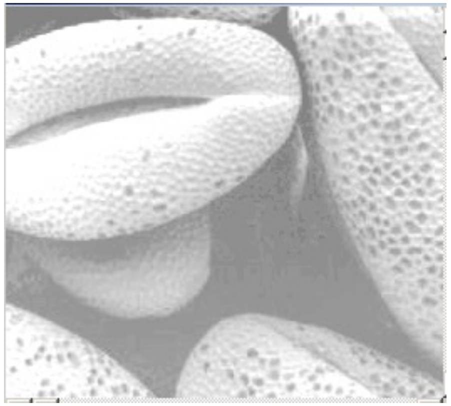


Dark image

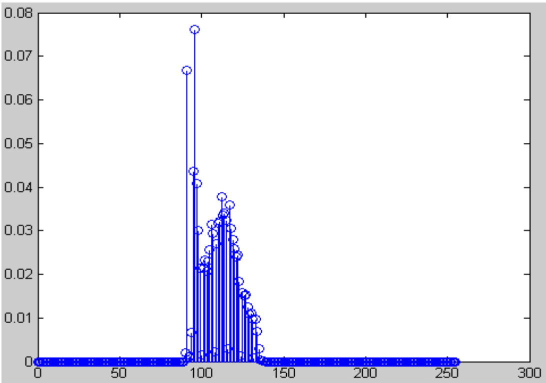


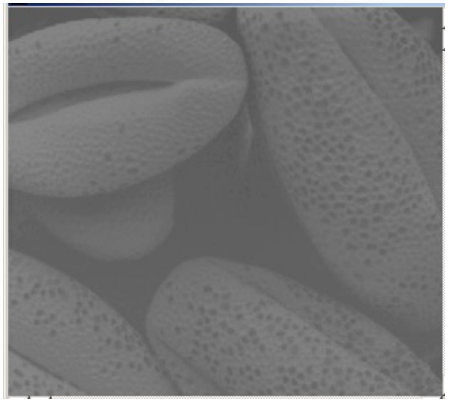
Example





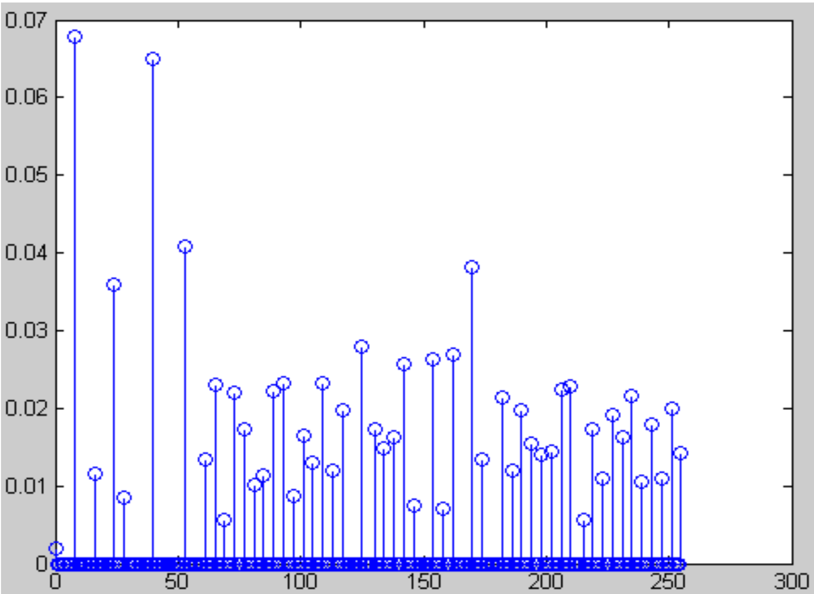
Bright image

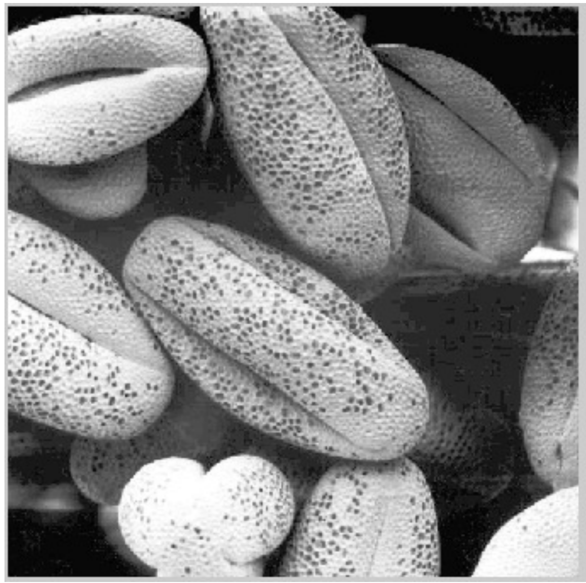




Low contrast image.

Histogram equalized Image and its Hostogram





Histogram Processing

- The last graph represents the best image
- It is a high contrast image
- The aim is to transform the first 3 Histograms into the 4th type
- **In other words we try to increase the dynamic range of the image in histogram processing**

Features of Histogram

- Histogram of dark image will be clustered towards lower gray level
- Histogram of a bright image will be clustered towards higher gray level
- For a low-contrast image, histogram will not be spread equally (histogram will be narrow)
- **For a high-contrast image, histogram will have equal spread in the gray level (0-255)**
- **Image brightness may be improved by modifying the histogram of the image**
- **Histogram Manipulation:** Modifies the histogram of an input image to improve visual quality of the image

Histogram Stretching

- Linear Stretching:
  - Here basic shape is not altered
  - Use basic equation of a straight line having a slope

$(S_{max} - S_{min})/r_{max} - r_{min})$ and perform y=mx+c

Where S_{max} : Max gray level of the output image

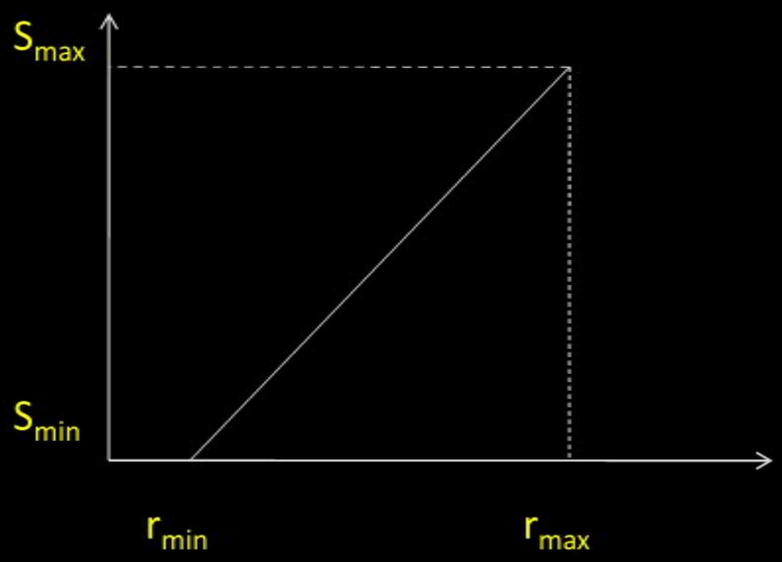
S_{min} : Min gray level of the output image

r_{max} : Max gray level of input image

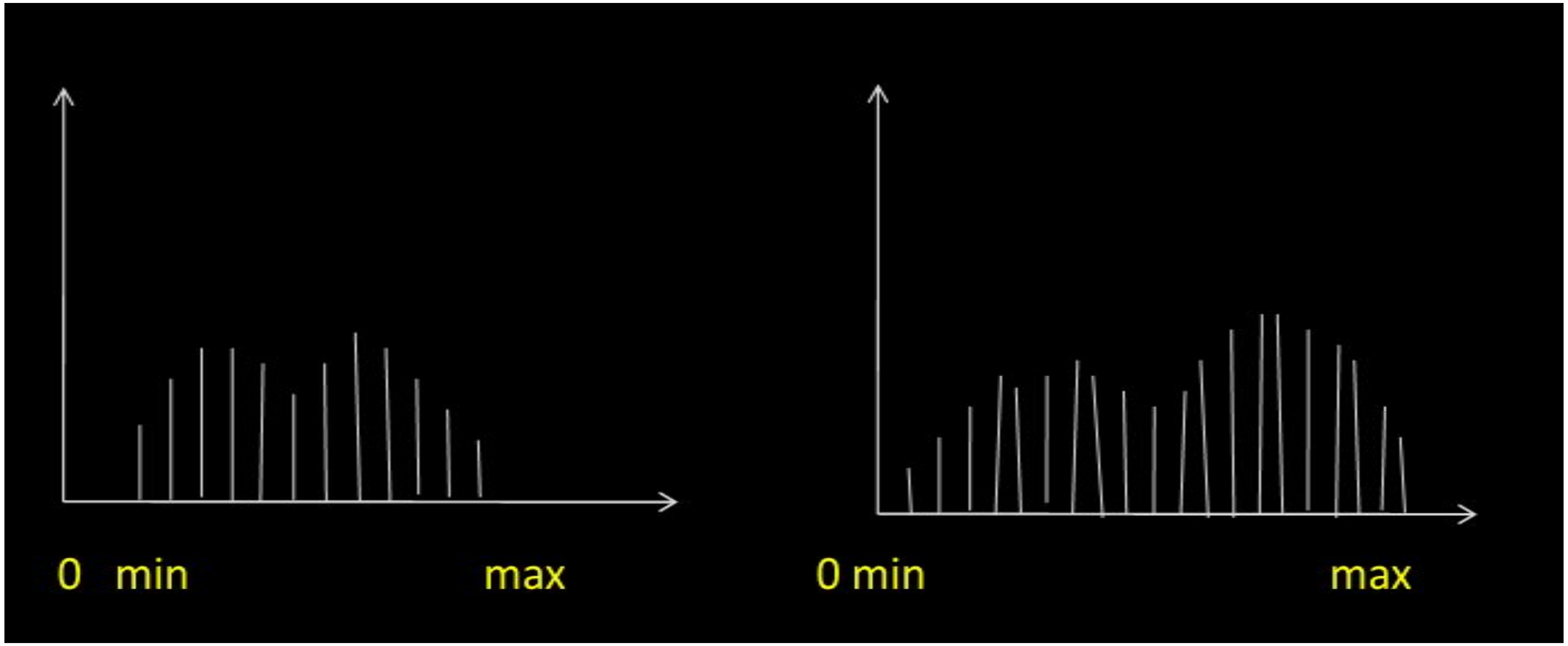
r_{min} : Min gray level of input image

Linear Stretching

$$S = T(r) = ((S_{max} - S_{min})/(r_{max} - r_{min}))(r - r_{min}) + Smin$$



Linear Stretching



Histogram of Input Image (r)

Histogram of Output Image (S) after stretching

Histogram Stretching Example

Ex. 1) Perform Histogram Stretching so that the new image has a dynamic range of 0 to 7 [0, 7].

Gray Levels	0	1	2	3	4	5	6	7
No. of Pixels	0	0	50	60	50	20	10	0

Dynamic range of input image is 2-6
Dynamic range of output image is 0-7

Sol^n:- $r_{min} = 2$; $r_{max} = 6$; $s_{min} = 0$; $s_{max} = 7$;

$S = (7 / 4)(r - 2) + 0;$
$S = (7 / 4)(r - 2)$

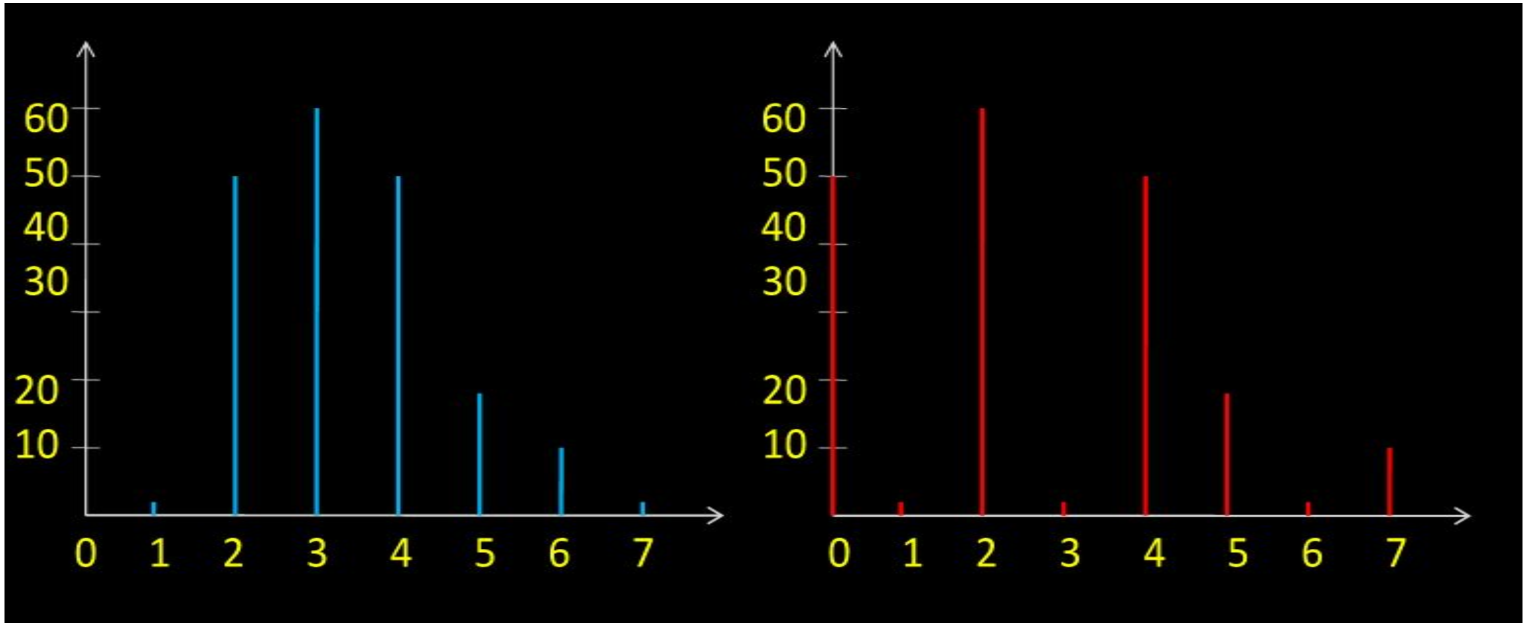
Example 1

- Determine the mapping

r	(7 / 4)(r - 2) = S
2	0 = 0
3	7/4 = 1.75 = 2
4	7/2 = 3.5 = 4
5	21/4 = 5.25 = 5
6	7 = 7

Stretching

- Stretched Histogram is



- Dynamic range increases but number of pixels at each gray level remains the same hence the shape does not change

Example 2

Ex. 2) Perform Histogram Stretching so that the new image has a dynamic range of 0 to 7 .

Gray Levels	0	1	2	3	4	5	6	7
No. of Pixels	100	90	85	70	0	0	0	0

Slope= (7-0)/(3-0)

S= 7/3(r - 0) + 0

r	s
0	0
1	2.3 =2
2	4.67 = 5
3	7

Example 2

- Stretched Histogram is

Gray Levels	0	1	2	3	4	5	6	7
No. of Pixels	100	0	90	0	0	85	0	70

- Dynamic range increases but number of pixels at each gray level remains same hence the shape does not change

Histogram Equalization

- Linear stretching is a good technique but not perfect since the shape remains same
- Most of time we need a flat histogram
- It can’t be achieved by Histogram stretching
- Hence Histogram equalization came into use
- Perfect image is one where all gray levels have equal number of pixels
- **Here the objective is not only to spread the range but also to have equal pixels at all gray levels**

- **Histogram Equalization:** A process that attempts to spread out the gray levels so that they are evenly distributed across their range
  - Reassigns the brightness values of pixels based its on histogram
  - It is a technique where the histogram of the resultant image is as flat as possible
  - *Provides more visually pleasing results across a wider range of images*

- We need to search for a transforms that converts any random histogram into flat histogram, $S= T(r)$
- Find T which produces equal values in each gray level
- Transform should satisfy following 2 conditions:
  - $T(r)$ must be single value and monotonically increasing in interval, $0 \le r \le 1$

  $0 \le T(r) \le 1$ for $0 \le r \le 1$

  $0 \le S \le 1$ for $0 \le r \le 1$
- **Here range of r is [0,1] (normalized range) instead of [0,255]**

Steps for Equalization

Procedure to perform histogram equalization:

1. Find the running sum of histogram values
2. Normalize the values from step (1) by dividing by the total number of pixels
3. Multiply the values from step (2) by the maximum gray-level value and round
4. Map the gray level values to the results from step (3) using a one-to-one correspondence

Example-1

- Perform histogram equalization of the image

$$\begin{bmatrix} 4 & 4. & 4. & 4. & 4 \\ 3. & 4 & 5. & 4. & 3 \\ 3. & 5. & 5. & 5. & 3 \\ 3. & 4. & 5. & 4. & 3 \\ 4. & 4. & 4. & 4. & 4 \end{bmatrix}$$

Sol:

- Maximum value is 5.
- We need 3 bits to represent this number.
- There are 8 possible gray levels from 0 to 7.

Solution

- Histogram of the image is

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0

Step 1: Compute the running sum (also known as cumulative frequency distribution) of histogram values

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running sum	0	0	0	6	20	25	25	25

Solution

Step 2: Divide the running sum obtained in Step 1 by total number of pixels, which is 25 is this case

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running sum	0	0	0	6	20	25	25	25
Running Sum/Total number of pixels	0/25	0/25	0/25	6/25	20/25	25/25	25/25	25/25

Solution

Step 3: Multiply the result obtained in Step 2 by maximum gray level value, which is 7 is this case

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running Sum	0	0	0	6	20	25	25	25
Runningsum/Total number of pixels	0/25	0/25	0/25	6/25	20/25	25/25	25/25	25/25
Multiply the above result by maximum gray level	$\frac{0}{25}*7$	$\frac{0}{25}*7$	$\frac{0}{25}*7$	$\frac{6}{25}*7$	$\frac{20}{25}*7$	$\frac{25}{25}*7$	$\frac{25}{25}*7$	$\frac{25}{25}*7$

Solution

Round the result to closest integer to get following table

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running Sum	0	0	0	6	20	25	25	25
Running Sum/Total number of pixels	0/25	0/25	0/25	6/25	20/25	25/25	25/25	25/25
Multiply the above result by maximum gray level	0	0	0	2	6	7	7	7

Solution

Step 4: Mapping the gray level by a one-to-one correspondence

Original gray level	Histogram equalised values
0	0
1	0
2	0
3	2
4	6
5	7
6	7
7	7

Solution

The original image and the histogram equalised image are shown side by side

$$\begin{bmatrix} 4 & 4 & 4 & 4 & 4 \\ 3 & 4 & 5 & 4 & 3 \\ 3 & 5 & 5 & 5 & 3 \\ 3 & 4 & 5 & 4 & 3 \\ 4 & 4 & 4 & 4 & 4 \end{bmatrix} \xrightarrow[\text{Equalisation}]{\text{Histogram}} \begin{bmatrix} 6 & 6 & 6 & 6 & 6 \\ 2 & 6 & 7 & 6 & 2 \\ 2 & 7 & 7 & 7 & 2 \\ 2 & 6 & 7 & 6 & 2 \\ 6 & 6 & 6 & 6 & 6 \end{bmatrix}$$

Original image **Histogram equalised image**

Example-2

- Perform histogram equalization of the image

$$\begin{pmatrix} 1 & 3 & 5 \\ 4 & 4 & 3 \\ 5 & 2 & 2 \end{pmatrix}$$

Sol:

- Maximum value is 5.
- We need 3 bits to represent this number.
- There are 8 possible gray levels from 0 to 7.

r_k	p_k	Cumulative running of pixels	$\frac{\text{Cumulative}}{\text{Total}} \times (L-1)$	Round off to the nearest grey level
0	0	0	$0/9 \times 7 = 0$	0
1	1	1	$1/9 \times 7 = 0.777$	1
2	2	3	$3/9 \times 7 = 2.333$	2
3	2	5	$5/9 \times 7 = 3.888$	4
4	2	7	$7/9 \times 7 = 5.444$	5
5	2	9	$9/9 \times 7$	7
6	0	9	$9/9 \times 7$	7
7	0	9	$9/9 \times 7$	7

$$\begin{pmatrix} 1 & 4 & 7 \\ 5 & 5 & 4 \\ 7 & 2 & 2 \end{pmatrix}$$

Equalized image

Example-3

- Perform histogram equalization of the image

$$f(x,y) = \begin{array}{|c|c|c|c|}\hline 1 & 2 & 3 & 4 \\ \hline 5 & 5 & 6 & 6 \\ \hline 6 & 7 & 6 & 6 \\ \hline 6 & 7 & 2 & 3 \\ \hline \end{array}.$$

Sol:

- Maximum value is 7.
- We need 3 bits to represent this number.
- There are 8 possible gray levels from 0 to 7.

Solution

- Histogram of the image is

Grey levels (r_k)	0	1	2	3	4	5	6	7
No. of pixels (p_k)	0	1	2	2	1	2	6	2

- Compute the running sum (also known as cumulative frequency distribution) of histogram values

r_k	p_k	Cumulative	$\frac{\text{Cumulative}}{\text{Total}\times(L-1)}$	Round-off value
0	0	0	$0/16\times7=0$	0
1	1	1	$1/16\times7=0.4375$	0
2	2	3	$3/16\times7=1.3125$	1
3	2	5	$5/16\times7=2.1875$	2
4	1	6	$6/16\times7=2.625$	3
5	2	8	$8/16\times7=3.5$	4
6	6	14	$14/16\times7=6.125$	6
7	2	16	$16/16\times7=7$	7

0	1	2	3
4	4	6	6
6	7	6	6
6	7	1	2

Equalized image

$f(x,y)=$

1	2	3	4
5	5	6	6
6	7	6	6
6	7	2	3

Original image

Solution

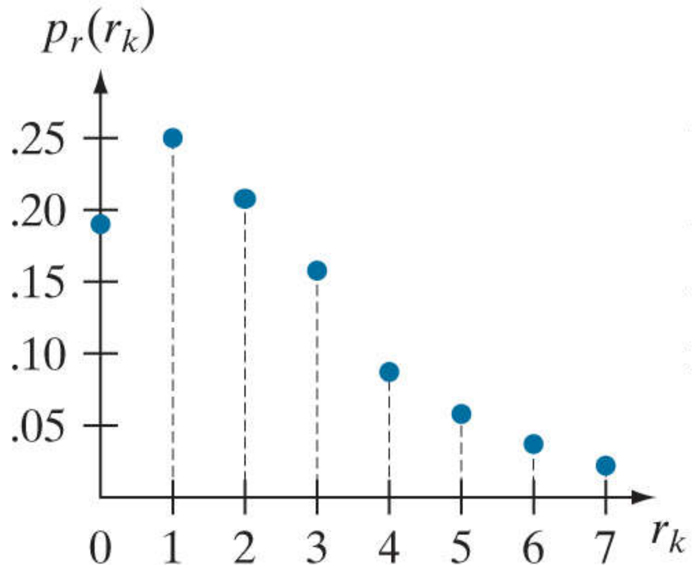
Example 5: Suppose that a 3-bit image (= 8) of size 64 × 64 pixels (= 4096) has the

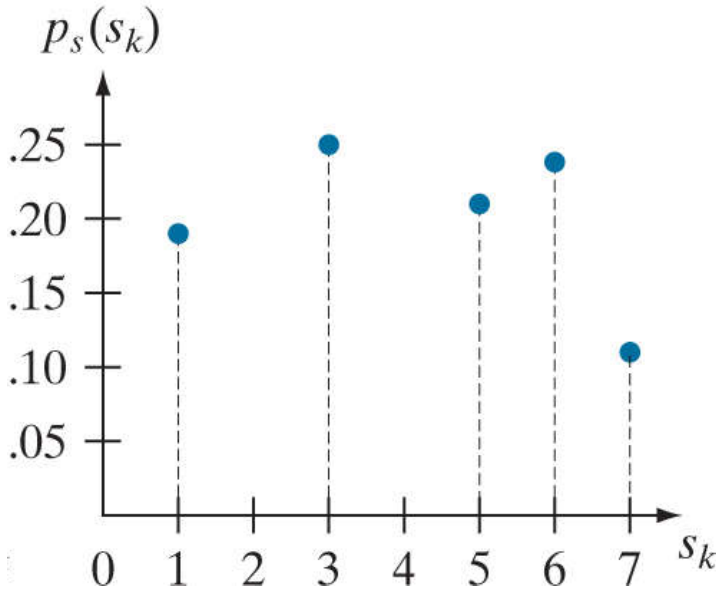
- intensity distribution in Table below

r_k	0	1	2	3	4	5	6	7
p_k	790	1023	850	656	329	245	122	81
Running sum	790	1813	2663	3319	3648	3893	4015	4096
RS/MN	0.19	0.44	0.65	0.81	0.89	0.95	0.98	1
x7	1.33	3.08	4.55	5.67	6.23	6.65	6.86	7
rounded	1	3	5	6	6	7	7	7

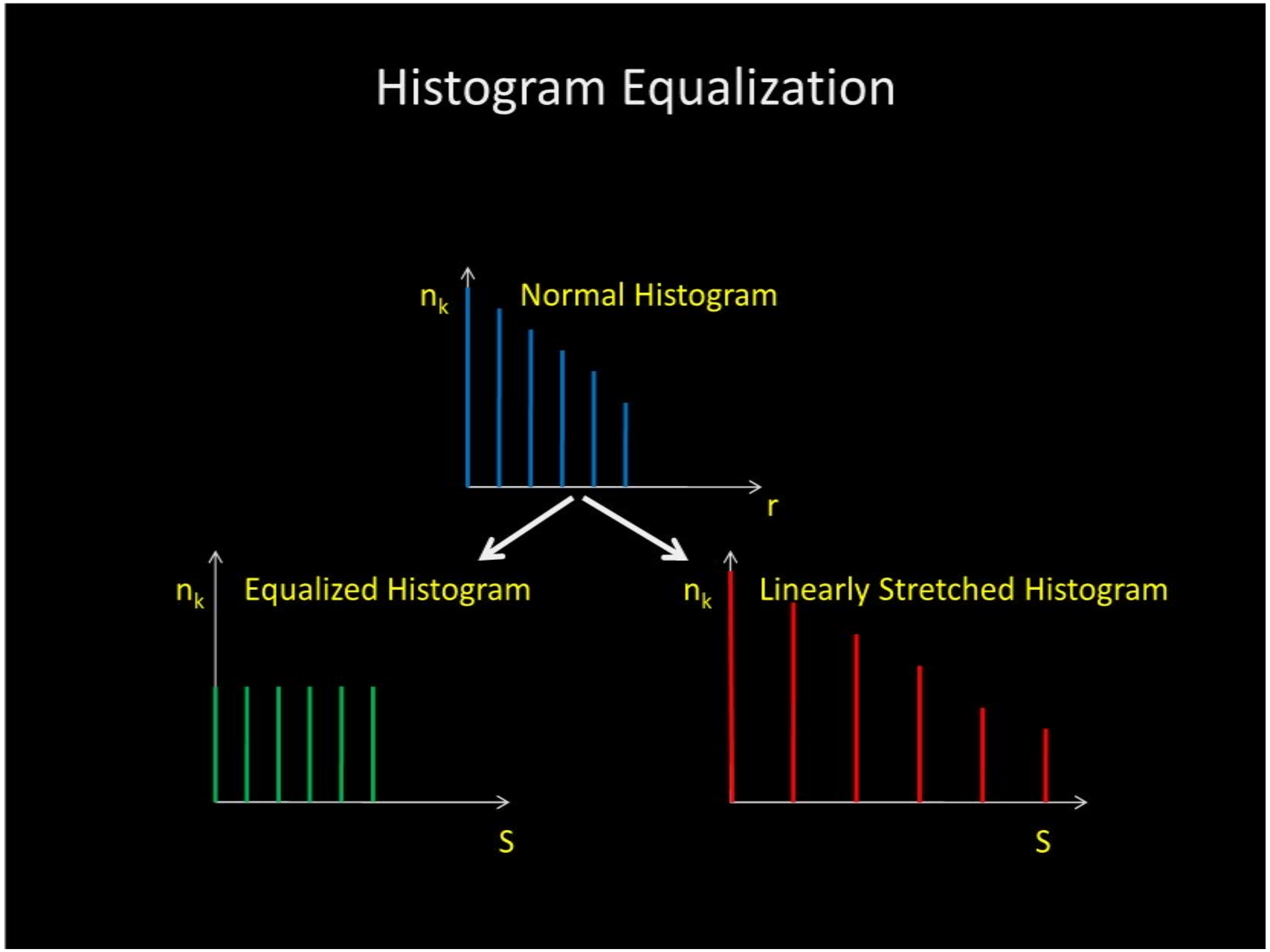
Solution

r_k	0	1	2	3	4	5	6	7
p_k	790	1023	850	656	329	245	122	81
rounded	1	3	5	6	6	7	7	7





Histogram Equalization



Types of Enhancement Techniques

Image Enhancement

Point Operations

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Spatial Operations

- Noise Smoothing
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- LP,HP,BP filtering
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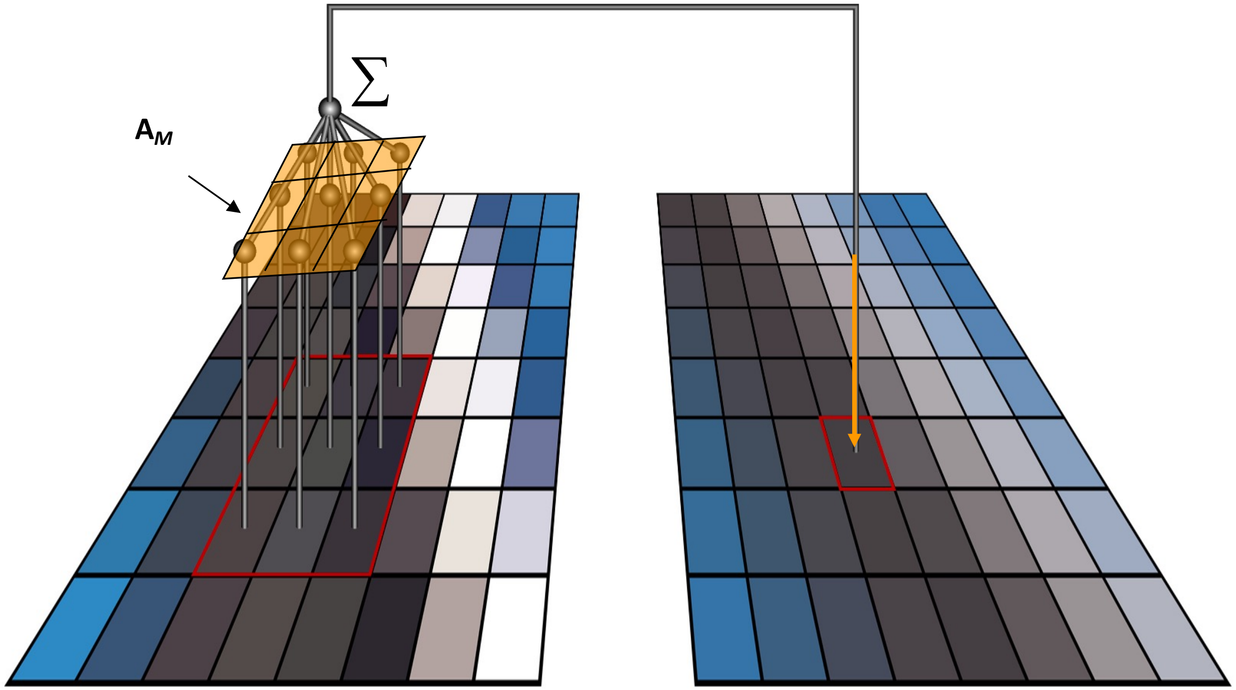
Pseudocoloring

- False Coloring
- Pseudocoloring

Spatial Domain

DIGITAL IMAGE PROCESSING-1

Spatial Operations (Neighbourhood Processing)



Local or Neighborhood Operations

- The pixels are modified based on some functions of the pixels in their neighborhood
- Work with the values of image pixels in the neighborhood and the corresponding values of a subimage that has the same dimension as the neighborhood
  - The subimage is called filter, mask, kernel, template or window
- Values in filter subimage (kernel) are referred to as coefficients rather than pixels

•3 x 3 Neighborhood / Mask / Window / Template:

	(y - 1)	y	(y + 1)	Y
(x - 1)	W1 g(x-1, y-1)	W2 g(x-1, y)	W3 g(x-1, y+1)	
x	W4 g(x, y-1)	W5 g(x, y)	W6 g(x, y+1)	
(x + 1)	W7 g(x+1, y-1)	W8 g(x+1, y)	W9 g(x+1, y+1)	
X				

Spatial Filtering

- Filtering operations performed directly on pixels (not frequency domain filtering)
- Process consists of moving the filter mask from point to point in an image
- At each point (x,y), the response of the filter at that point is calculated using a predefined relationship
  - Ex. For a linear spatial filter, response is sum of products of filter coefficients and corresponding image pixels in the area spanned by filter mask

Steps Involved

- **To achieve neighborhood processing:**
- **Place the mask on the image.**
- **Multiply each mask component with the pixel component.**
- **Add them and place value at the center. Similar to *CONVOLUTION.***
- **Only here we need not flip the mask as it is symmetric.**
- **If g is original image & f is modified image, then:**

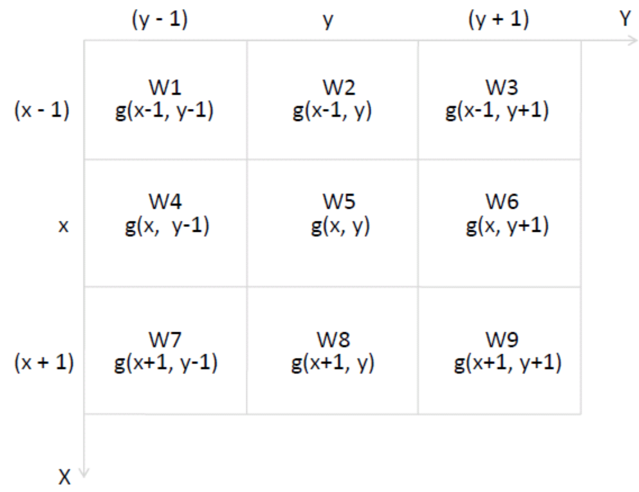
$$f(x, y) = g(x-1,y-1).w1 + g(x-1,y).w2 + g(x-1,y+1).w3 + g(x,y-1).w4 + g(x, y).w5 + g(x,y+1).w6 + g(x+1,y-1).w7 + g(x+1,y).w8 + g(x+1,y+1).w9$$

	(y - 1)	y	(y + 1)	Y
(x - 1)	W1 g(x-1, y-1)	W2 g(x-1, y)	W3 g(x-1, y+1)	
x	W4 g(x, y-1)	W5 g(x, y)	W6 g(x, y+1)	
(x + 1)	W7 g(x+1, y-1)	W8 g(x+1, y)	W9 g(x+1, y+1)	
X				

Steps Involved

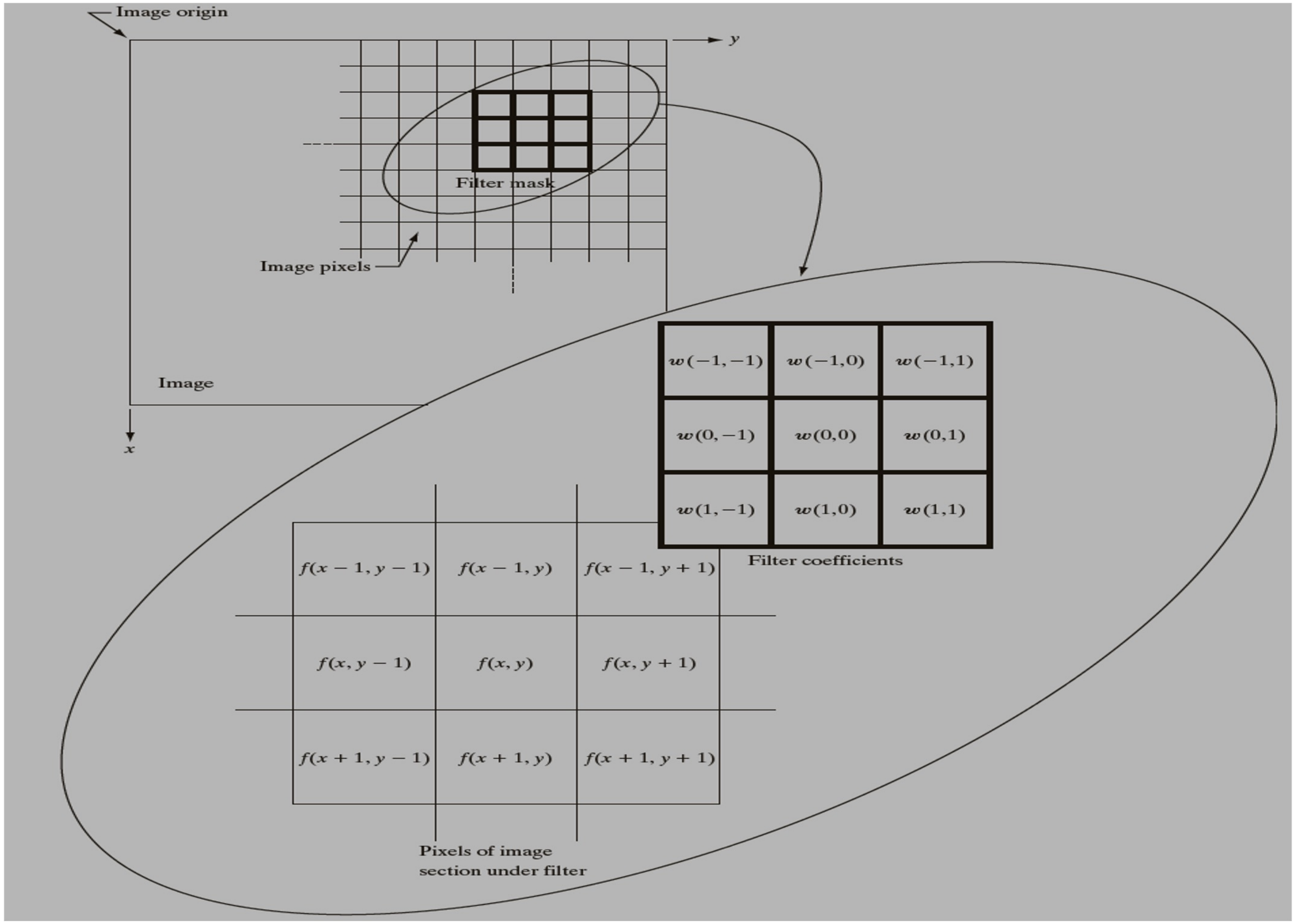
- Once f(x, y) is calculated, shift mask by 1 step to right.
- Now, W5 coincide with g(x, y+1).
- Application of neighborhood processing : Image Filtering.

  E.g. LPF, HPF, BPF, BRF



- In 1D signals, if a signal represents voltage then, how fast the signal changes is indication of frequency.
- Same concept is applied to images where we have gray levels instead.
- If gray scale changes slowly over a region then LF area (Ex. Background)
- If gray scale changes abruptly over a region then HF area (Ex. Edges, Boundaries)

Spatial Filters



Next Session

- Spatial filtering
- Convolution
- Image Smoothing (averaging)
- Image Sharpening Filters
- Sharpening using Laplacian operator
- Unsharp Masking
- Enhancement using Frequency domain

THANK YOU

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