Histogram Processing

Histogram Processing

The histogram of a digital image with gray levels from 0 to L-1 is a discrete function $h(r_k)=n_k$

where:

r_k is the k^{th} gray level

n_k is the no. of pixels in the image with that gray level

n is the total number of pixels in the image

and $k = 0, 1, 2, \ldots, L-1$

Normalized histogram: $P(r_k)=n_k/n$

sum of all components = 1

Image Enhancement in the Spatial Domain

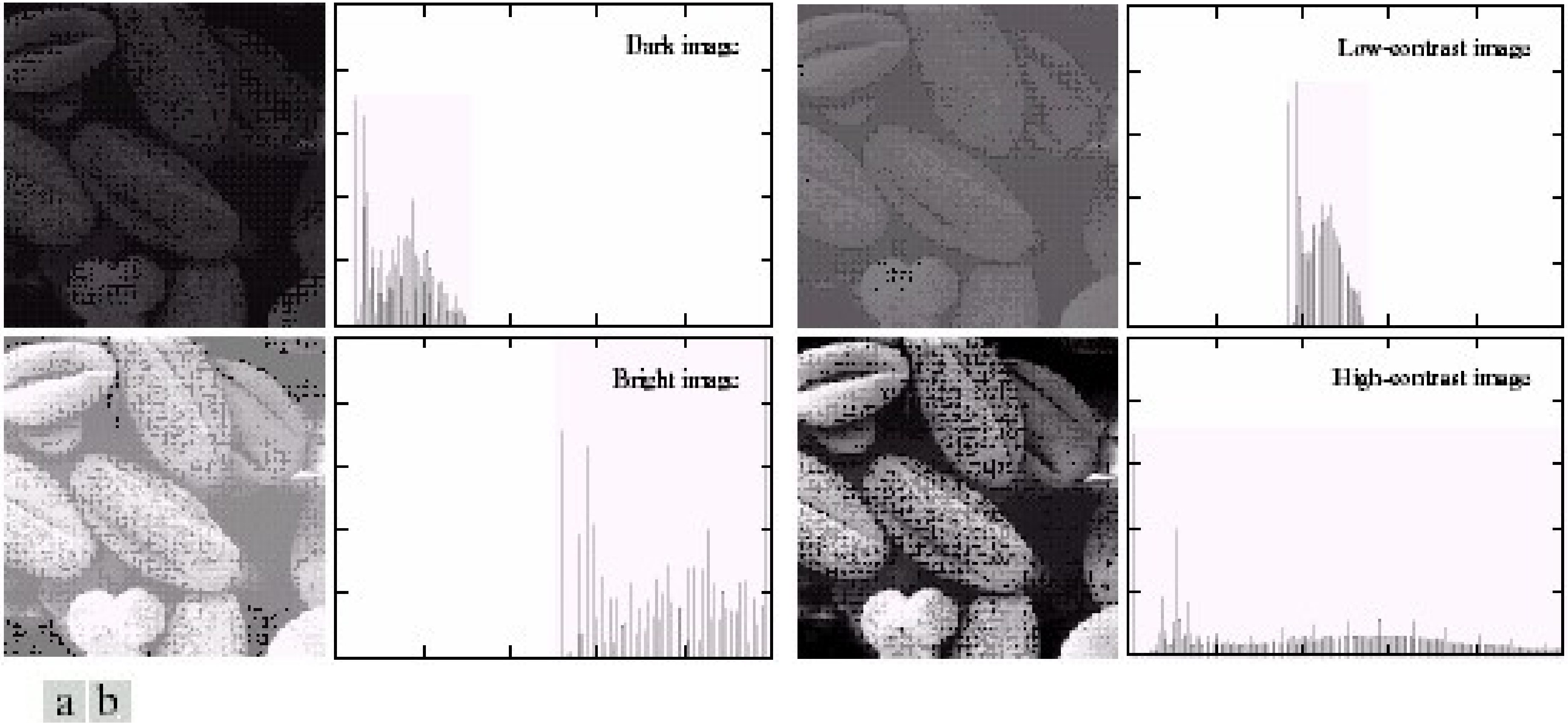
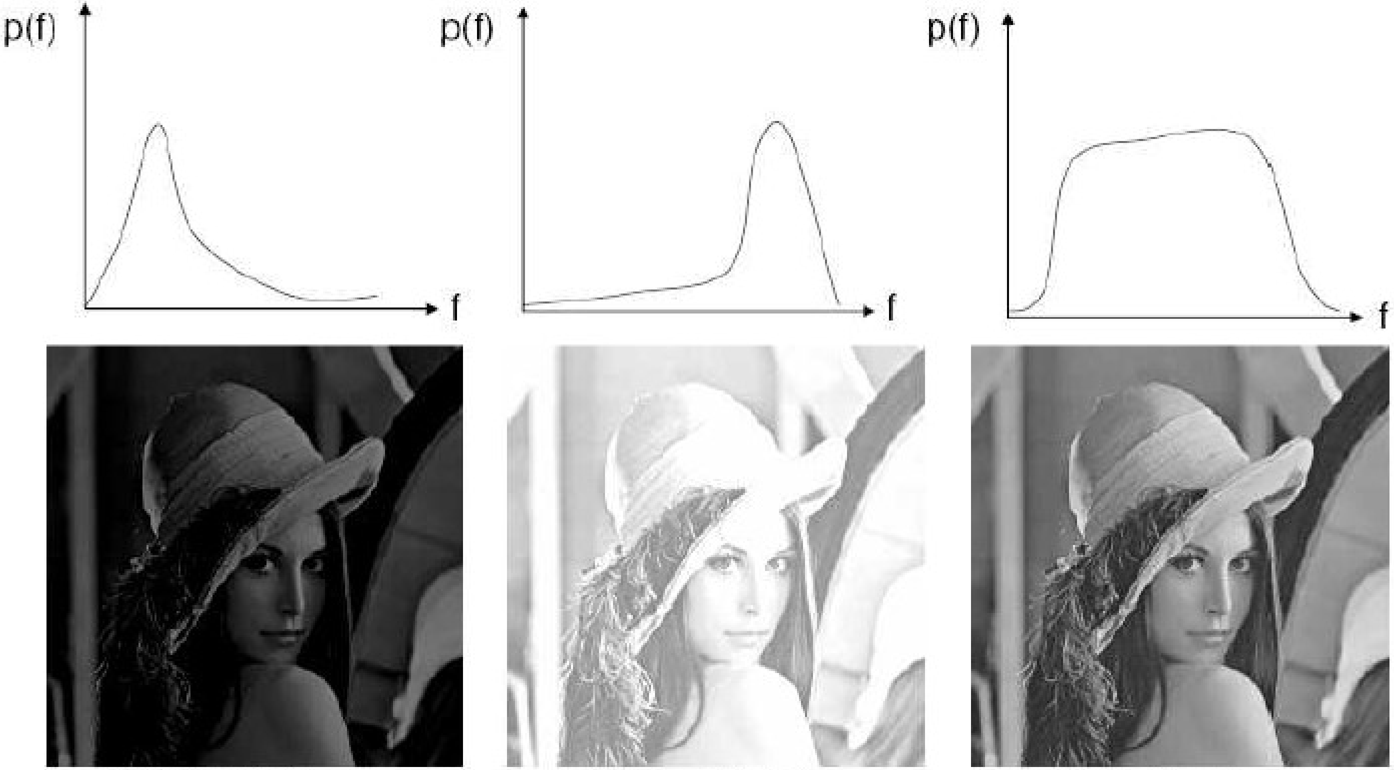


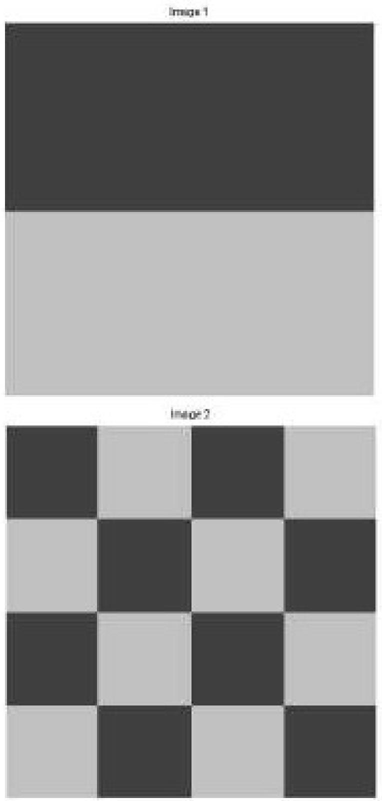
FIGURE 3.15 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

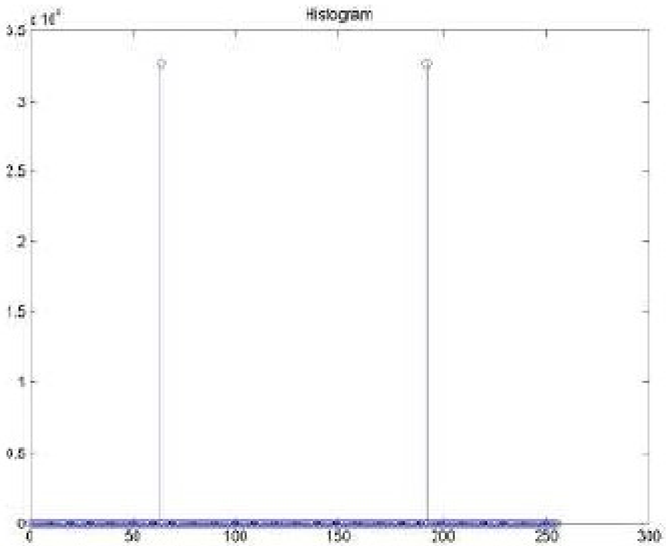
Histogram & Image Contrast



(a) Too dark (b) Too bright (c) Well balanced

Different Images with Same Histogram!



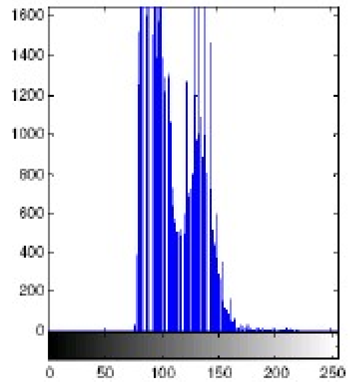


Histogram reflects the pixel intensity distribution, not the spatial distribution!

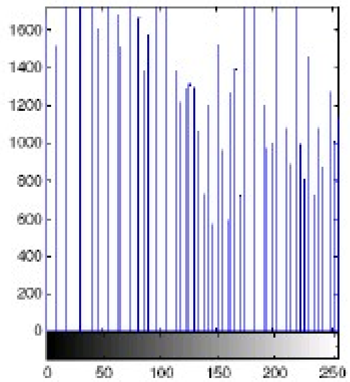
Correcting the Pouting Child

Original image with low contrast

Enhanced image



Original girl image with low contrast



Enhancement image with histogram equalization

Histogram Processing

- ✓ The shape of the histogram of an image does provide useful info about the possibility for contrast enhancement.
- ✓ It improves the visual quality of the image

There are Three methods for Contrast enhancement

(1) Histogram equalization
(2) Histogram matching (specification)
(3) Local enhancement

Histogram Equalization

Let the variable r represent the gray levels in the image to be enhanced

If r = 0 represents BLACK and

If r = 1 represents WHITE

For continuous function the pixel values lie in the interval [0,1]

For discrete function the pixel values to be in the interval [0,L-1]

For any r in the interval [0,1], the transformation is of the form

$$S = T(r)$$

Histogram Equalization

The transformation satisfies the conditions

(a) T(r) is single valued and monotonically increasing in the interval $0 \leq r \leq 1$ and

(b) $0 \leq T(r) \leq 1$ for $0 \leq r \leq 1$

Fig shows the transformation function

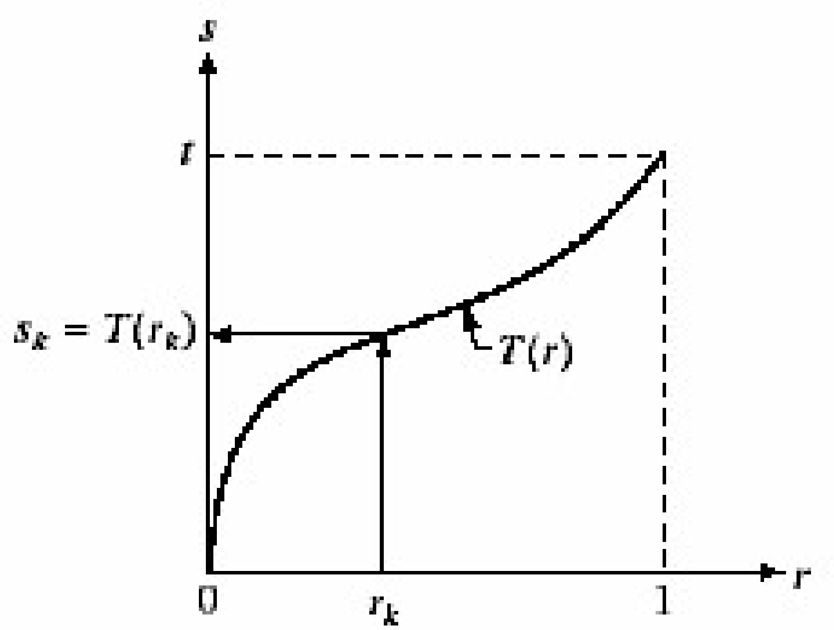


FIGURE 3.16 A gray-level transformation function that is both single valued and monotonically increasing.

Histogram Equalization

The Inverse transformation from s back to r is denoted as

$$r = T^{-1}(s) \qquad 0 \leq s \leq 1$$

For gray levels that take on discrete values, we deal with probabilities:

$$p_r(r_k) = n_k/n, \ k=0,1,.., L-1$$

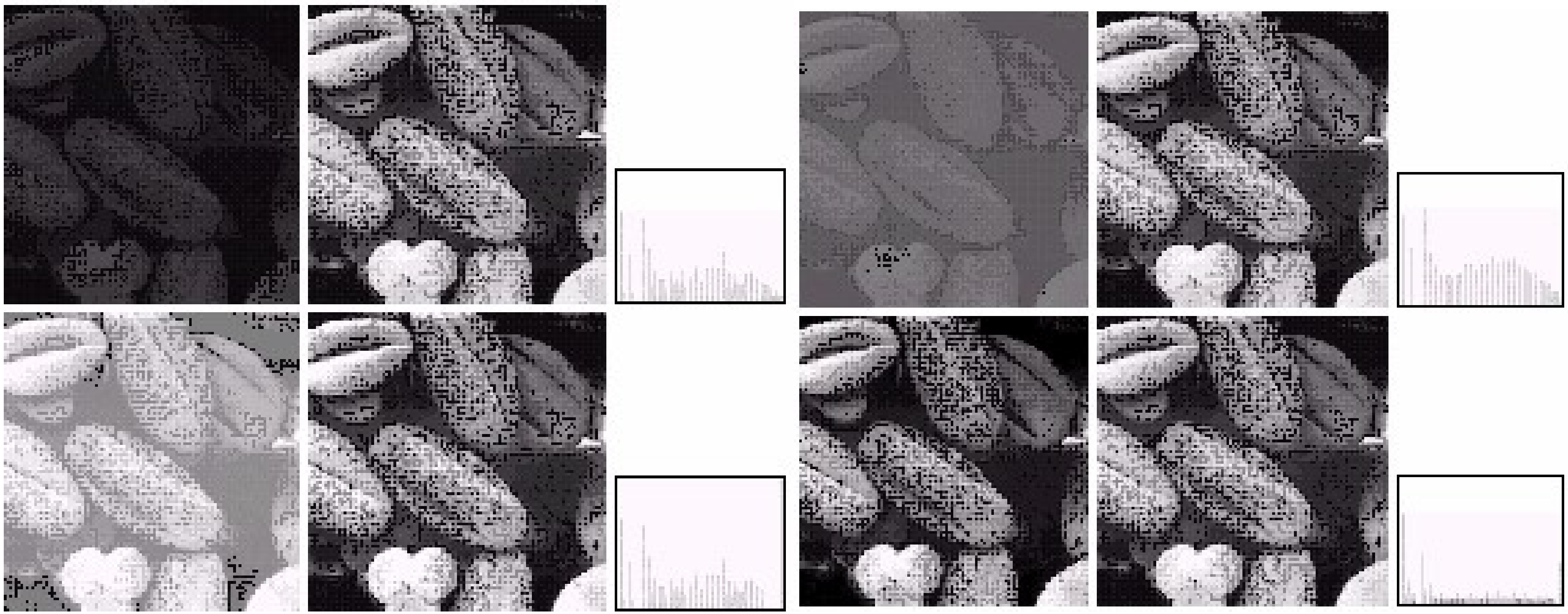
The plot of $p_r(r_k)$ versus r_k is called a histogram and the technique used for obtaining a uniform histogram is known as histogram equalization (or histogram linearization).

Histogram Equalization

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p_r(r_j)$$

- Histogram equalization(HE) results are similar to contrast stretching but offer the advantage of full automation, since HE automatically determines a transformation function to produce a new image with a uniform histogram.

Histogram Equalization



a b c

FIGURE 3.17 (a) Images from Fig. 3.15. (b) Results of histogram equalization. (c) Corresponding histograms.

Histogram Matching (or Specification)

- Histogram equalization does not allow interactive image enhancement and generates only one result i.e. an approximation to a uniform histogram.

- Sometimes though, we need to be able to specify particular histogram shapes capable of highlighting certain gray-level ranges.

Histogram Specification

- ➢ Equalization method capable of generating only one result i.e. an Approximation to a uniform histogram.

- ✓ Some times the ability to specify particular histogram shapes capable of highlighting certain gray-level ranges in an image is desirable.

Let $P_r(r)$ and $P_z(z)$ be the original and desired PDF of continuous image gray levels

First HE is used on the original image by the eq

$$0 \leq r \leq 1$$

$$S = T(r) = \int_0^r P_r(w)\,dw$$

Histogram Specification

If the desired image were available, its levels could also be equalised by using the transformation function

$$v = G(z) = \int_0^z P_z(w)\,dw$$

The inverse transformation function $z = G^{-1}(v)$

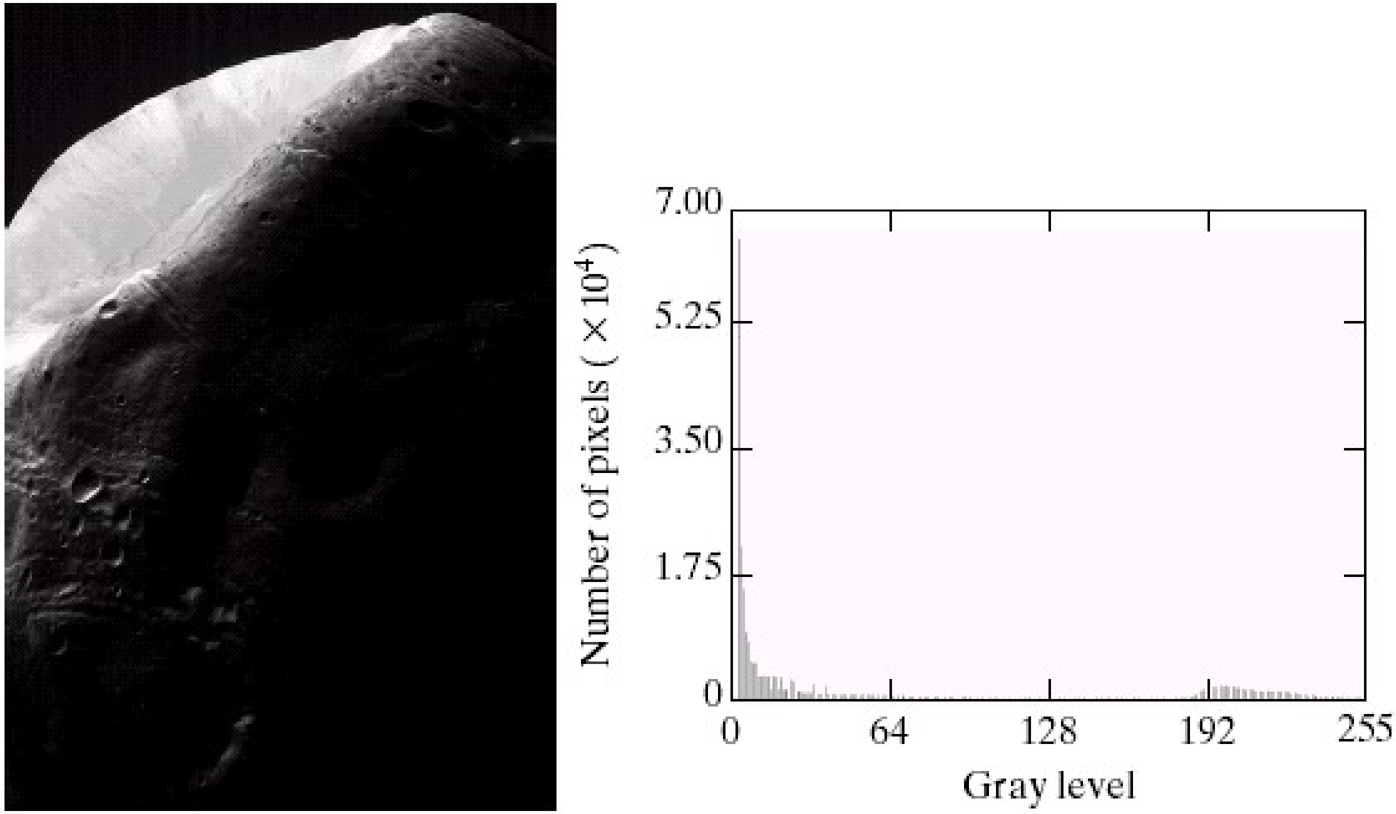
- The new, processed version of the original image consists of gray levels characterized by the specified density $p_z(w)$.

p_z: specified desirable PDF for output

Histogram Specification

- The principal difficulty in applying the histogram specification method to image enhancement lies in being able to construct a meaningful histogram. So…
- Either a particular probability density function (such as a Gaussian density) is specified and then a histogram is formed by digitizing the given function,
- Or a histogram shape is specified on a graphic device and then is fed into the processor executing the histogram specification algorithm.

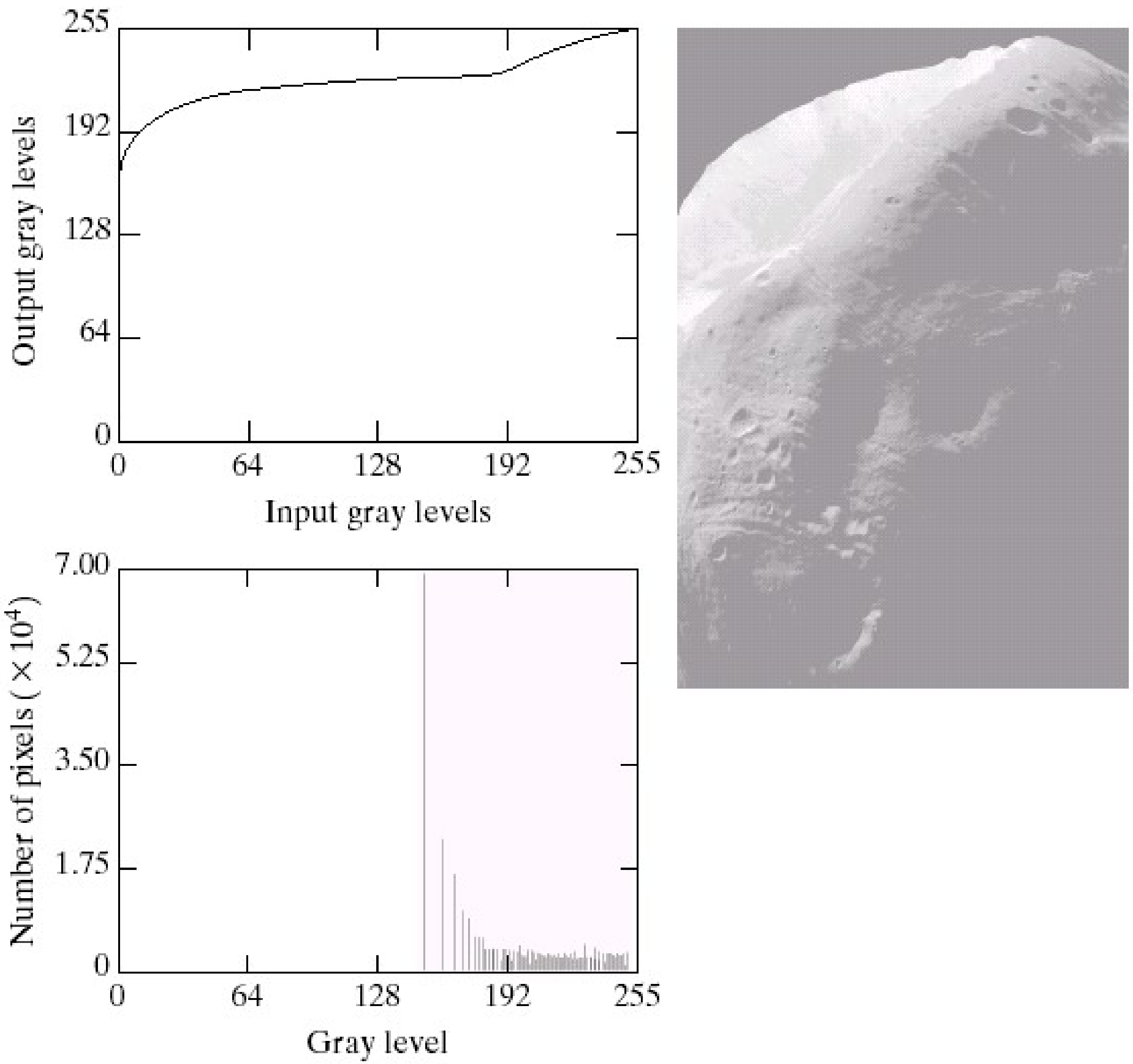
Image Enhancement in the Spatial Domain



a b

FIGURE 3.20 (a) Image of the Mars moon Photos taken by NASA's *Mars Global Surveyor*. (b) Histogram. (Original image courtesy of NASA.)

Image Enhancement in the Spatial Domain



a b
c

FIGURE 3.21
(a) Transformation function for histogram equalization.
(b) Histogram-equalized image (note the washed-out appearance).
(c) Histogram of (b).

a	c
b	
d	

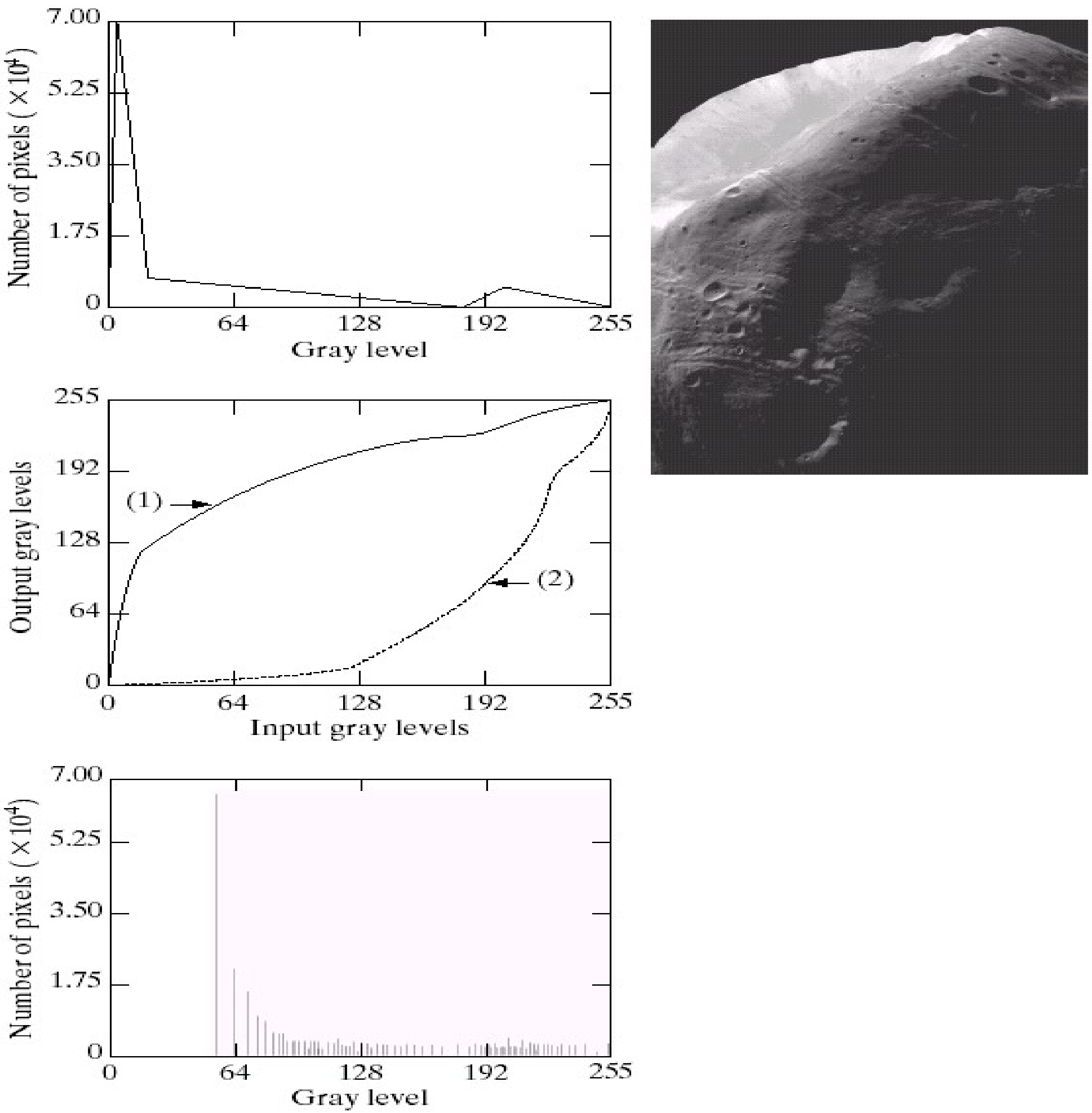


FIGURE 3.22
(a) Specified histogram.
(b) Curve (1) is from Eq. (3.3-14), using the histogram in (a); curve (2) was obtained using the iterative procedure in Eq. (3.3-17).
(c) Enhanced image using mappings from curve (2).
(d) Histogram of (c).

Local Enhancement

- The two methods Equalisation and specification are global
- i.e. pixels are modified by a transformation based on the gray level distribution over an entire image.
- This approach is useful in overall enhancement of image.
- But it is often necessary to enhance details over small areas.
- The two methods Equalization and specification are easily adoptable to local enhancement.

Local Enhancement

- The procedure is to define a square or rectangle neighborhood and move the center of this area from pixel to pixel
- At each location, the histogram of the points in the neighborhood is computed and either equalisation or specification function is obtained.
- This function is finally used to map the gray level of the pixel centered in the neighborhood.
- The center of the neighborhood region is then moved to an adjacent pixel location and the procedure is repeated.

Local Enhancement

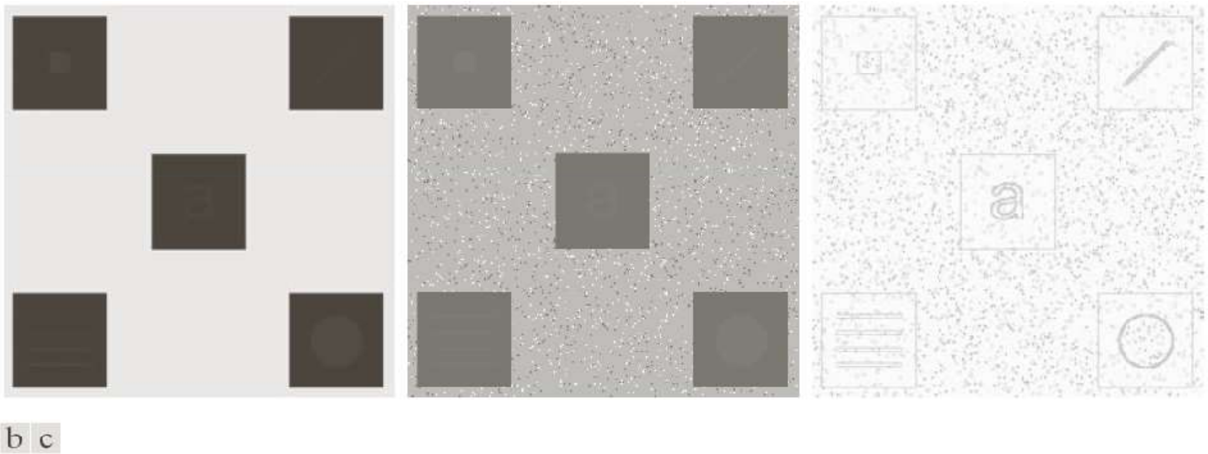
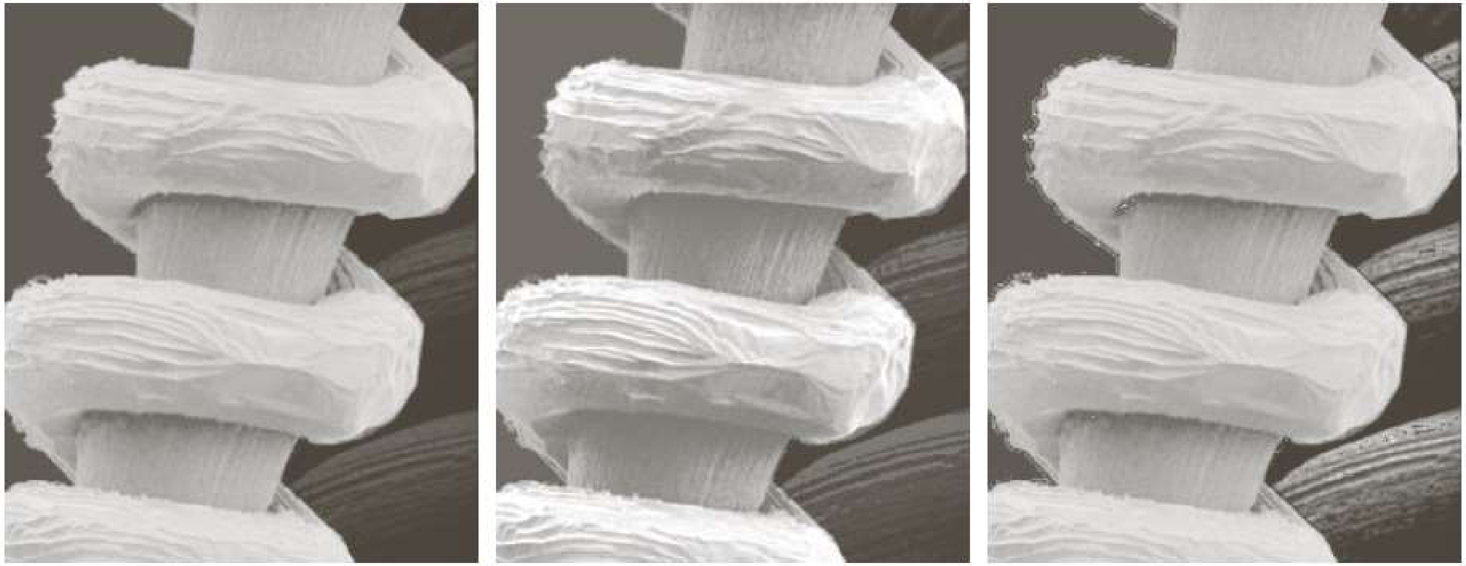


FIGURE 3.26 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization applied to (a), using a neighborhood of size 3 × 3.

Local Enhancement



a b c

FIGURE 3.27 (a) SEM image of a tungsten filament magnified approximately 130×. (b) Result of global histogram equalization. (c) Image enhanced using local histogram statistics. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)