Image Enhancement and Restoration

IMAGE QUALITY AND NEED FOR IMAGE ENHANCEMENT

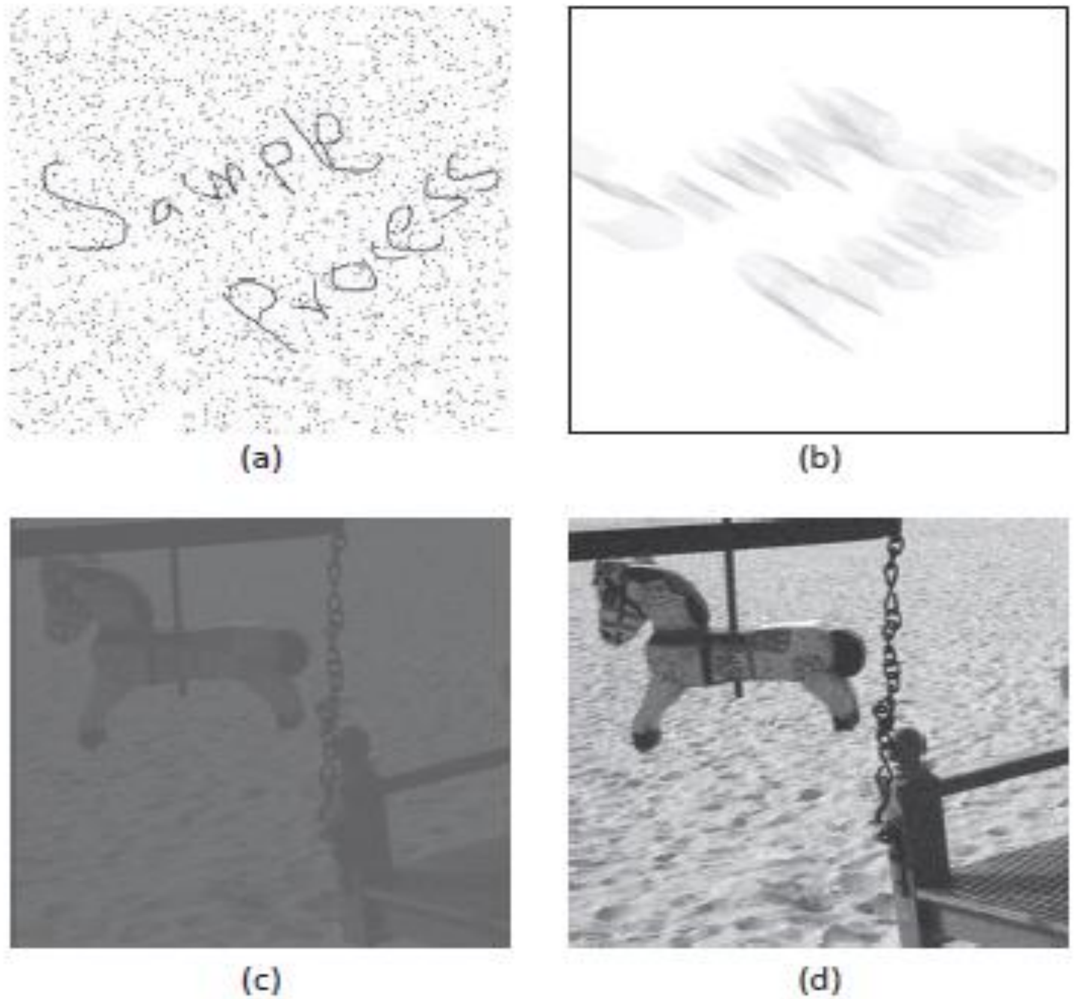


Fig. 5.1 Various sample images (a) Image with noise (b) Image with blur (c) Image with brightness problem (d) Good quality image

Image Quality Factors

1. Noise
2. Contrast
3. Brightness
4. Spatial resolution

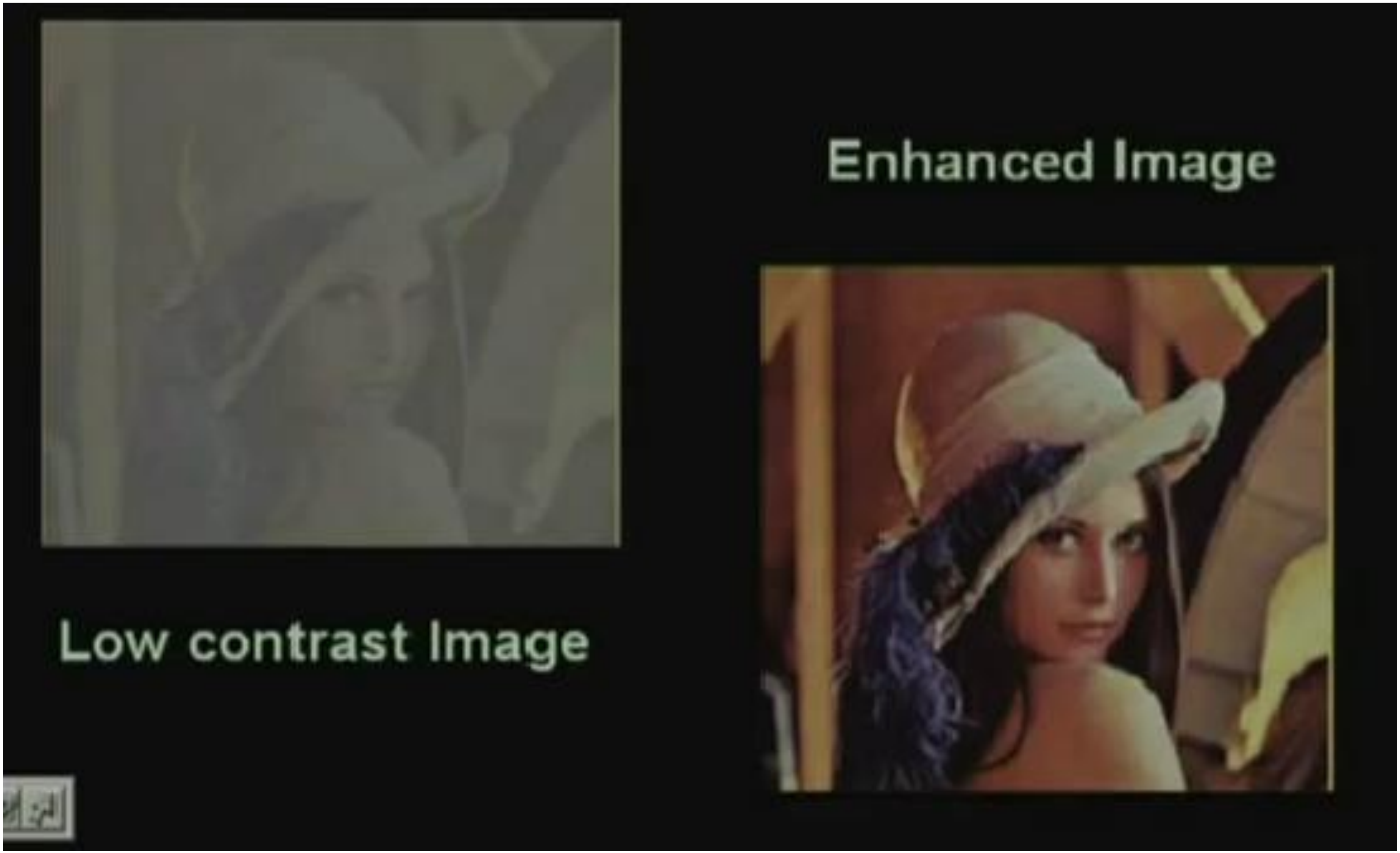
Noisy Image

Filtered Image

Defocused
Motion Blurred
Deblurred

Low contrast Image

Enhanced Image


Enhanced Image
Low contrast Image

Cancer Detection

IMAGE ENHANCEMENT

Processing an Image to enhance certain features of the image →

The result is more suitable than the original image for certain specific applications

- Processing techniques are very much problem oriented
- Best technique for enhancement of X-ray image may not be the best for enhancement of microscopic mages

Image Enhancement

1. Noise removal.
2. Image darkness – Contrast to be improved
3. Edges to be highlighted for certain

   operations.

IMAGE ENHANCEMENT - Techniques

Enhancement techniques fall under two broad categories

- Spatial Domain Technique
  - Work on Image Plane itself
  - Direct manipulation of pixels in an image
- Frequency Domain Technique
  - Modify Fourier Transform coefficients of an image
  - Take inverse Fourier Transform of the modified coefficients to obtain the enhanced image

Spatial Domain Operations

- Mask processing
- Point Processing
- Histogram based techniques

General representation of Transformation functions:

1. $g(x) = T[f(x)]$ → 1-D

2. $g(x,y) = T[f(x,y)]$ → 2-D

Where $f(x,y)$ → (x,y) in original image

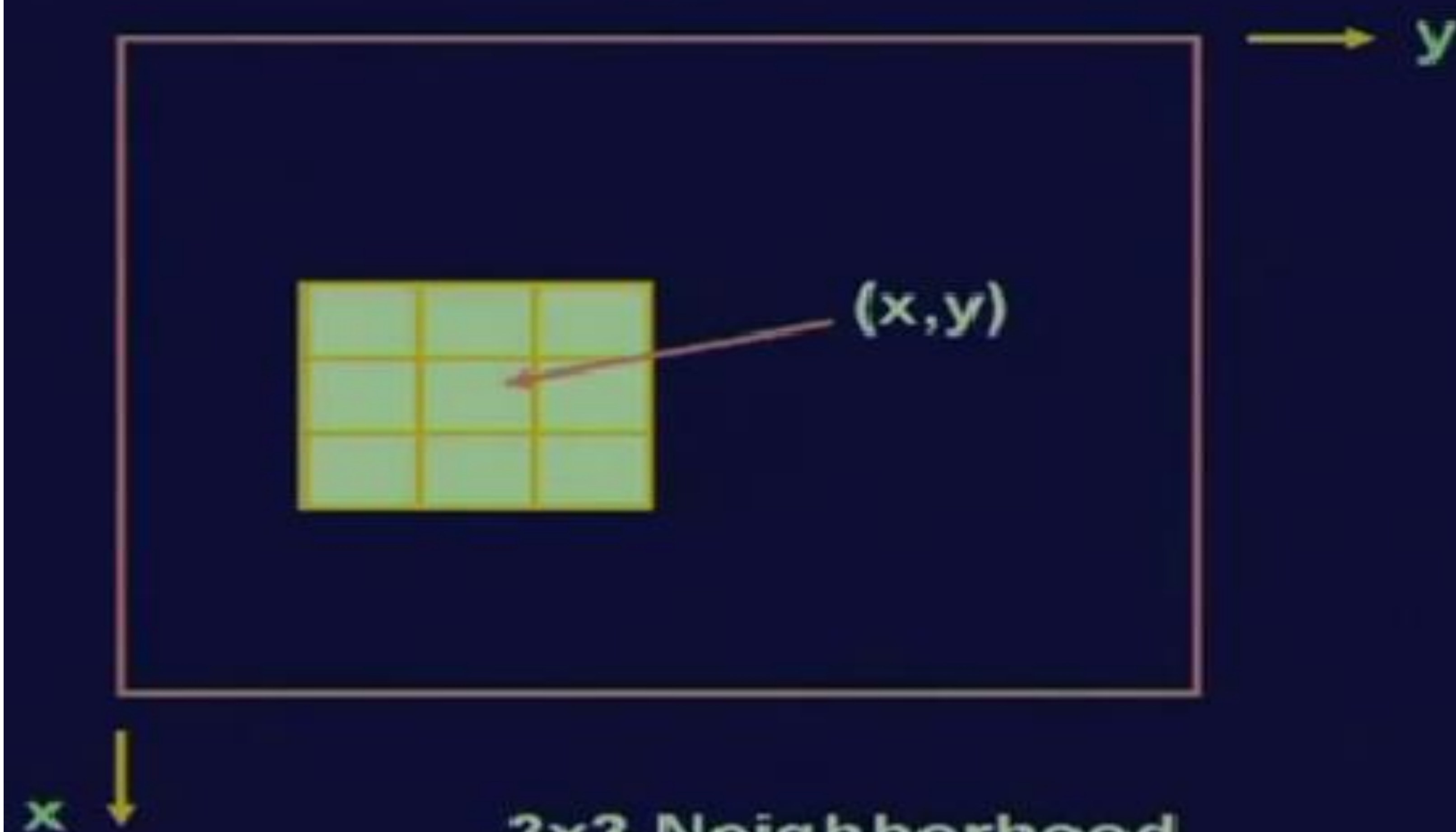
$g(x,y)$ → (x,y) in Transformed Image

T → Transformation function

T → works directly on $f(x,y)$ of i/p image

T → Defined over neighborhood of $f(x,y)$

Neighborhood



3x3 Neighborhood

For **point processing** the general transformation function is restricted to 1X1 neighborhood.

$$g(x,y) = T[f(x,y)]$$

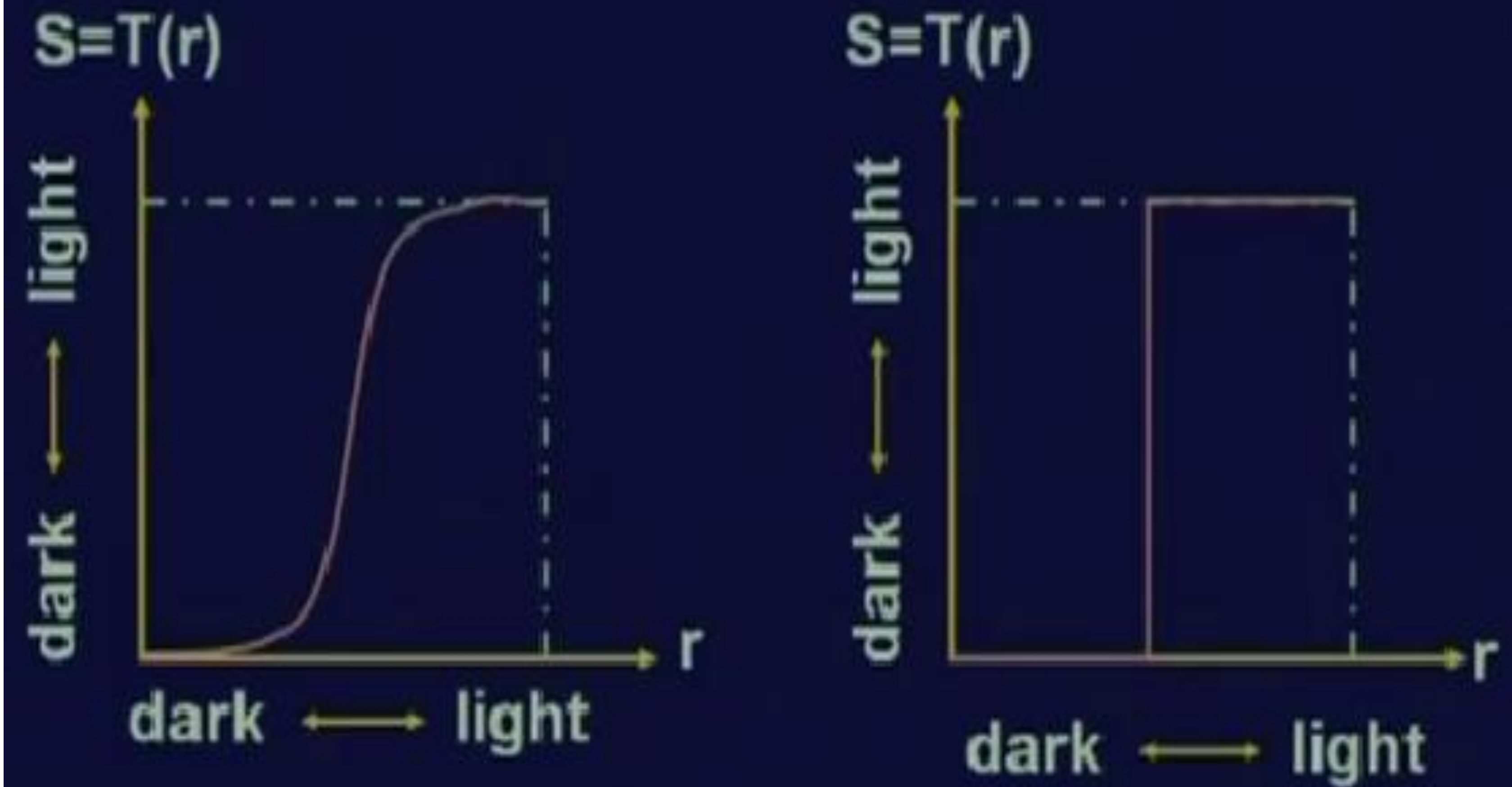
T→ Works directly on f(x,y) without considering the neighborhood pixels.

$$S = T(r)$$

r → pixel value in original image.

S → pixel value in corresponding location of processed image.

Point Processing



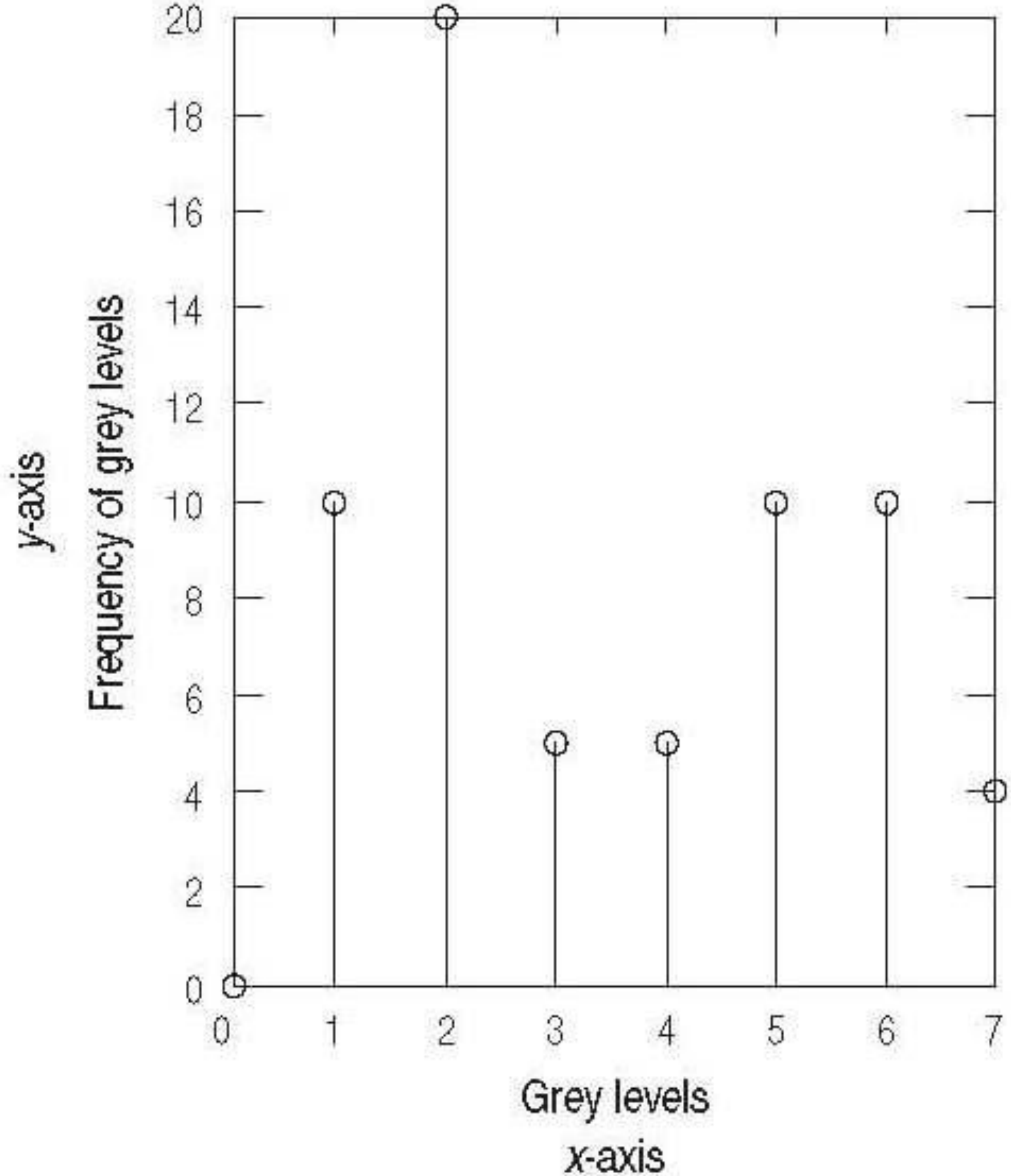
Contrast stretching

Thresholding

Image Quality Assessment tool

- Histograms

$$\begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 2 & 2 & 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 & 2 & 2 & 3 & 3 \\ 3 & 3 & 3 & 4 & 4 & 4 & 4 & 4 \\ 5 & 5 & 5 & 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 7 & 7 & 7 & 7 & 6 & 6 \\ 6 & 6 & 6 & 6 & 6 & 6 & 6 & 6 \end{pmatrix}$$



20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
y-axis
Frequency of grey levels
Grey levels
x-axis

Advantages of Histogram

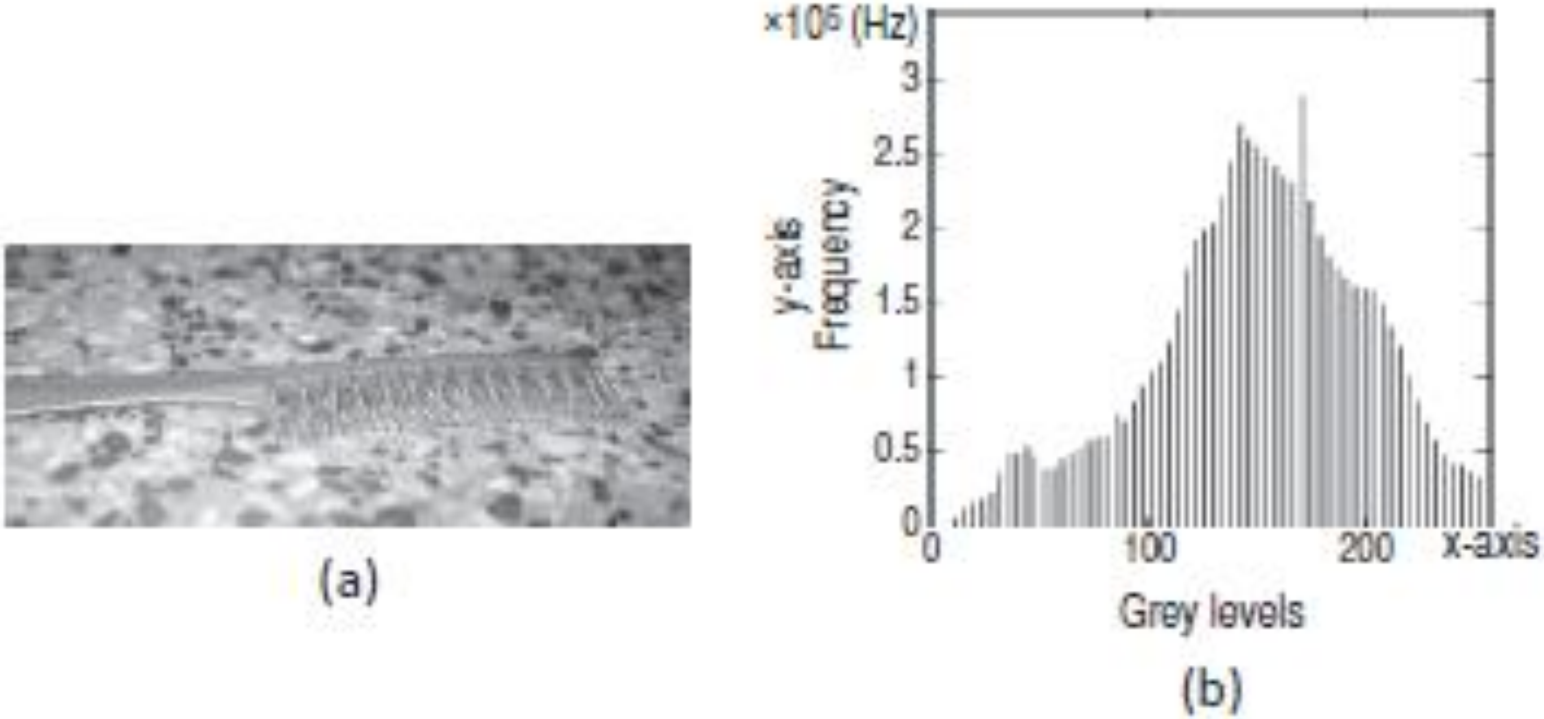


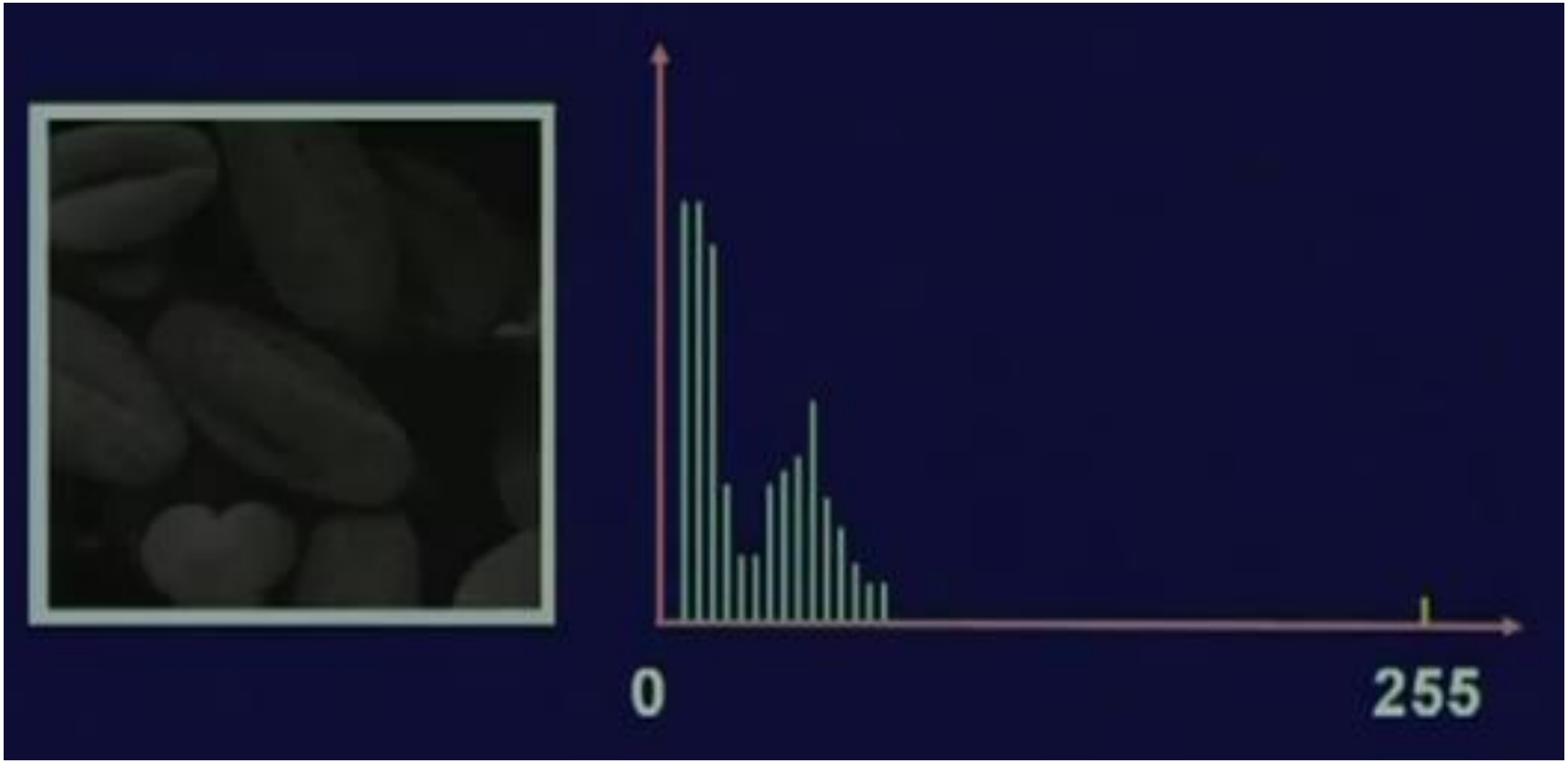
Fig. 5.4 Histogram (a) Sample image (b) Histogram of the sample image

$$\text{Dynamic range} = f_{\max} - f_{\min}$$

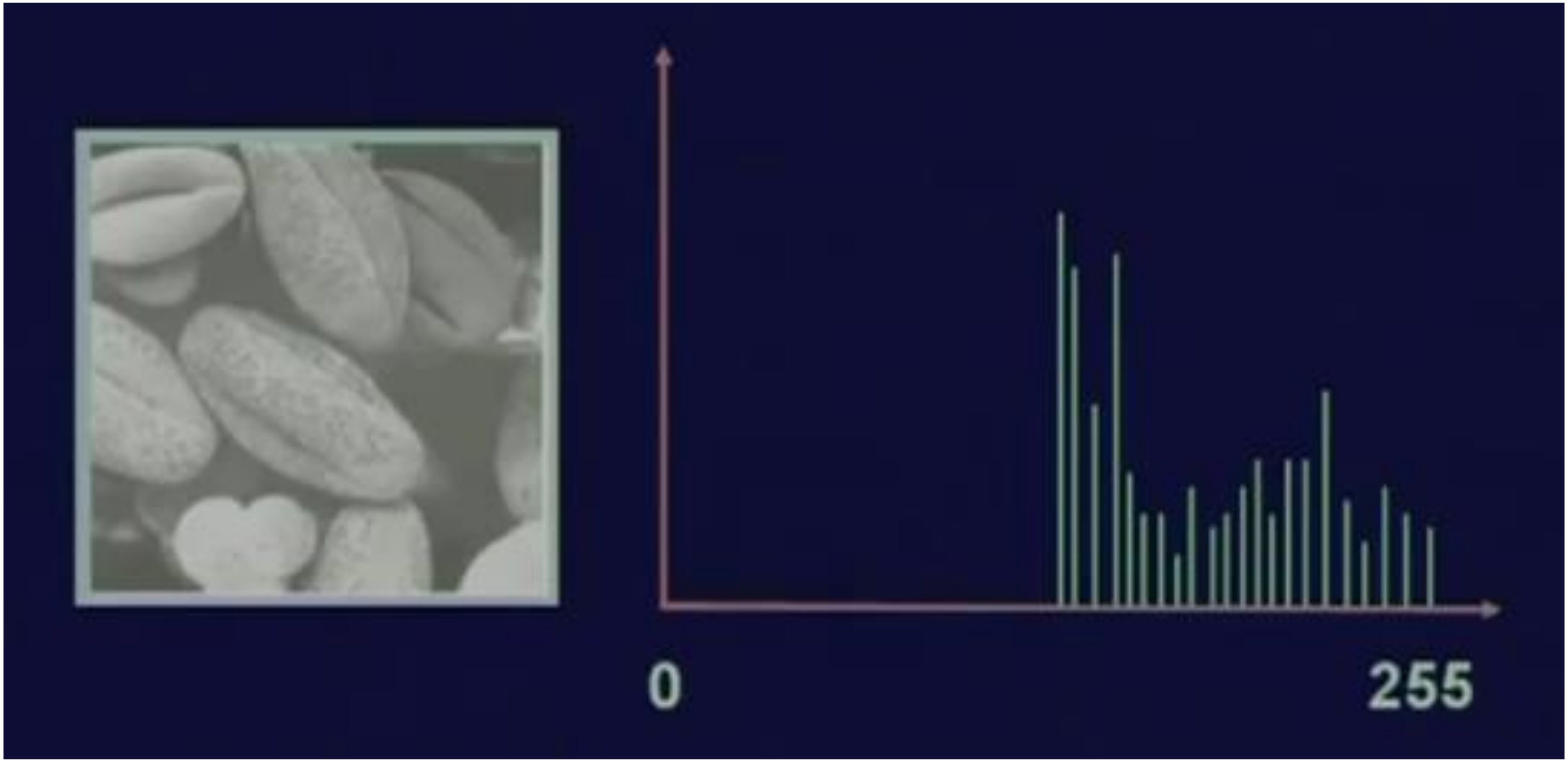
Here $f_{\max}$ is the maximum pixel value and $f_{\min}$ is the minimum pixel value of the image. The dynamic range can also be expressed as

$$\text{Dynamic range} = 20\log(f_{\max} - f_{\min}) \text{ dB}$$

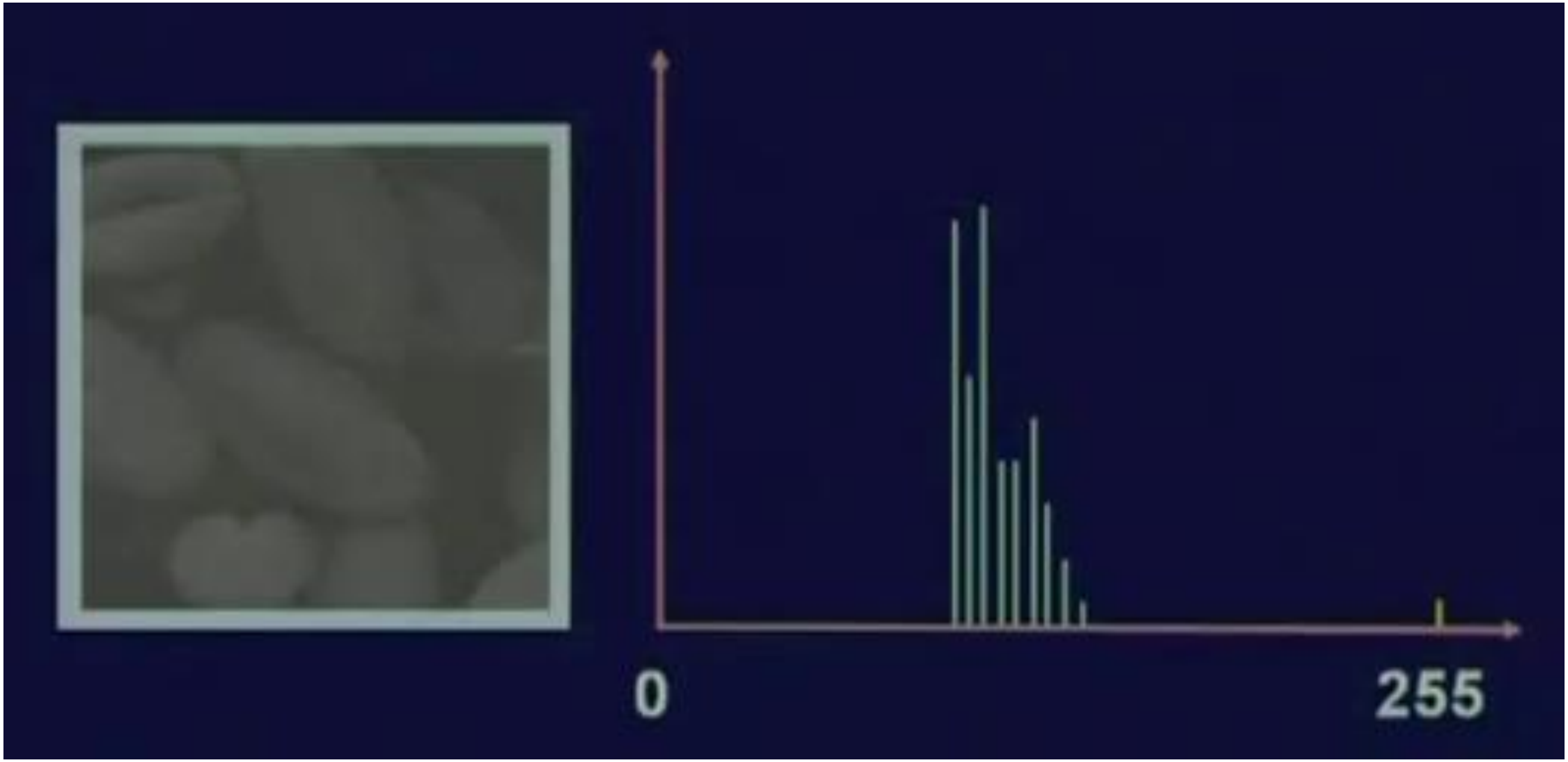
Dark Image



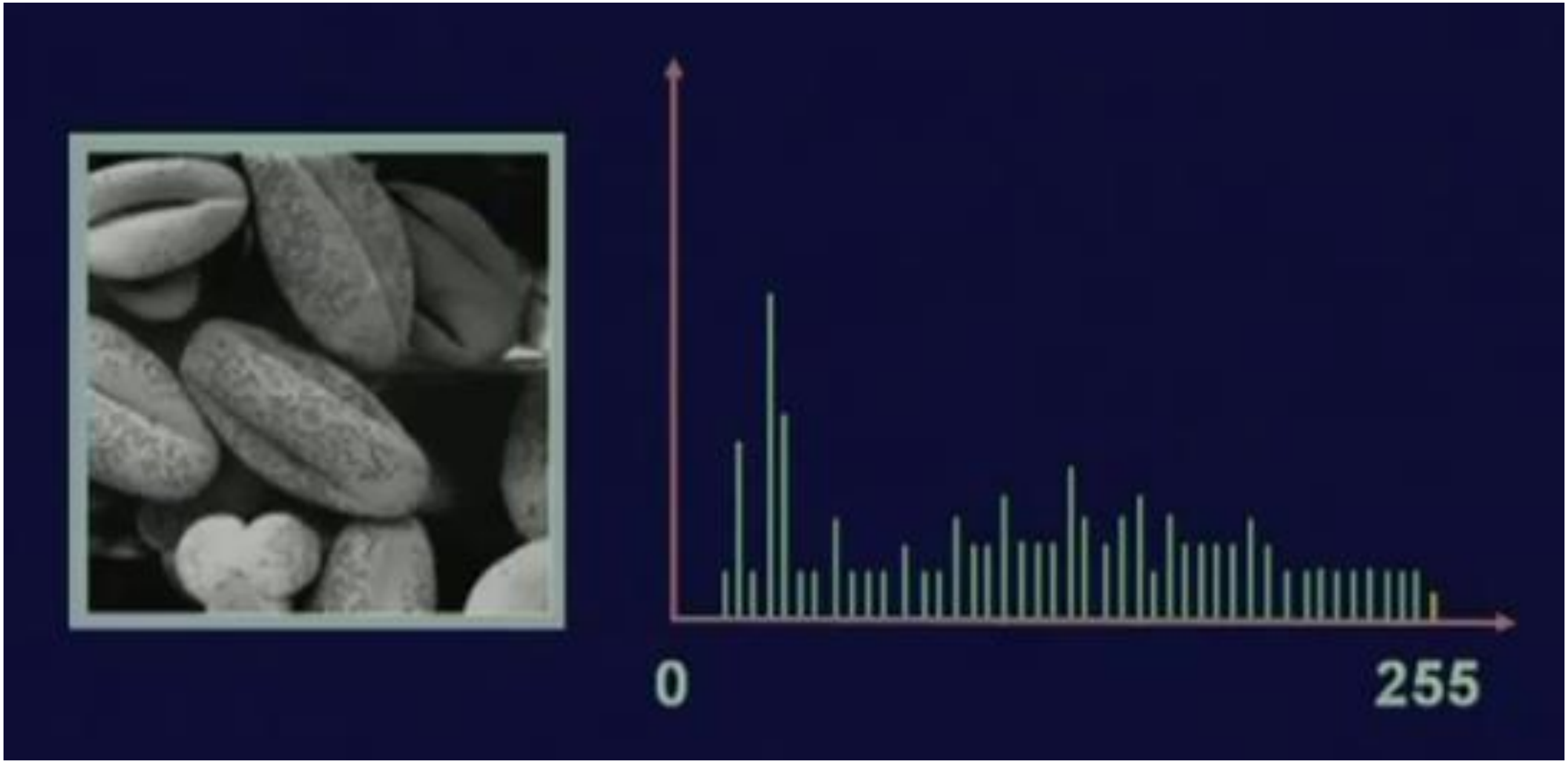
Bright Image



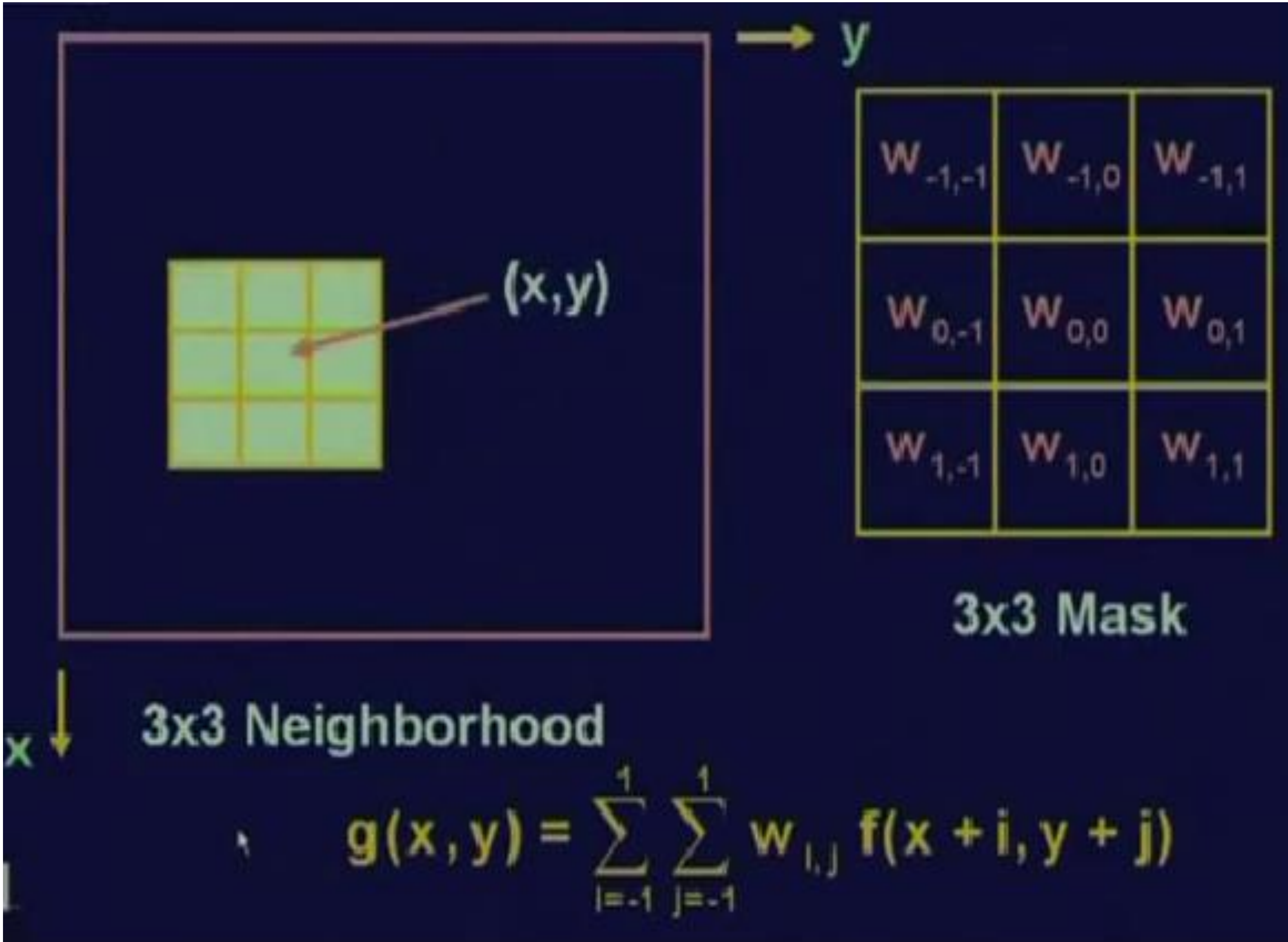
Low contrast Image



High contrast Image



Mask Processing



Mask Processing

- Based on the type of operation to be done the value of ‘Wi’ is chosen.(sharpening, averaging, etc.,)
- Appropriately the type of mask is chosen 3X3 or 5X5 or 7X7

Neighborhood Operations

The value assigned to a pixel is a function of its gray label and the gray labels of its neighbors.

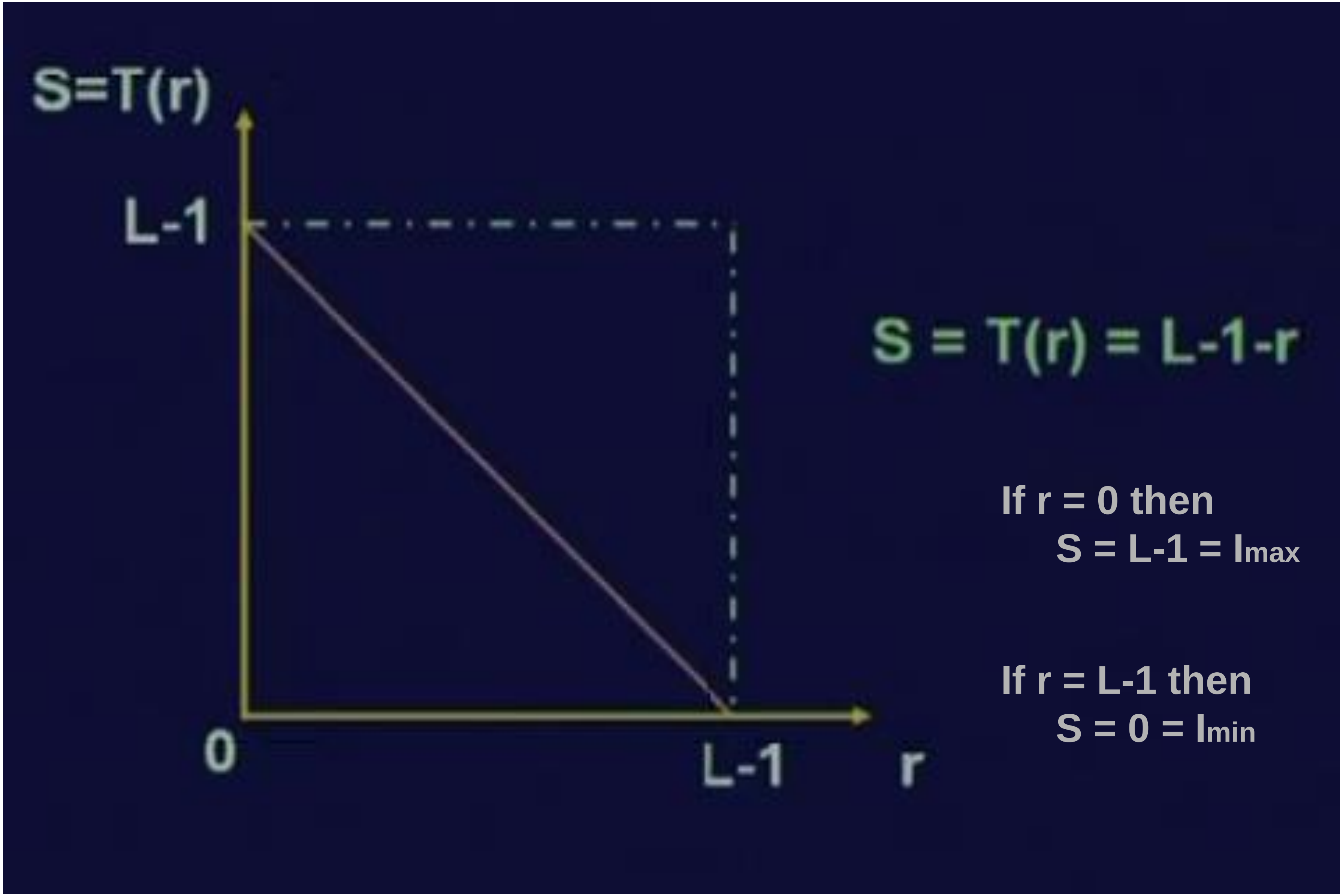
Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

$$Z = 1/9\ (Z_1+Z_2+Z_3+\ldots\ldots+Z_9) = \text{Average}$$

Point processing

- **Image Negative.**
- **Contrast stretching.**
- **Dynamic range compression.**
- **Clipping.**
- **Thresholding.**
- **Grey Level or Intensity Slicing.**
- **Bit plane slicing.**

Image Negative



Binary Image Negative operation

$g(x,y) = L - 1 - f(x,y)$

Where L is the number of grey levels in the image.

Considering the 3X3 image f(x,y).

1	0	1
0	1	1
1	0	0

This image has two gray levels(0,1) so L=2. Hence the inversion transformation can be performed to yield.

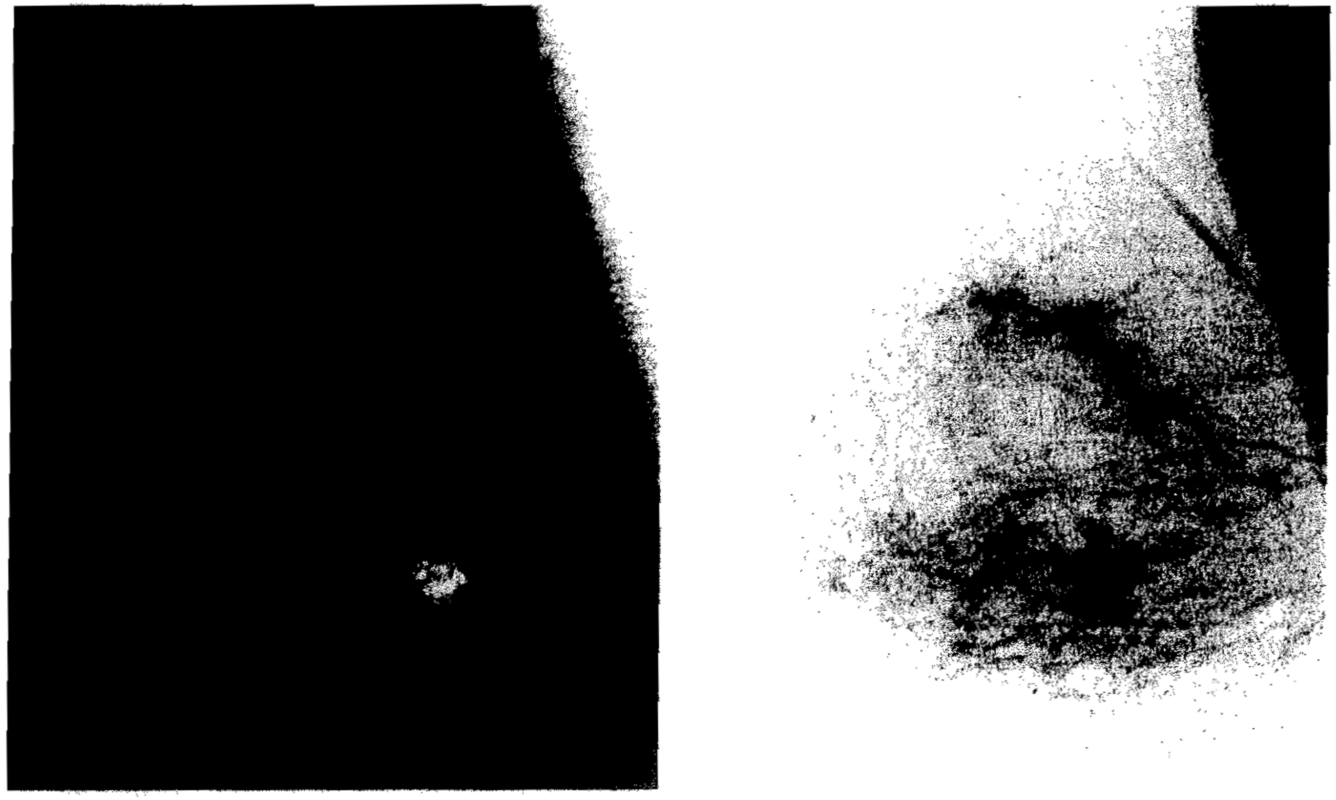
$g(x,y) = L - 1 - f(x,y)$

$= 2-1-1 = 0$

$= 2-1-0 = 1$

0	1	0
1	0	0
0	1	1

Binary Image Negative operation



Grey scale Image Negative operation

$g(x,y) = L - 1 - f(x,y)$

Where L is the number of grey levels in the image.

Considering the 3X3 image f(x,y).

1	2	3
0	1	1
2	2	3

This image has 4 gray levels(0,1,2,3) so L=4. Hence the inversion transformation can be performed to yield.

$g(x,y) = L - 1 - f(x,y)$

$= 4-1-1 = 2$

$= 4-1-2 = 1$

2	1	0
3	2	2
1	1	0

Image Negative

Problem

Obtain the digital negative of the following 8X8 grey scale image.

122	150	200
255	255	255
250	250	240

Solution

This image has 256 gray levels so L=256. Hence the inversion transformation can be performed to yield.

$$g(x,y) = L - 1 - f(x,y)$$

$$= 256\text{-}1\text{-}122 = 2$$

$$= 256\text{-}1\text{-}150 = 105$$

133	105	55
0	0	0
5	5	15

Power Law Transformation

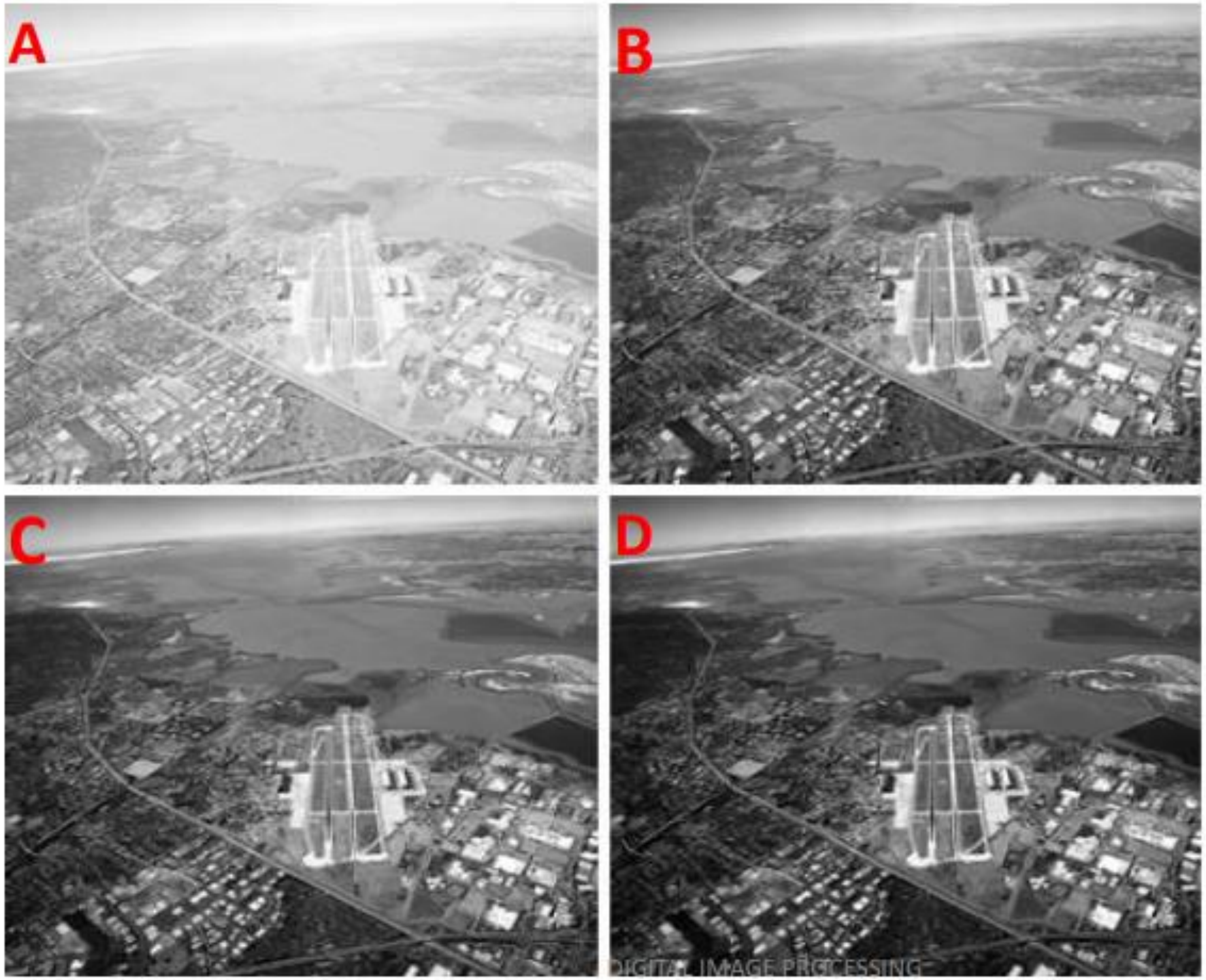
Expression for power law transformation is given by:

$$s = c * (r^{\gamma})$$

s is the output pixels value.
r is the input pixel value.
c and γ are real numbers.

- For various values of γ different levels of enhancements can be obtained.
- This technique is quite commonly called as *Gamma Correction* , used in monitor displays.

Power Law Transformation



A : original image
For c=1
B : γ =3.0
C : γ =4.0
D : γ =5.0

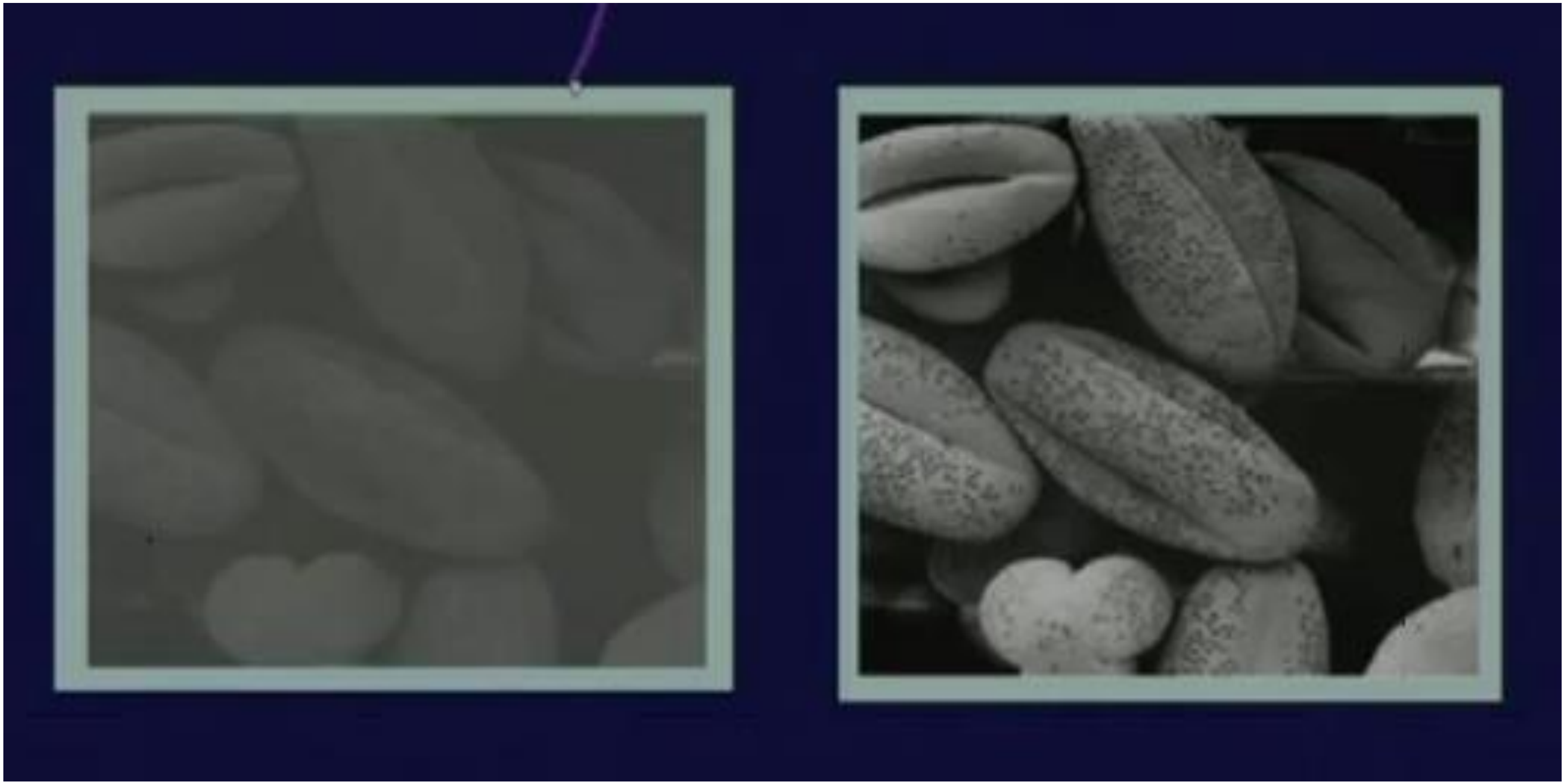
Low contrast image

Contrast is low due to

- Poor Illumination .
- Low Dynamic range

  $DR = I_{max} - I_{min}$
- Improper aperture setting in the camera

Contrast Stretching Result



Contrast Stretching

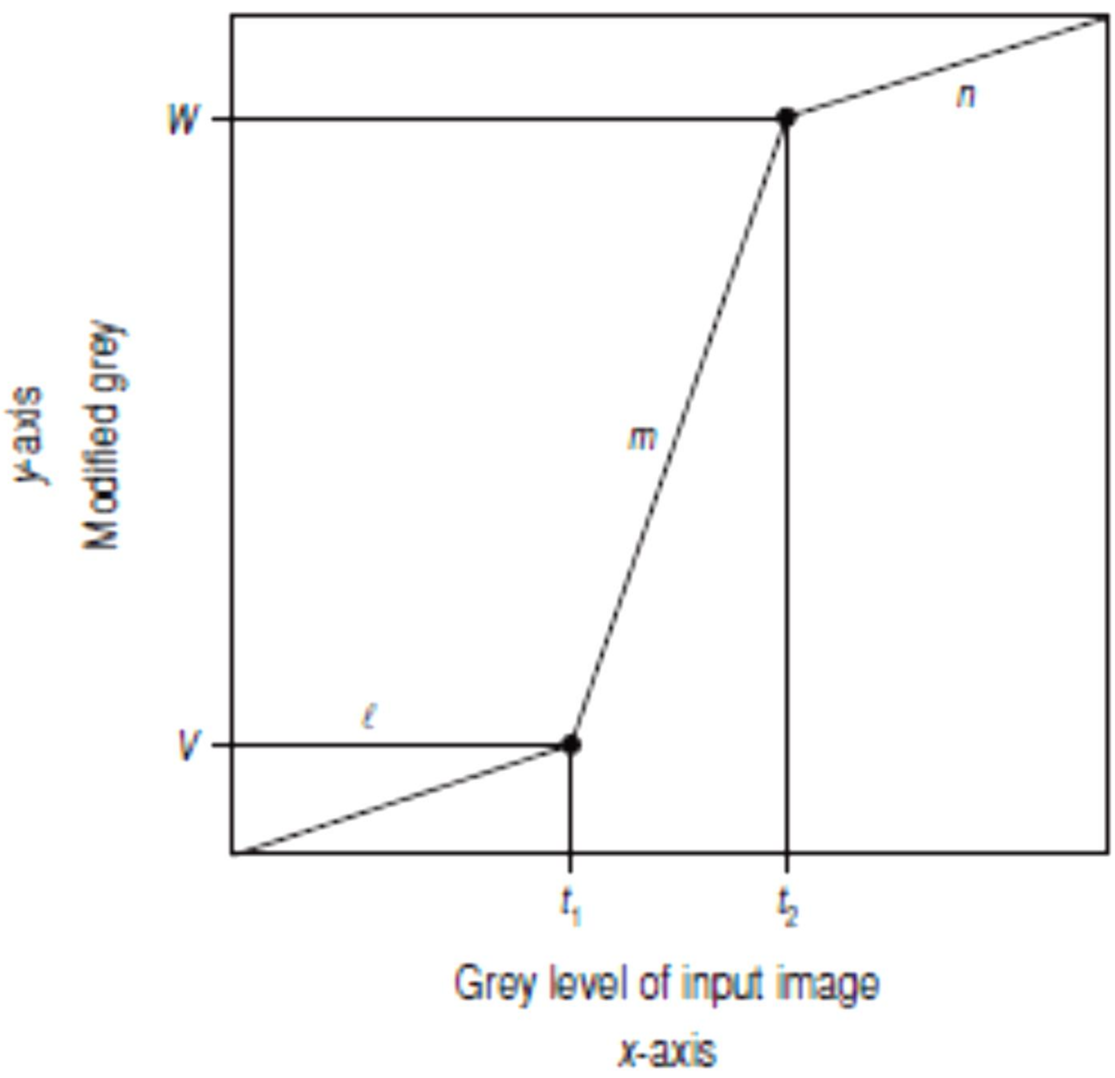


Fig. 5.8 Contrast stretching function

- **l,m,n, are the slope of the function.**

- **Contrast stretching can be achieved by controlling the slope and other parameters such as threshold.**

- **When the slope is < 1 = dynamic range reduces resulting in relatively dark image**

- **When the slope is > 1 = dynamic range increases resulting in relatively bright image**

Contrast Stretching

$$s(x,y) = \{\ell \times r\}$$

$$m \times (r - t_1) + v$$

$$n \times (r - t_2) + w$$

What would be the DR of the following image if the slope of the image are given as l=0.2, m=0.5, and n=0.1

Assuming the grey levels (r) of the i/p image range from 0 – 7.

And t1=2 and t2=5

Applying the piecewise function for contrast stretching

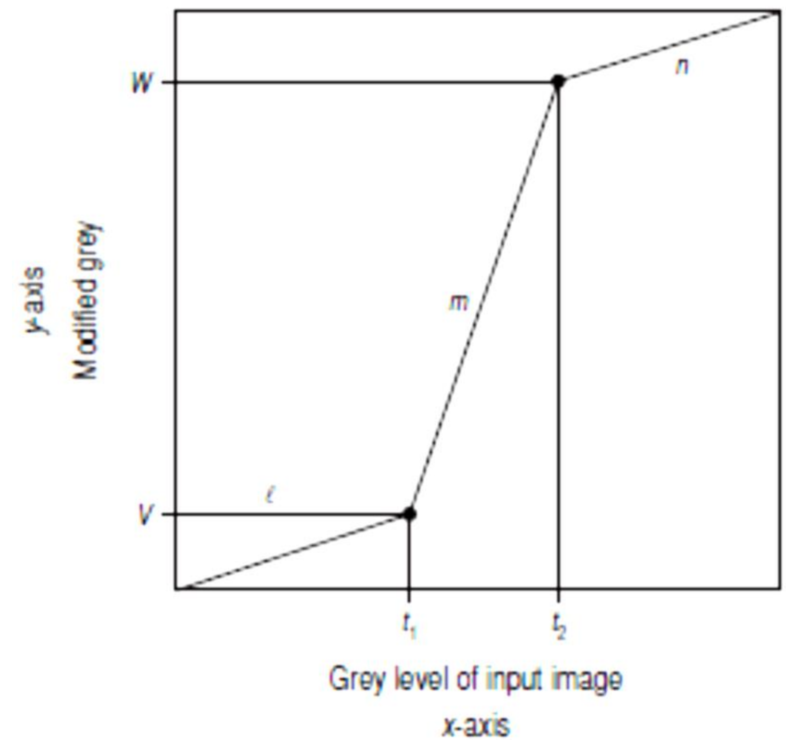


Fig. 5.8 Contrast stretching function

Contrast Stretching

s=l*r, 0<=r<=t1
s=m x (r – t1) + v, t1<r<=t2
S= n x (r – t2) + w, t2<r

What would be the DR of the following image if the slope of the image are given as l=0.2, m=0.5, and n=0.1

Assuming the grey levels (r) of the i/p image range from 0 – 7.

And t1=2 and t2=5

Applying the piecewise function for contrast stretching

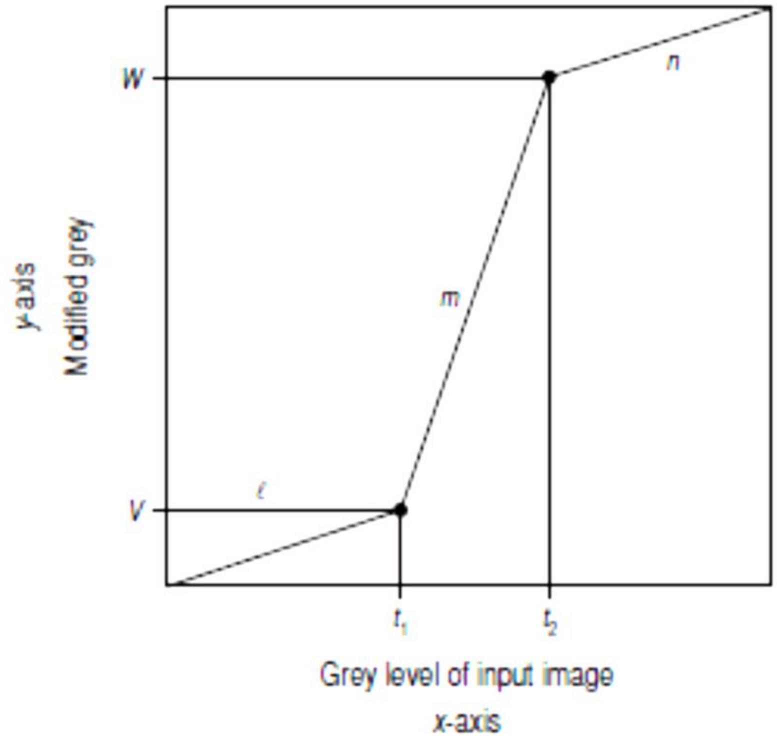


Fig. 5.8 Contrast stretching function

Contrast Stretching

For slope l=0.2 and t1=2 and t2=5. The output for grey value r =0,1,2 is given by: **(r x l)**

$r_0 = 0.2 \text{ X } 0 = 0$

$r_1 = 0.2 \text{ X } 1 = 0.2$

$r_2 = 0.2 \text{ X } 2 = 0.4$

For slope m=0.5. the value v is obtained from last output value of r_2. **$m \times (r - t_1) + v$**

$r_3 = (3\text{-}2) \text{ X } 0.5 + 0.4 = 0.9$

$r_4 = (4\text{-}2) \text{ X } 0.5 + 0.4 = 1.4$

$r_5 = (5\text{-}2) \text{ X } 0.5 + 0.4 = 1.9$

Contrast Stretching

For slope n=0.1. the value W is obtained from last output value of r_5. **$n \times (r - t_2) + w$**

$r_6 = (6\text{-}5) \text{ X } 0.1 + 1.9 = 2$

$r_7 = (7\text{-}5) \text{ X } 0.1 + 1.9 = 2.1$

Hence, the contrast range 0 – 7 has been stretched to an output range of 0 – 2.1.

If slope is < 1 = Image would become darker due to reduction in DR.

Contrast Stretching

$$s(x, y) = \{\ell \times r\}$$

$$m \times (r - t_1) + v$$

$$n \times (r - t_2) + w$$

What would be the DR of the following image if the slope of the image are given as l=1.2, m=1.5, and n=1.1

Assuming the grey levels (r) of the i/p image range from 0 – 7.

And t1=2 and t2=5

Applying the piecewise function for contrast stretching

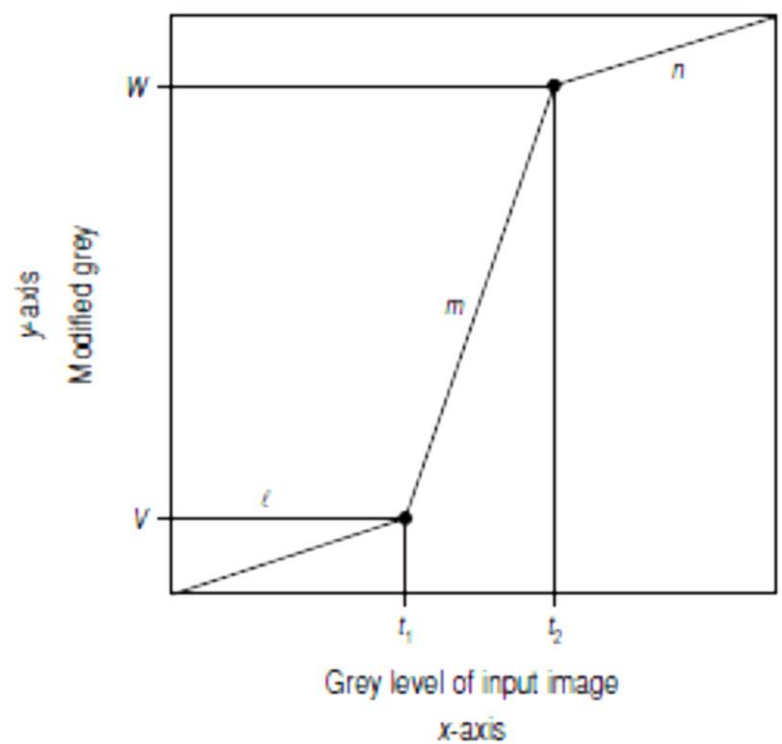
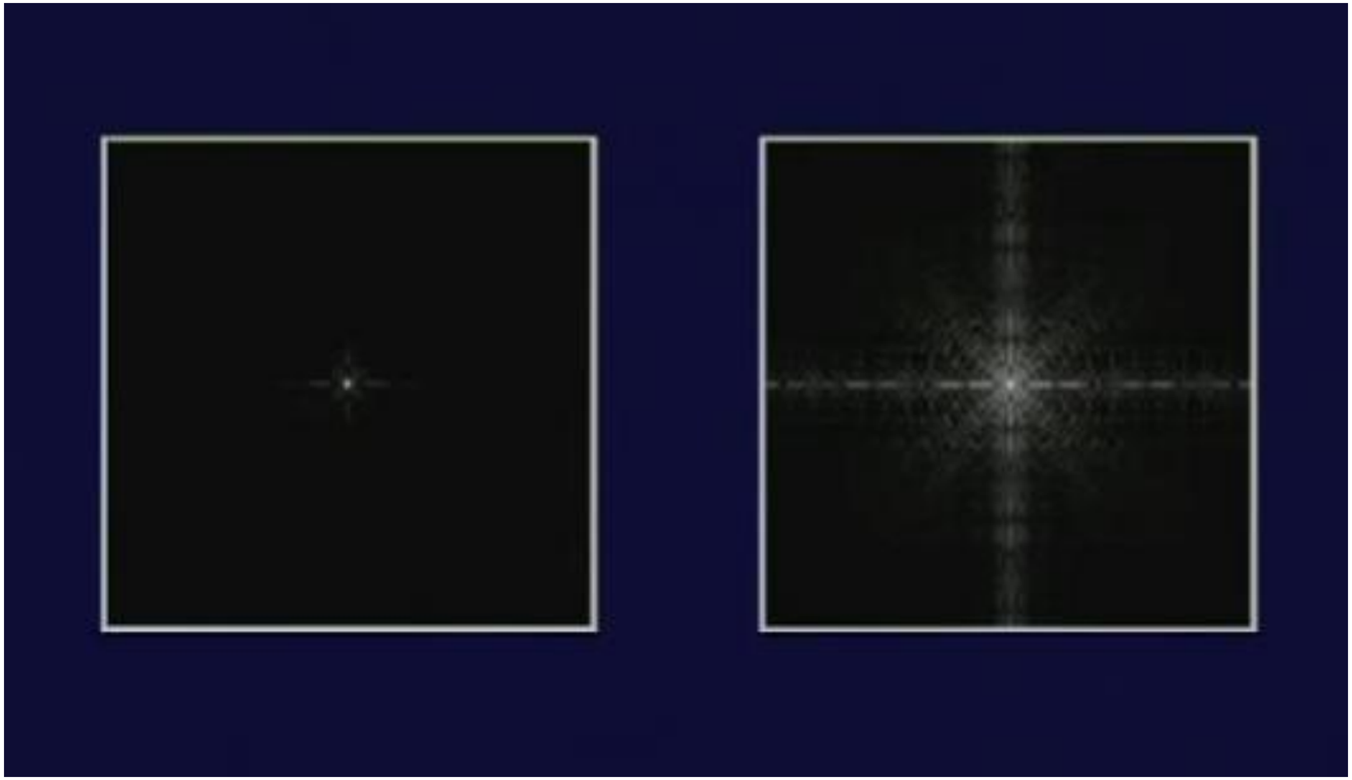
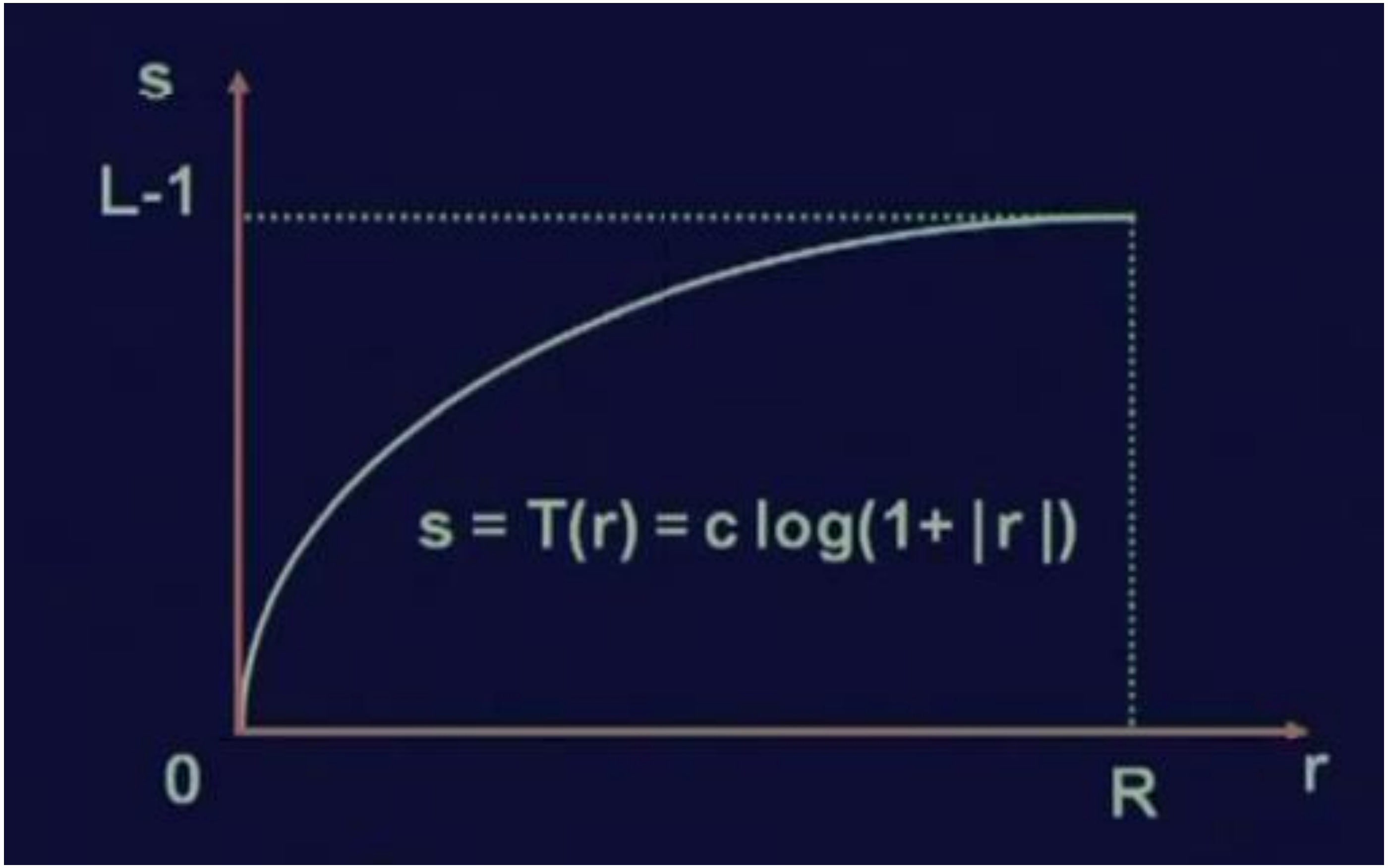


Fig. 5.8 Contrast stretching function

Dynamic range compression



Dynamic range compression



Range Normalization

- It’s a special form of contrast stretching.
- Assuming a grey scale image ranging from a to b.
- To attain a Normalized range, the contrast range from c to d. The following steps are accomplished.

Range Normalization

1. Subtract a from each grey level so that the range now becomes $0-(b-a)$.

2. Multiply the result by $\frac{(d-c)}{(b-a)}$. Now the range becomes $0-(d-c)$

3. Add c to the result. This results in the range $c-d$.

This transformation can now be described as

$$g(x,y)=\left(\frac{(d-c)}{(b-a)}\right)\times(f(x,y)-a)+c$$

Thus the input image of range (a to b) can be transformed to an output image of range (c to d) using this transformation.

Problem

A grey level image is given, whose range is 10-60. It is necessary to transform this image to another image B, whose range should be 120-180. what should be the gray level transform function?

Solution:

Here a=10, b=60, c=120, & d=180

$g(x,y) = [180-120/(60-10)] * (f(x,y)-10) + 120$

$= 1.2 \times (f(x,y) - 10) + 120$

If

10	**15**
20	**50**

then the transformed image is

?	**?**
?	**?**

Problem

A grey level image is given, whose range is 10-60. It is necessary to transform this image to another image B, whose range should be 120-180. what should be the gray level transform function?

Solution:

Here a=10, b=60, c=120, & d=180

$g(x,y) = [180-120/(60-10)] * (f(x,y)-10) + 120$

$= 1.2 \times (f(x,y) - 10) + 120$

If

10	**15**
20	**50**

then the transformed image is

120	**126**
132	**168**

Problem

A grey level image is given, whose range is 20-40. It is necessary to transform this image to another image B, whose range should be 140-180. what should be the gray level transform function?

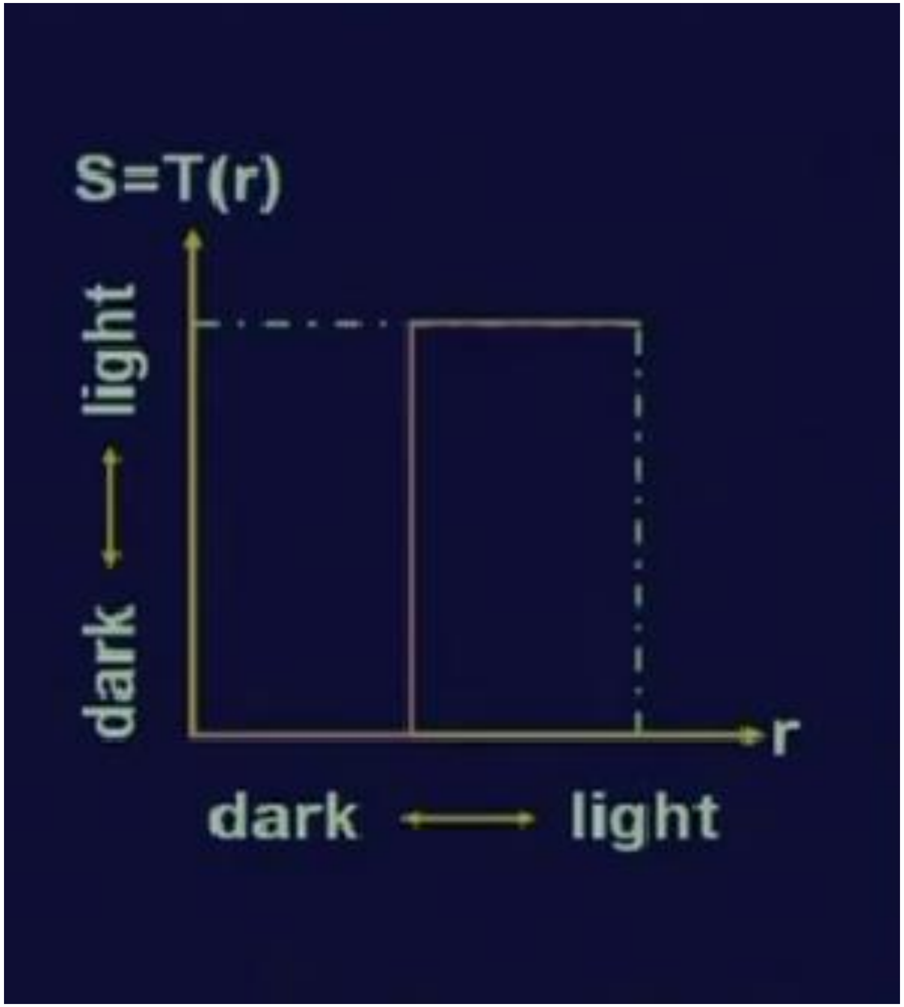
20	25	30
40	50	30
25	35	45

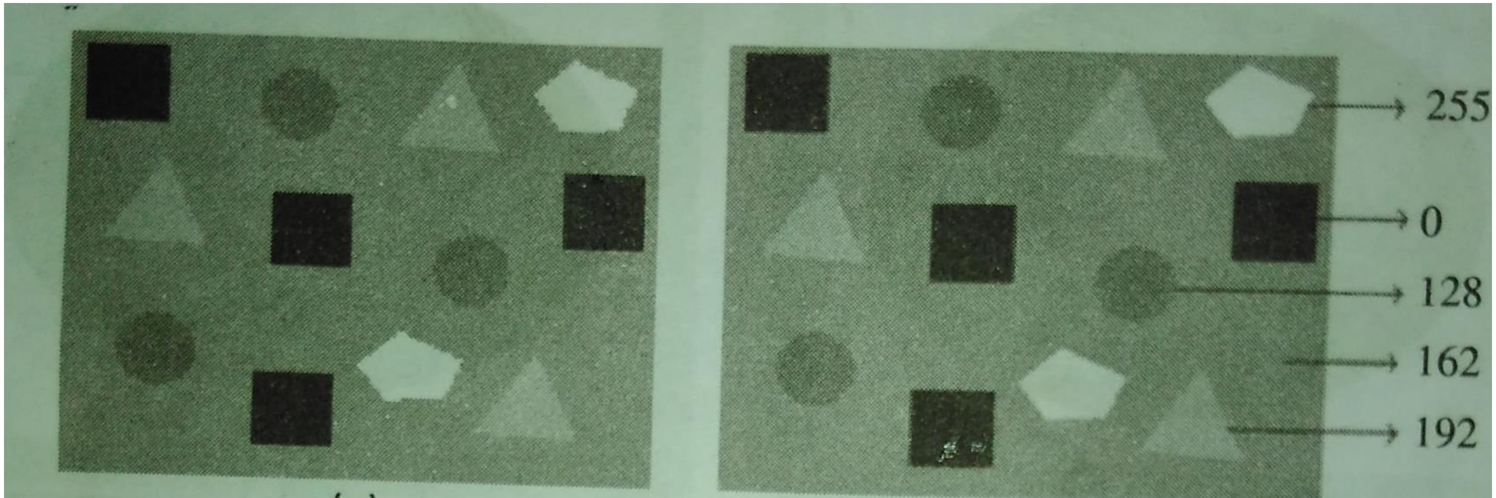
Thresholding

Binarizing (Thresholding) In thresholding, the transformation takes every pixel of the image and compares it with the threshold operation to produce the corresponding pixel in the resultant image. The transformation can be written as

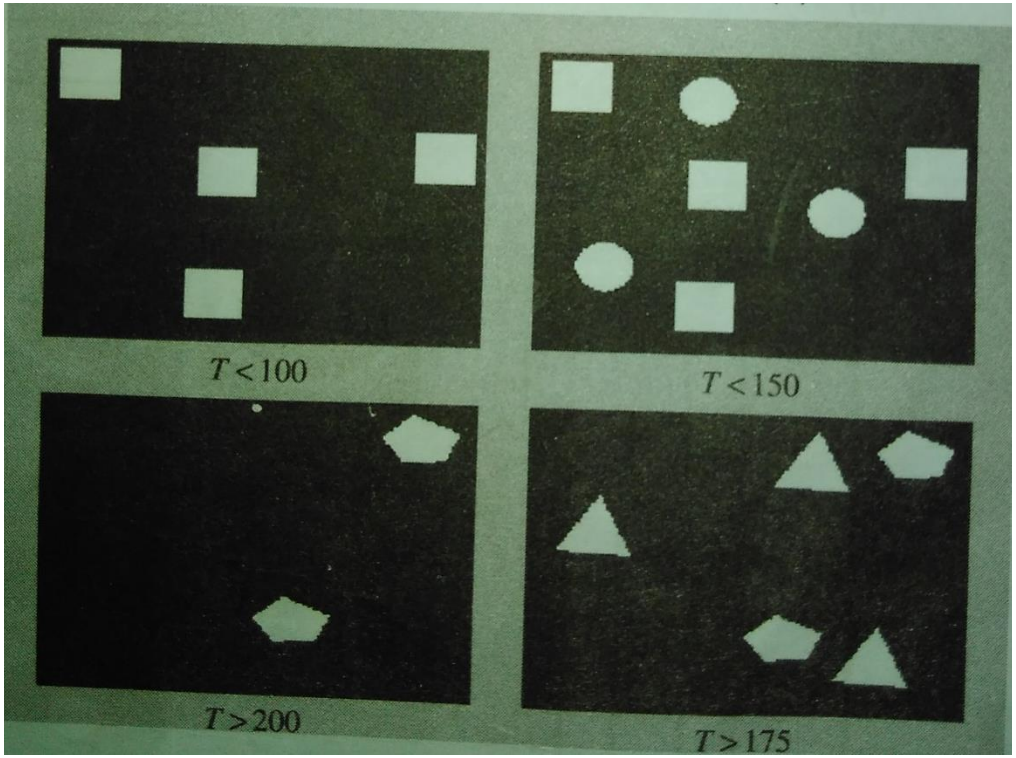
$$g(x, y) = \begin{cases} 0 & \text{for } f(x, y) \leq T \\ L-1 & \text{otherwise} \end{cases}$$

Thresholding





(a) (b)



$T < 100$ $T < 150$

$T > 200$ $T > 175$

Intensity Slicing

- Some times it is necessary to highlight a specific range of intensity levels in an image called the **ROI**.
- For example:
  - If the ROI appears bright in a dark background, the brightness of the ROI can be further increased.
  - And the darkness of the background can be further decreased, thus increasing the contrast.

Gray Level Slicing

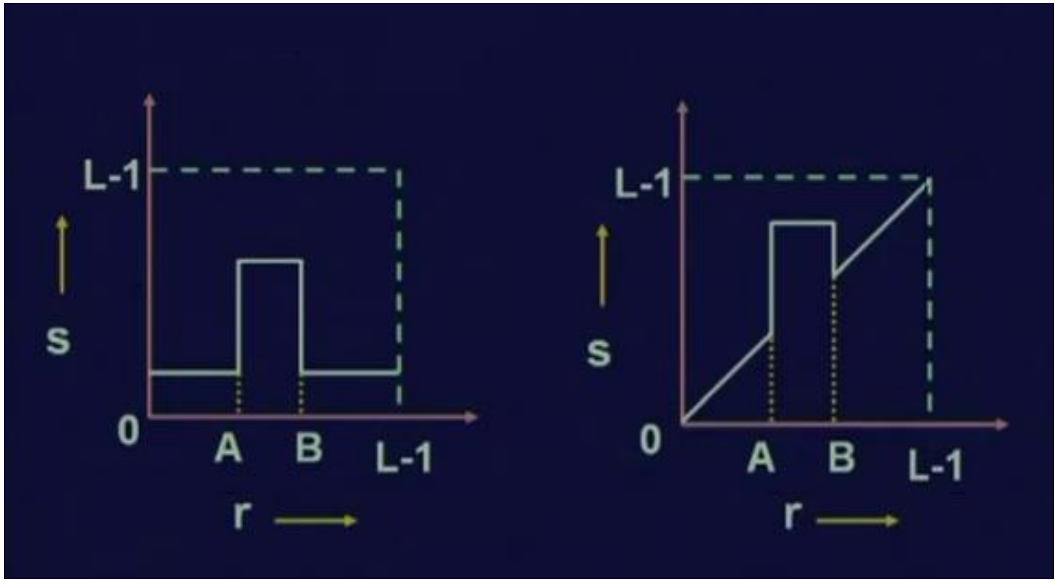
1. Without background

   The transformation is given as follows:

$$S = L - 1 \text{ when } t_1 \le r \le t_2$$
$$= 0 \text{ otherwise}$$

2. With background

$$S = L - 1 \text{ when } t_1 \le r \le t_2$$
$$= r \text{ otherwise}$$



Intensity Slicing

Example 5.5 Perform grey level slicing on the following image:

3	4	5
6	6	7
1	2	2

Solution

Grey level slicing is done as follows:

1. Without background

   The transformation is given as follows:

$$S = L - 1 \text{ when } t_1 \le r \le t_2$$
$$= 0 \text{ otherwise}$$

This results in the following image for $t_1 = 3$ and $t_2 = 6$:

7	7	7
7	7	0
0	0	0

It can be observed that the pixels in the range 3–6 are transformed to the level $L - 1$, i.e., $8 - 1 = 7$, while all other pixels become 0.

2. With background

$S = L - 1$ when $t_1 \le r \le t_2$

$= r$ otherwise

This results in the following image for $t_1 = 3$ and $t_2 = 6$:

7	7	7
7	7	7
1	2	2

It can be observed that the pixels in the range 3–6 are transformed to the level $L - 1$, i.e., $8 - 1 = 7$, while all other pixels retain their original value.

Intensity Slicing

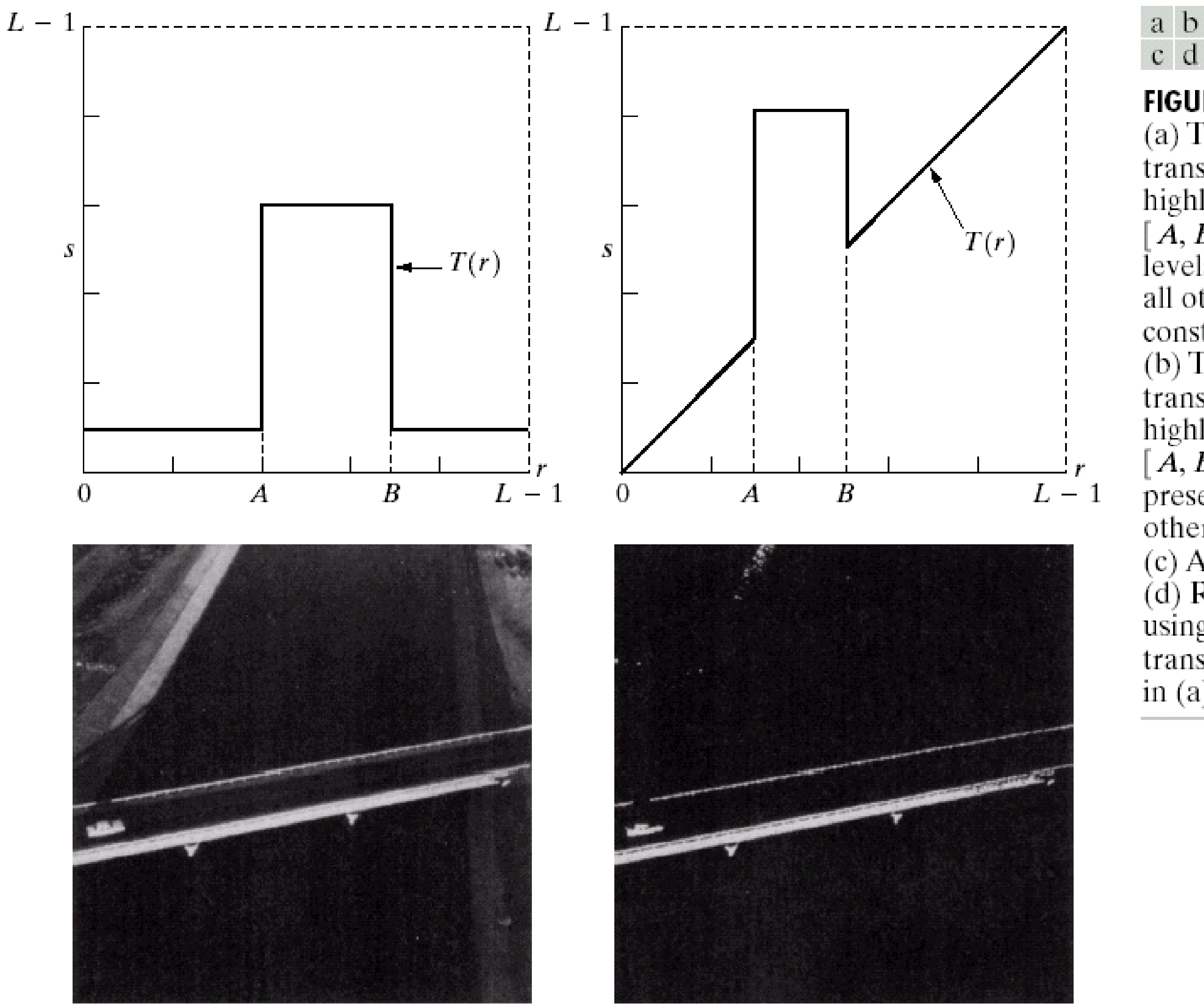
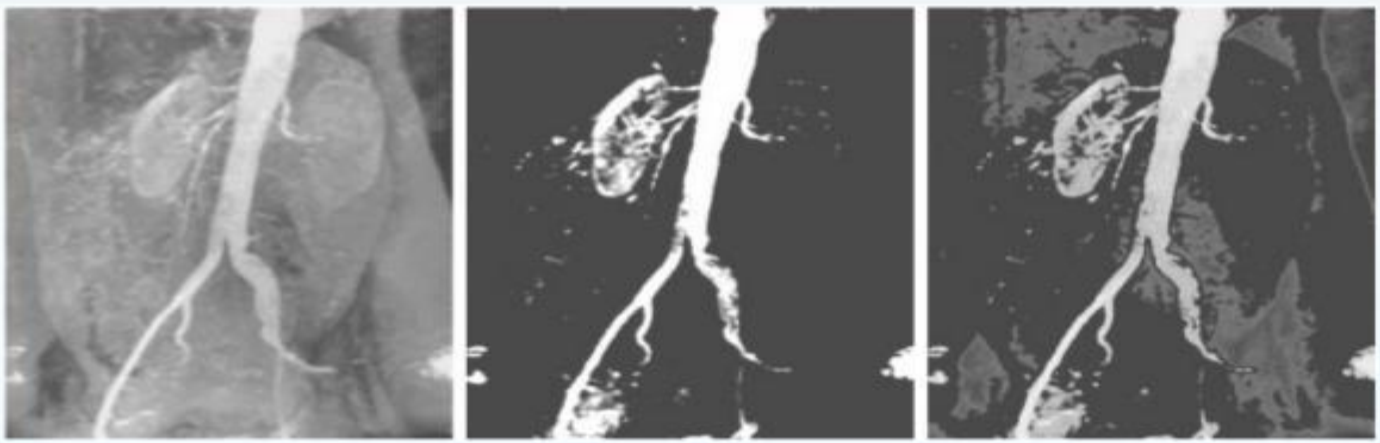


FIGURE 3.11 (a) This transformation highlights range [A, B] of gray levels and reduces all others to a constant level. (b) This transformation highlights range [A, B] but preserves all other levels. (c) An image. (d) Result of using the transformation in (a).


Gray-level Sliced Image
Original Image

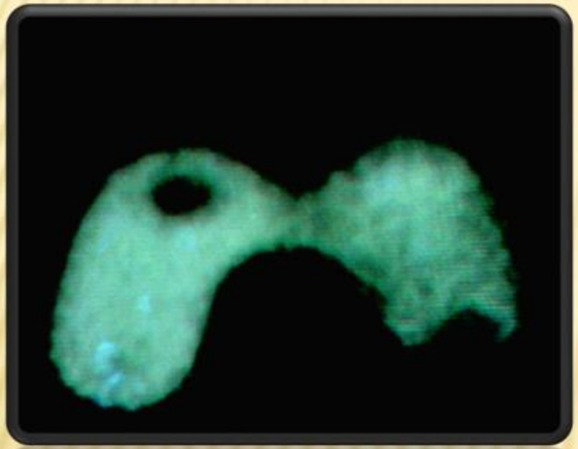
Gray-level slicing Example



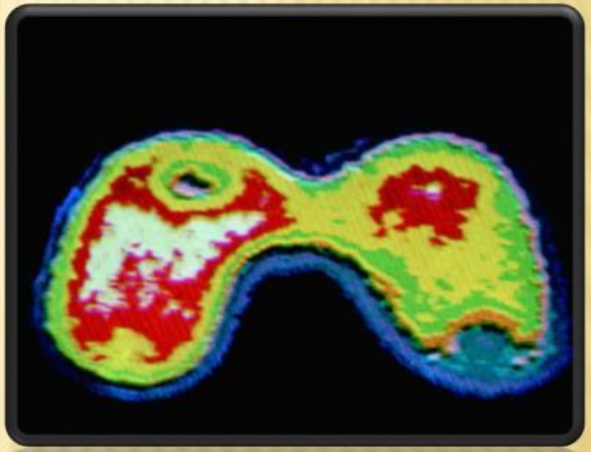
MULTI LEVEL INTENSITY SLICING EXAMPLE

$$g(x, y) = C_k \qquad \text{for } l_{k-1} < f(x, y) \le l_k$$

C_k = Color No. k
l_k = Threshold level k



An X-ray image of the Picker Thyroid Phantom.



After density slicing into 8 colors

Bit-Plane Slicing

- To highlight the contribution made to the total image appearance by specific bits.
  - i.e. Assuming that each pixel is represented by 8 bits, the image is composed of 8 1-bit planes.
  - Plane 0 contains the least significant bit and plane 7 contains the most significant bit.

Bit-Plane Slicing

- More on bit planes:
  - Only the higher order bits (top four) contain visually significant data. The other bit planes contribute the more subtle details.
  - Plane 7 corresponds exactly with an image thresholded at gray level 128.

Bit-Plane Slicing

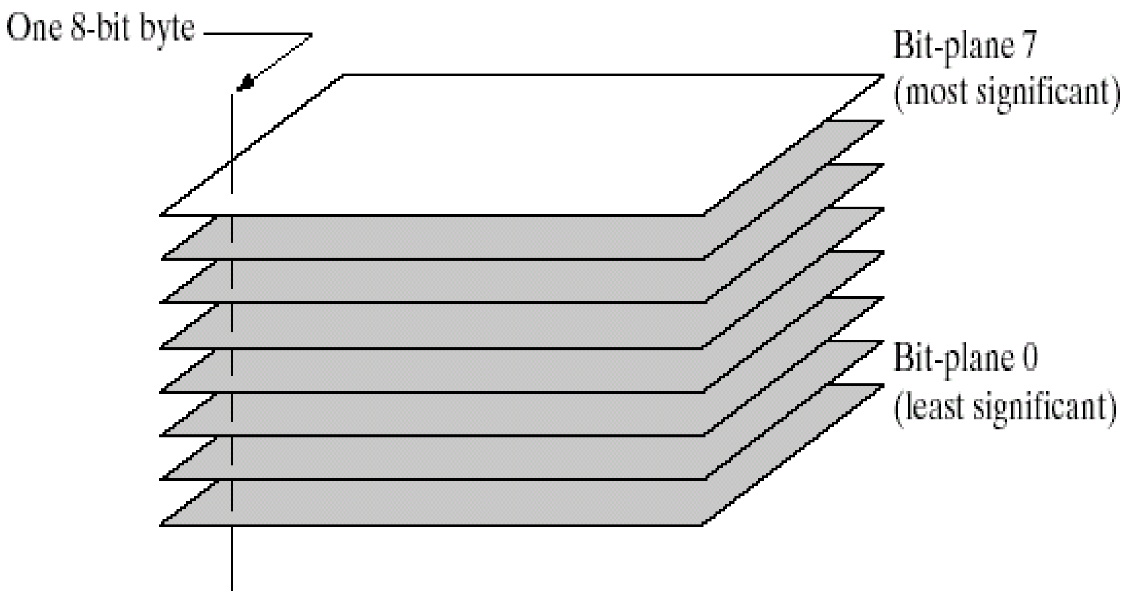


FIGURE 3.12
Bit-plane representation of an 8-bit image.

Bit plane Slicing

Example 5.6 Show the bit-plane slicing of the following image:

7	6	5
4	3	2
1	1	0

Solution

The binary equivalent of the pixels is

111	110	101
100	011	010
001	001	000

Suppose the LSB is changed to 0, this image is reduced to

110	110	100
100	010	010
000	000	000