SYDE 575: Introduction to Image Processing

Image Enhancement by Point Processing

Chapter 3

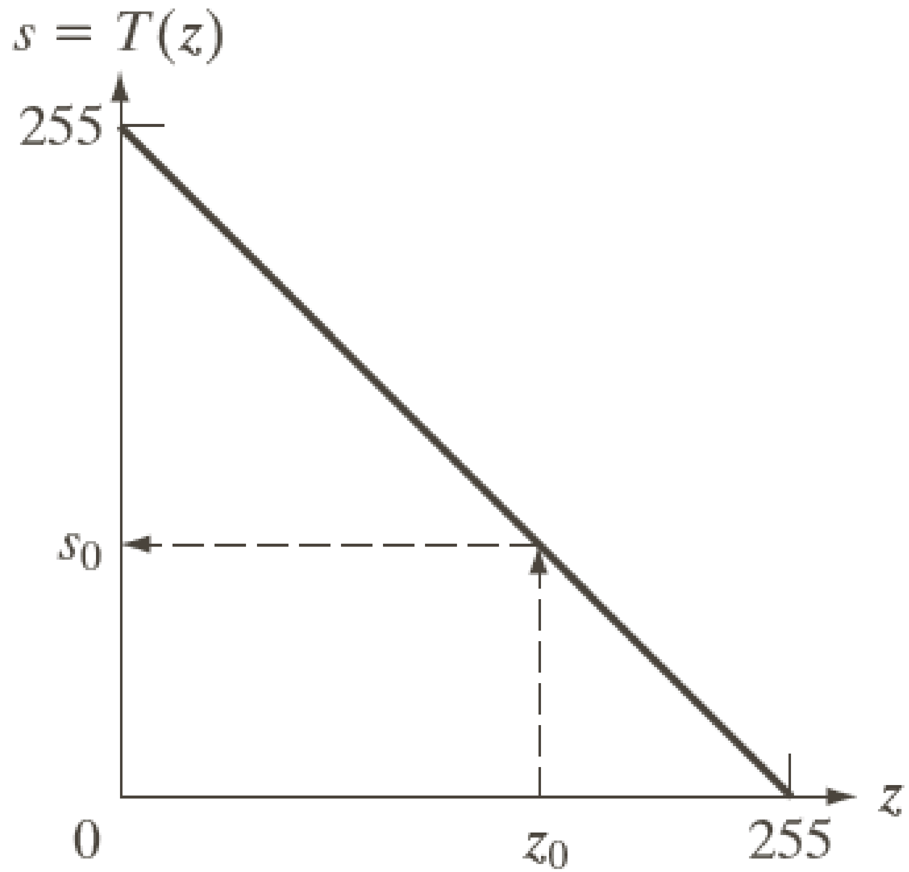
Point Processing

- Simplest of image enhancement techniques
- Processing based only on intensity of individual pixels

$$s = T(z)$$

output pixel — transform — input pixel

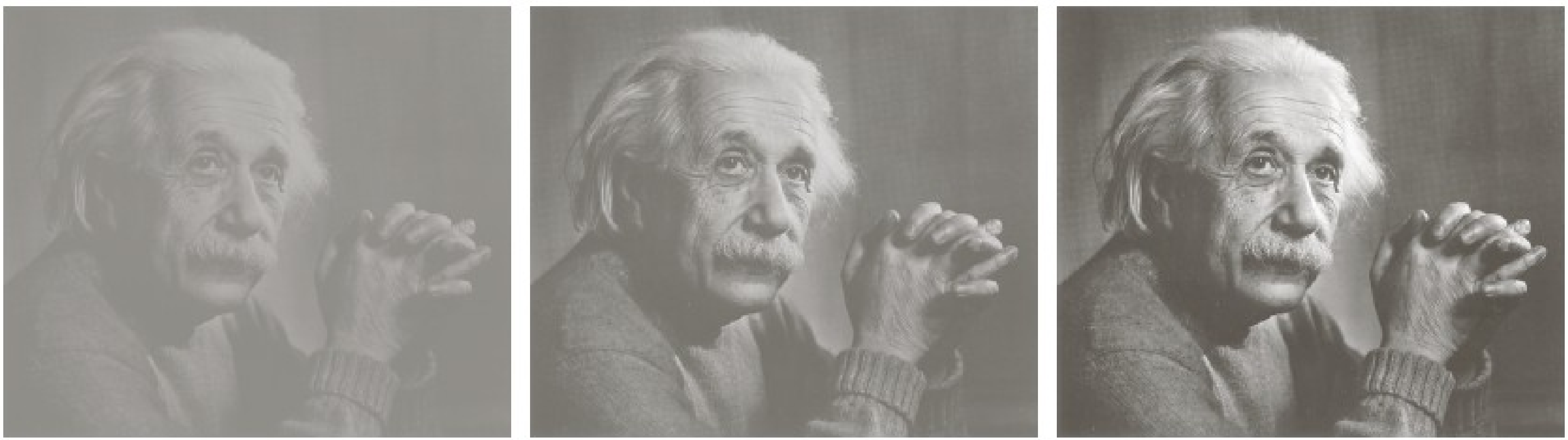
Intensity Transformation Function



Source: Gonzalez and Woods

Example: Negative

Levels of Contrast



a b c

FIGURE 2.41 Images exhibiting (a) low contrast, (b) medium contrast, and (c) high contrast.

Source: Gonzalez and Woods

Gamma Correction

- Various devices used for image acquisition and display respond based on power law
- Process used to correct power law response phenomena is called *gamma correction*

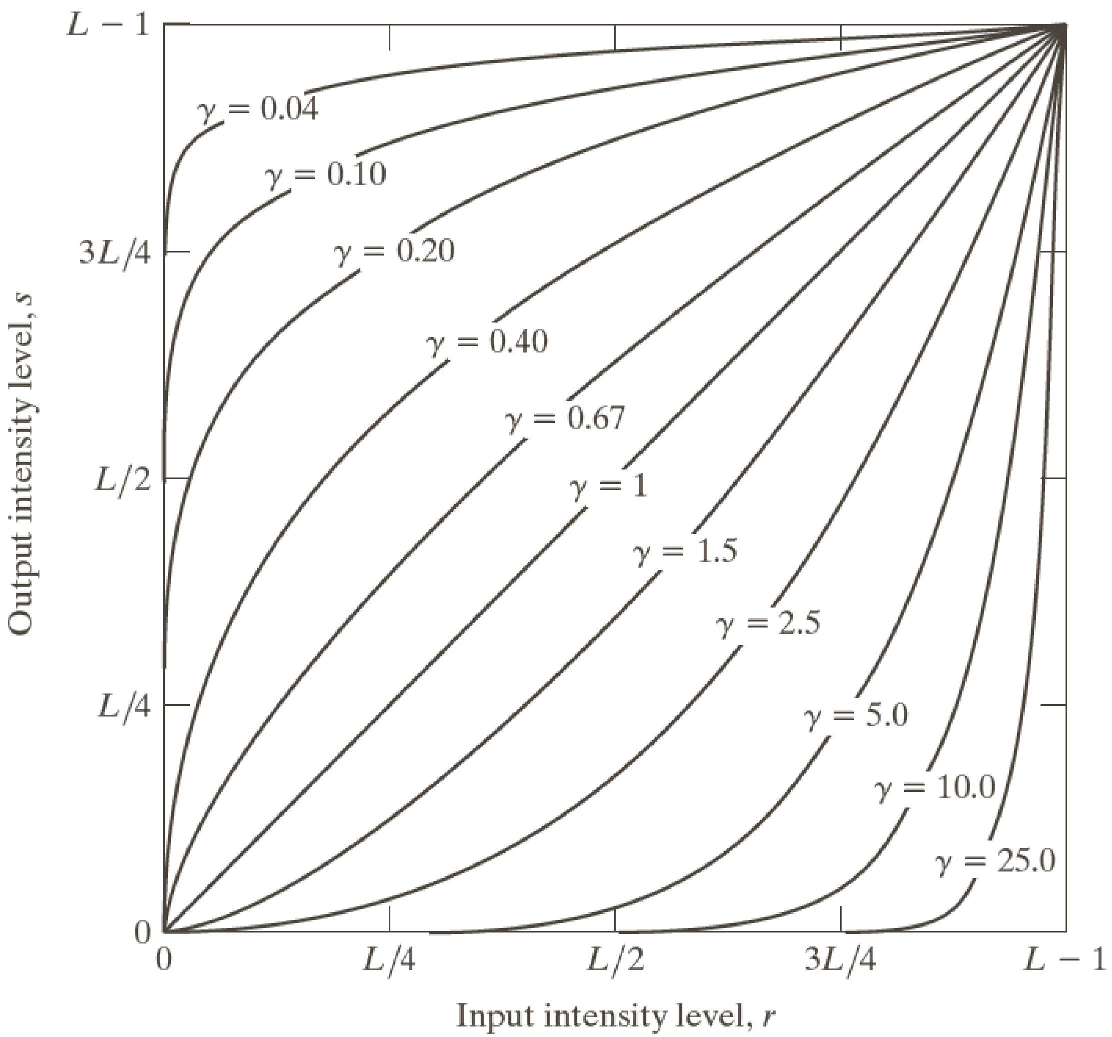
$$s = z^{\gamma}$$

γ ← gamma

s: output pixel

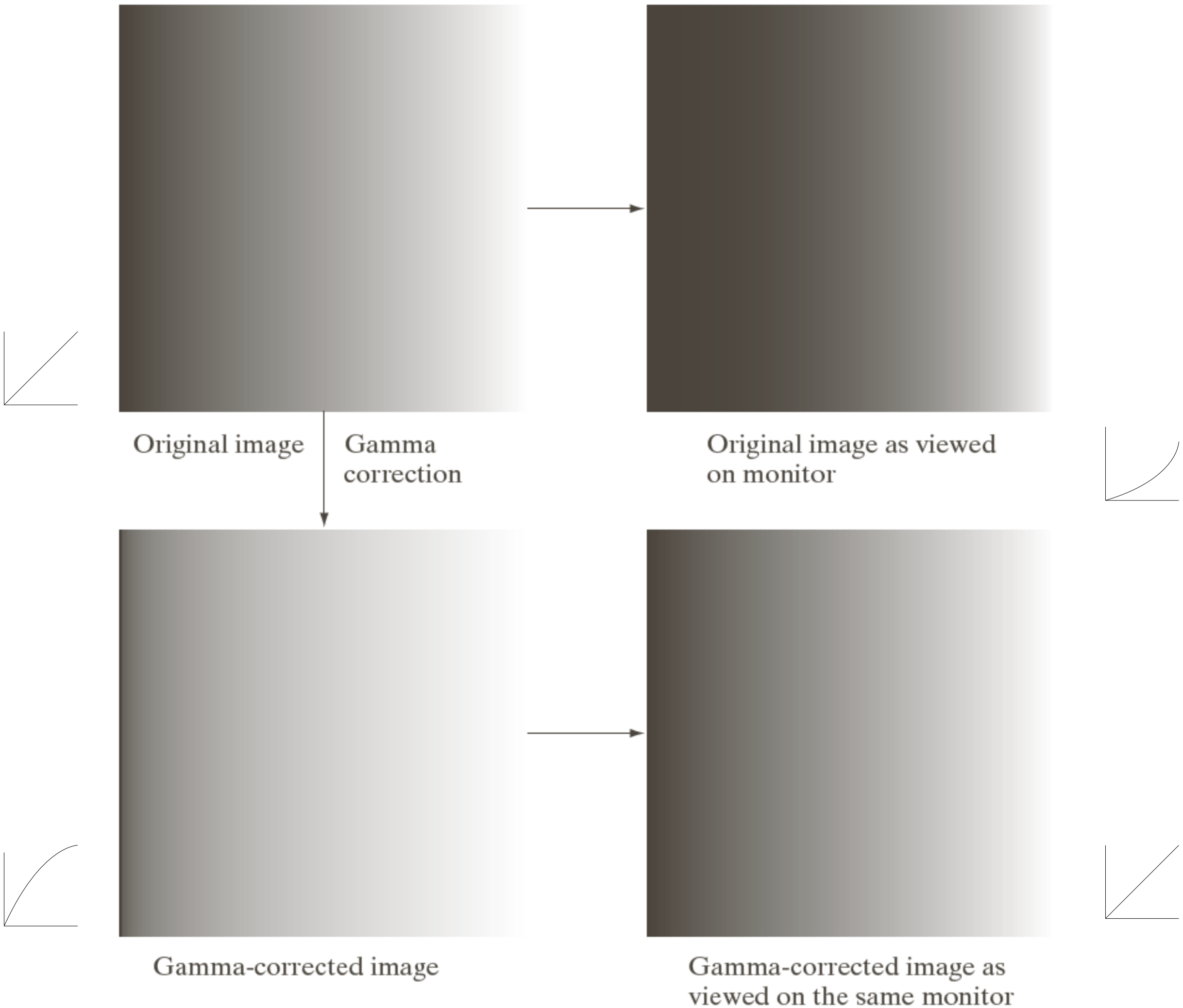
z: input pixel

Gamma Curves



Source: Gonzalez and Woods

Gamma Correction: Example



Source: Gonzalez and Woods

Power-law Transformation for Contrast Enhancement

- May also be used to adjust contrast of an image by either expanding or compression gray levels

$$\gamma < 1, \quad \text{gray-level expansion}$$

$$\gamma > 1, \quad \text{gray-level compression}$$

Gray-level expansion

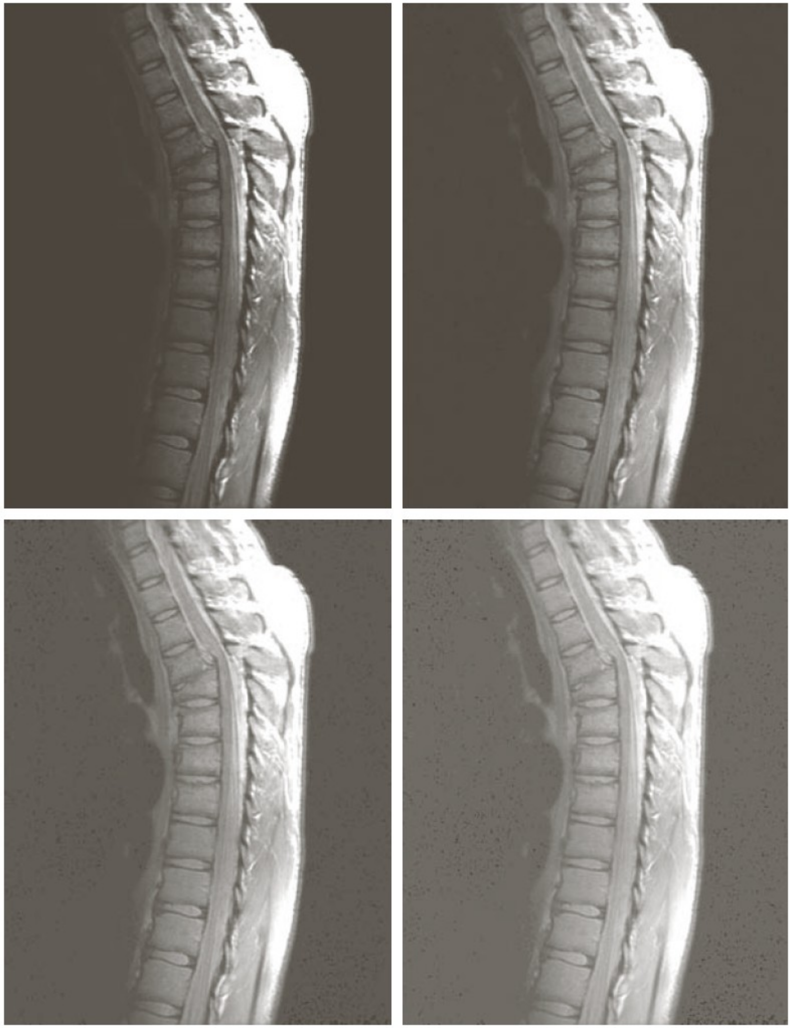


FIGURE 3.8 (a) Magnetic resonance image (MRI) of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4$, and 0.3, respectively. (Original image courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Source: Gonzalez and Woods

Gray-level Compression

a b
c d

FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0$, 4.0, and 5.0, respectively. (Original image for this example courtesy of NASA.)

Source: Gonzalez and Woods

Histograms

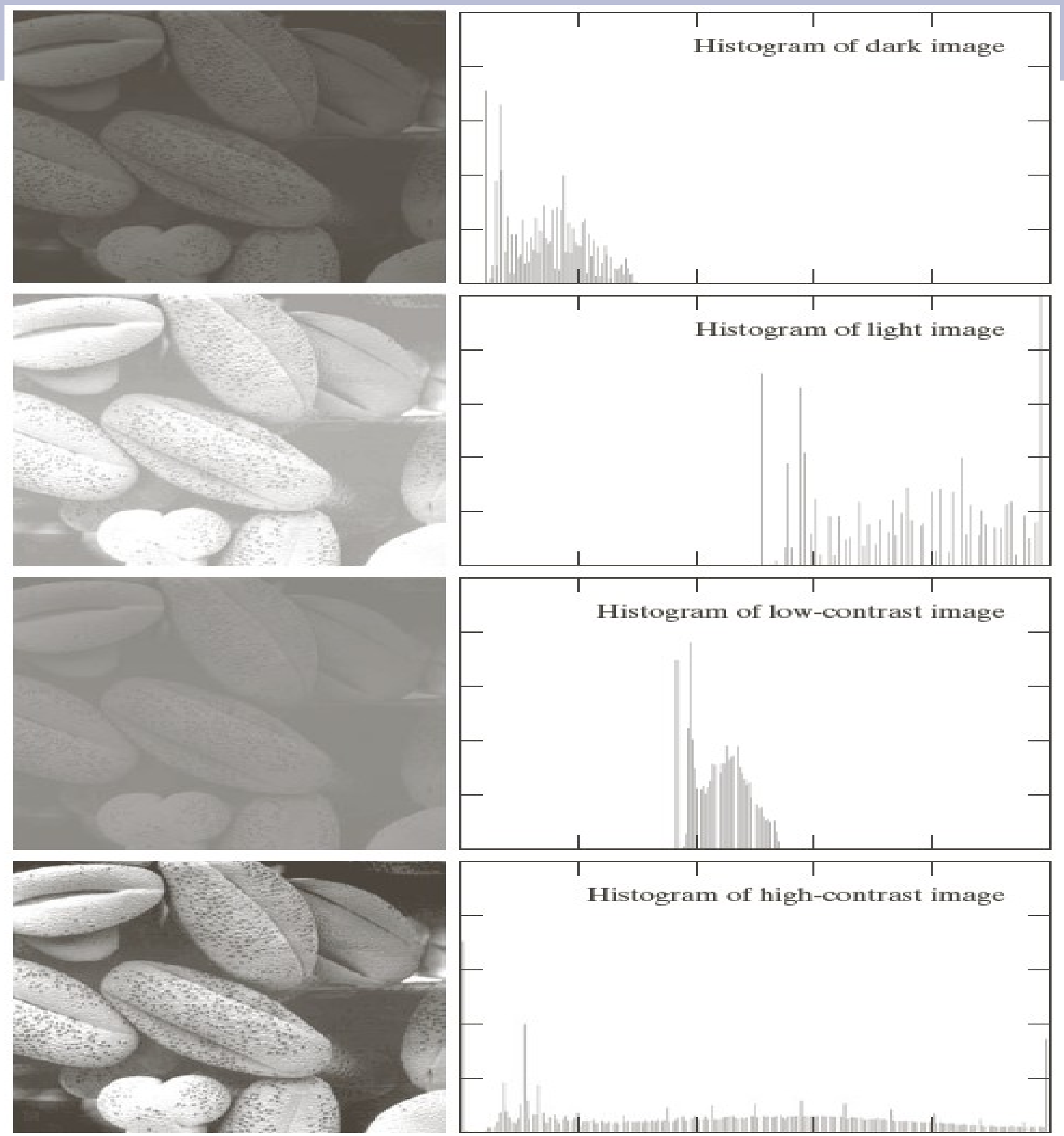
- Histogram
  - Discrete function $h(z_k)$ showing the number of occurrences n_k for the k^{th} gray level z_k

$$h(z_k) = n_k$$

- Normalized Histogram
  - Gives estimate of probability of occurrence of gray level z_k *(probability distribution function)*

$$p(z_k) = n_k / n, \quad \sum_{0}^{L-1} p(z_k) = 1$$

Histograms: Example



Source: Gonzalez and Woods

Histogram Equalization

- High-contrast images are often desirable from a visual perspective
- High-contrast images have histograms where the components cover a wide dynamic range
- Distribution of pixels are close to a uniform distribution
- Intuitively, low-contrast images can be enhanced by transforming its pixel distribution into a uniform distribution to achieve high contrast

Histogram Equalization

- Let *p(z)* and *p(s)* denote the probability density functions of *z* and *s*
- For *s=T(z), p(s)* can be expressed as,

$$p(s) = p(z)\left|\frac{dz}{ds}\right|$$

- Since we want to transform the input image such that the pixel distribution is uniform,

$$p(s) = 1, \ 0 \le s \le 1$$

Histogram Equalization

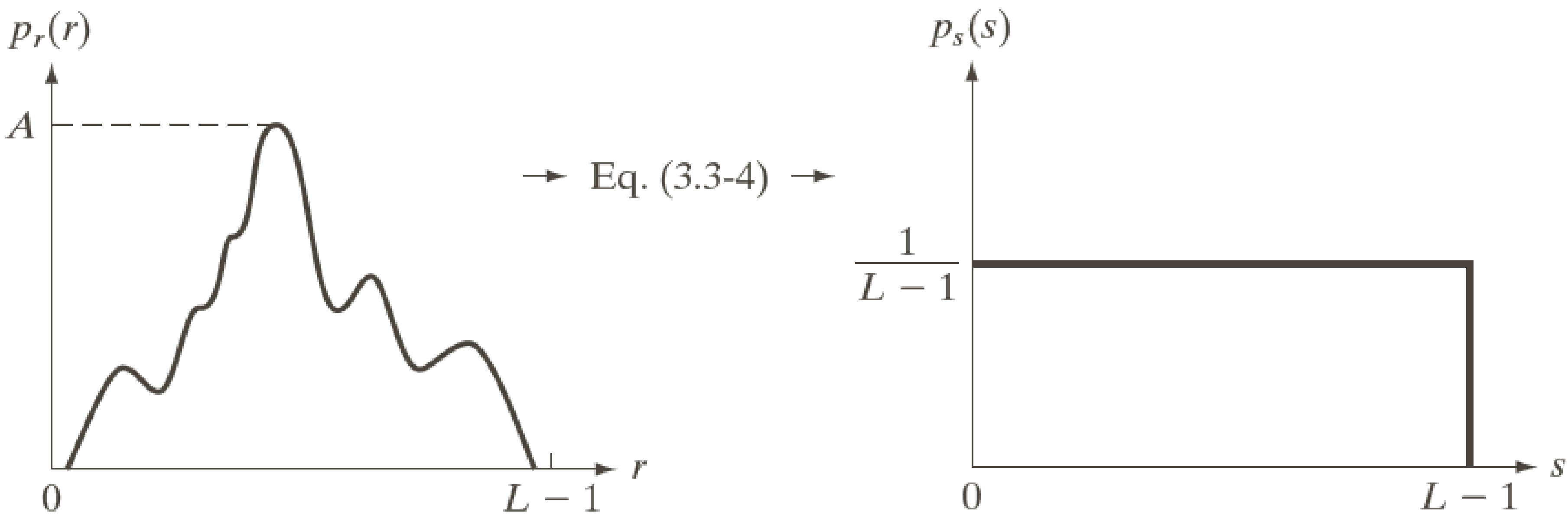
- What transformation will give you a uniform distribution for *s?*
  - Cumulative distribution function (CDF)

$$s = T(z) = \int_0^z p(w)dw$$

- Why?

$$\frac{ds}{dz} = \frac{d\left[\int_0^z p(w)dw\right]}{dz} = p(z) \qquad p(s) = p(z)\left|\frac{1}{p(z)}\right| = 1$$

Histogram Equalization



a b

FIGURE 3.18 (a) An arbitrary PDF. (b) Result of applying the transformation in Eq. (3.3-4) to all intensity levels, r. The resulting intensities, s, have a uniform PDF, independently of the form of the PDF of the r's.

Source: Gonzalez and Woods

Histogram Equalization

- For discrete case,

$$s_k = T(z_k) = \sum_{j=0}^{k} p(z_j)$$

$$p(z_k) = n_k / n, \quad \sum_{0}^{L-1} p(z_k) = 1$$

Histogram Equalization: Example

r_k	n_k	$p_r(r_k) = n_k/MN$
$r_0 = 0$	790	0.19
$r_1 = 1$	1023	0.25
$r_2 = 2$	850	0.21
$r_3 = 3$	656	0.16
$r_4 = 4$	329	0.08
$r_5 = 5$	245	0.06
$r_6 = 6$	122	0.03
$r_7 = 7$	81	0.02

TABLE 3.1 Intensity distribution and histogram values for a 3-bit, 64×64 digital image.

Source: Gonzalez and Woods

Histogram Equalization: Example

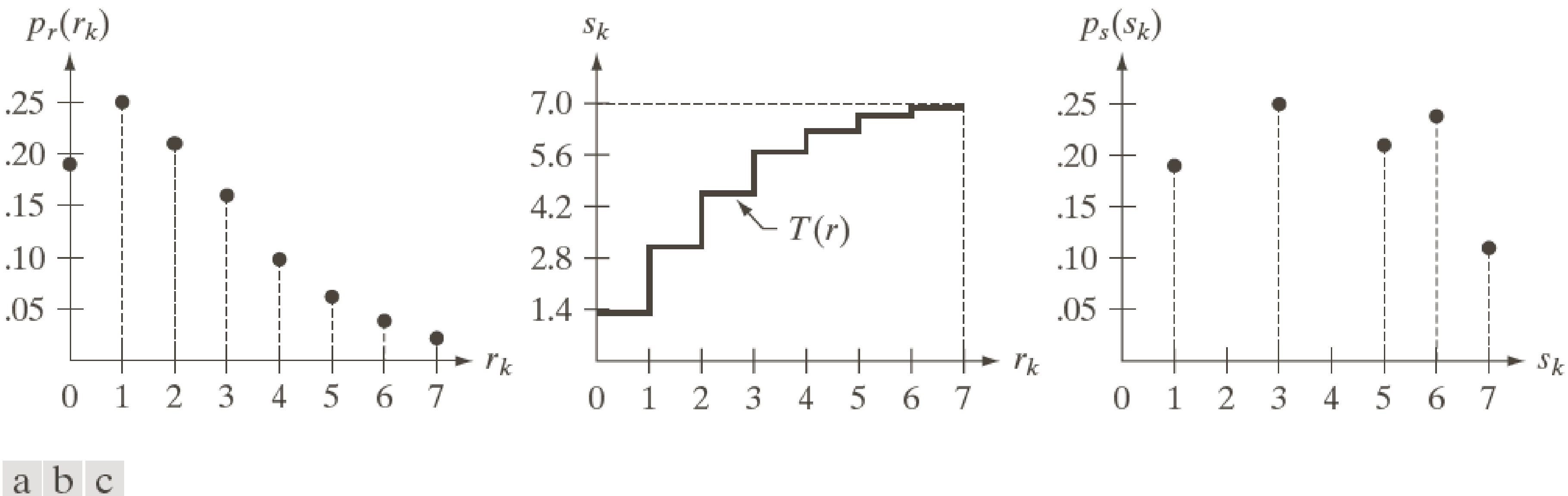


FIGURE 3.19 Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.

Source: Gonzalez and Woods

Histogram Equalization: Example

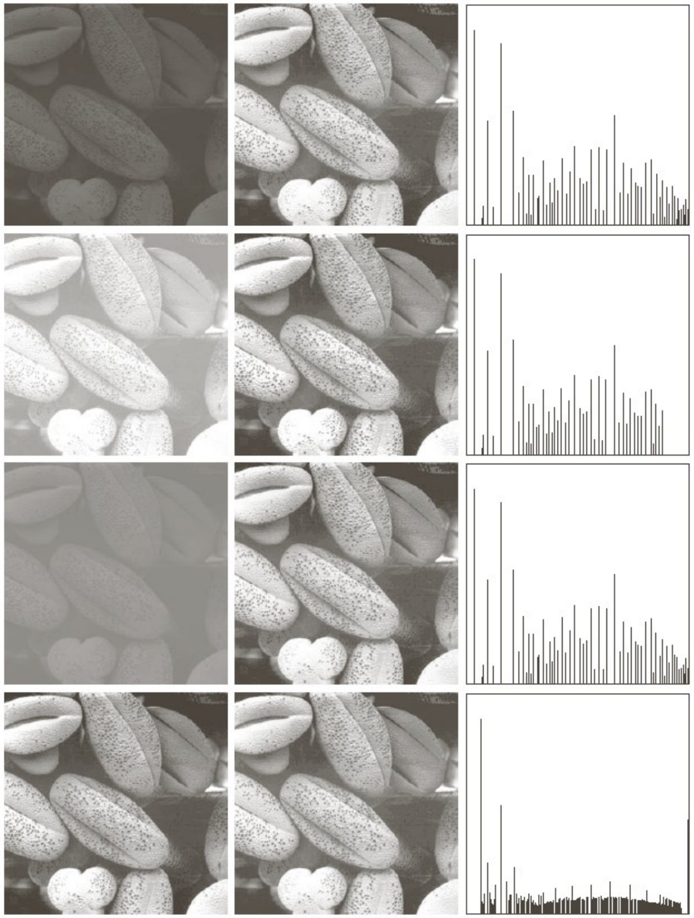


FIGURE 3.20 Left column: images from Fig. 3.16. Center column: corresponding histogram-equalized images. Right column: histograms of the images in the center column.

Source: Gonzalez and Woods

Local Histogram Equalization

- Global approach good for overall contrast enhancement
- However, there may be cases where it is necessary to enhance details over small areas in image
- Solution: perform histogram equalization over a small neighborhood

Local Histogram Equalization: Example

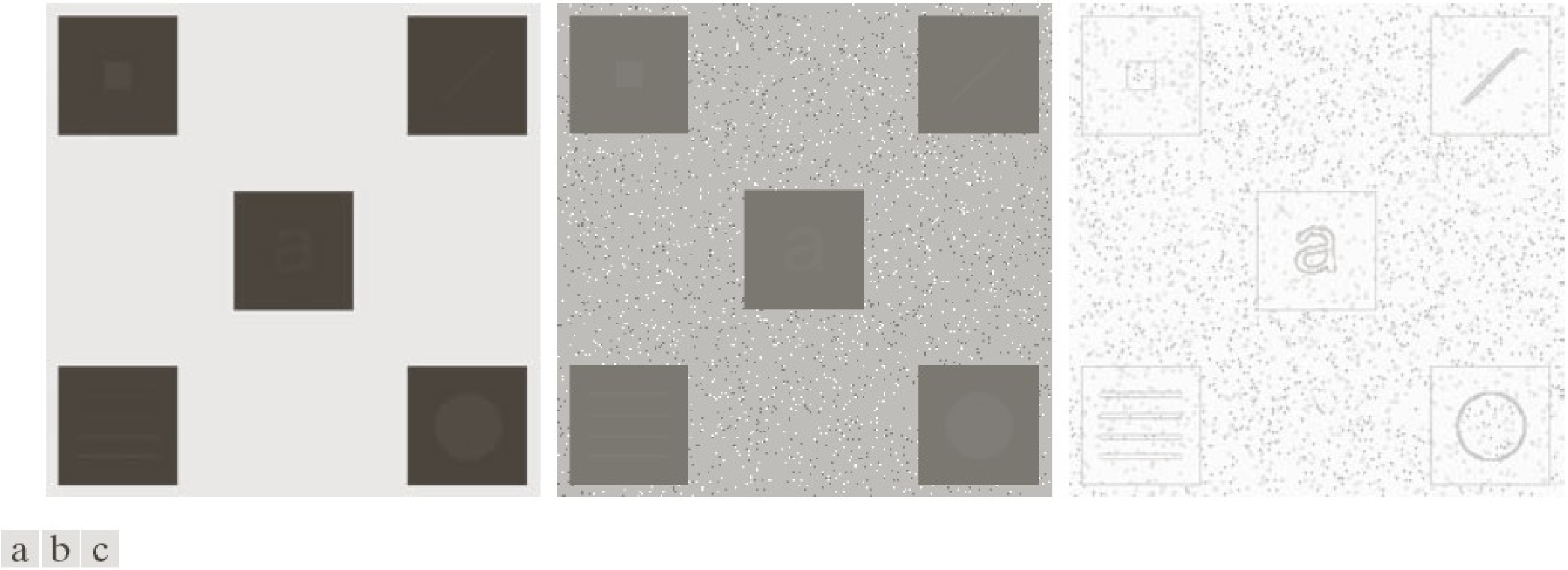


FIGURE 3.26 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization applied to (a), using a neighborhood of size 3×3.

Source: Gonzalez and Woods