Image Enhancement

Image Enhancement

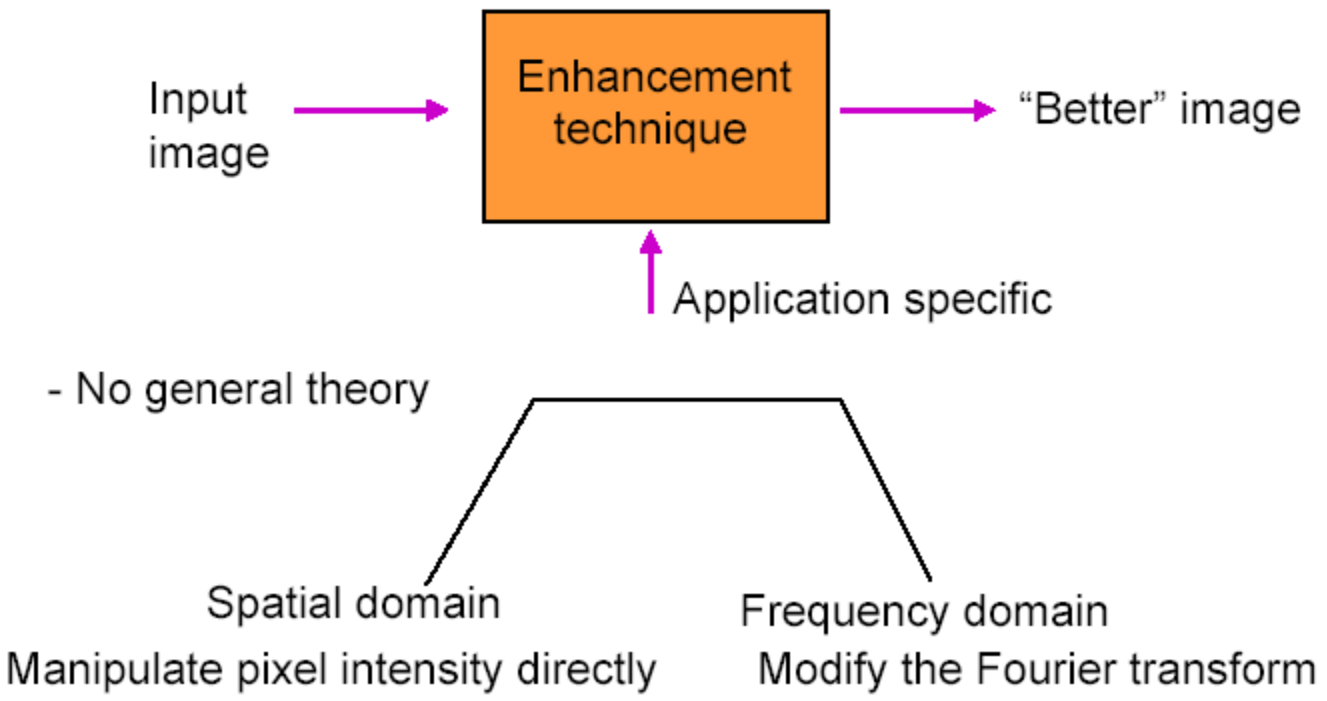
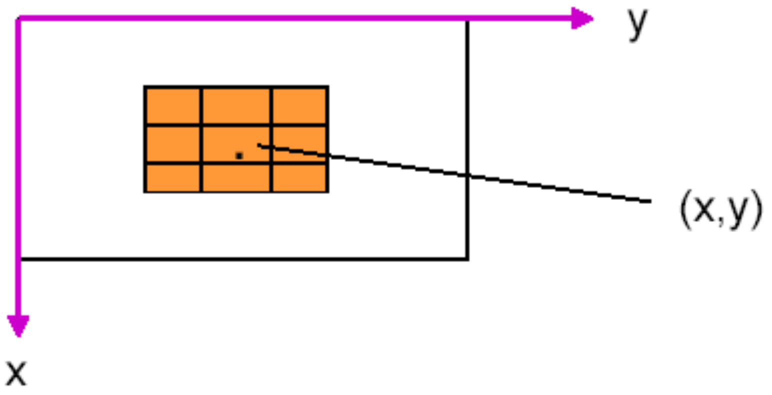


Image Enhancement in Spatial Domain

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

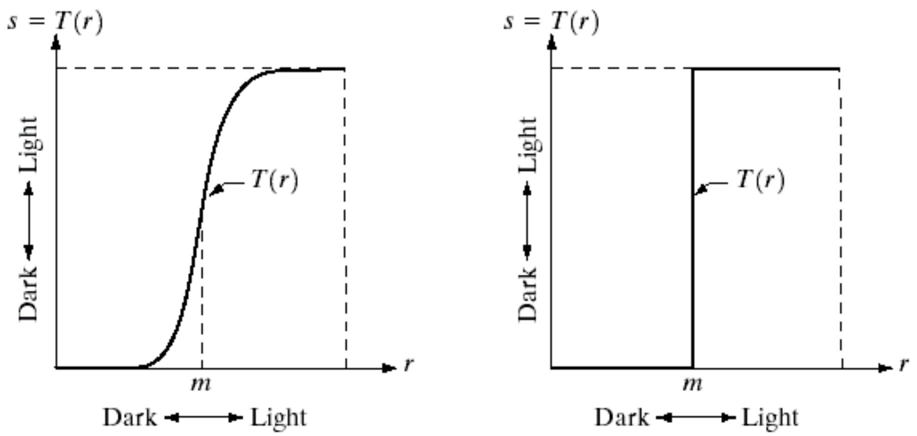


Simplest case: Neighbourhood is (x,y)

[g(.) depends only on the value of f at (x,y)]

Image Enhancement in Spatial Domain

Gray Level Transformation Functions



a b

FIGURE 3.2 Gray-level transformation functions for contrast enhancement.

Image Enhancement in Spatial Domain

Gray Level Transformation Functions

FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.

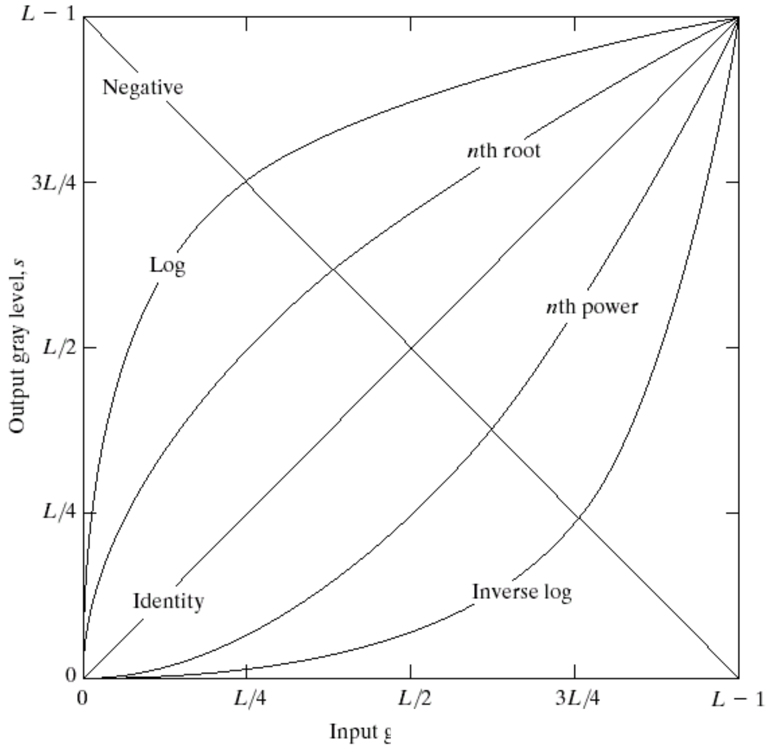
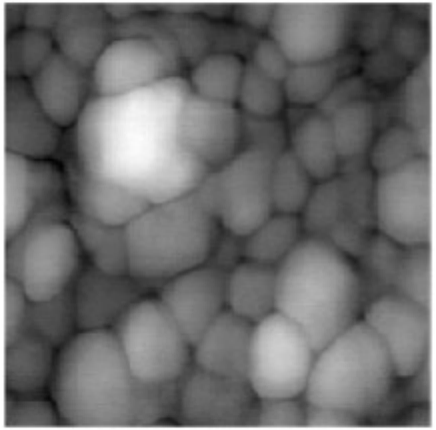


Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Negative image: Example: $g(x,y) = 255 - f(x,y)$



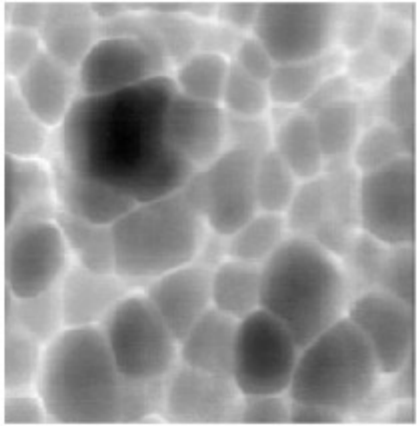


Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Compressing dynamic range

$s = c \log(1 + |r|)$ $c \longrightarrow$ Scaling factor

Example: Displaying the Fourier Spectrum

a b

FIGURE 3.5
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.

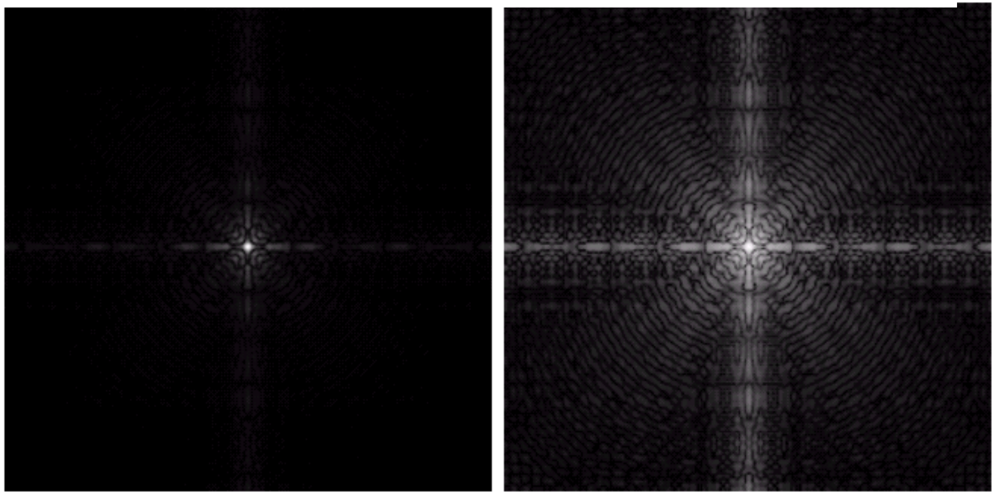


Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Power Function

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

C and γ are positive constants.

Often referred to as "gamma correction".

CRT –intensity-to-voltage response follows a power function (typical value of gamma in the range 1.5-2.5.)

Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Power Function

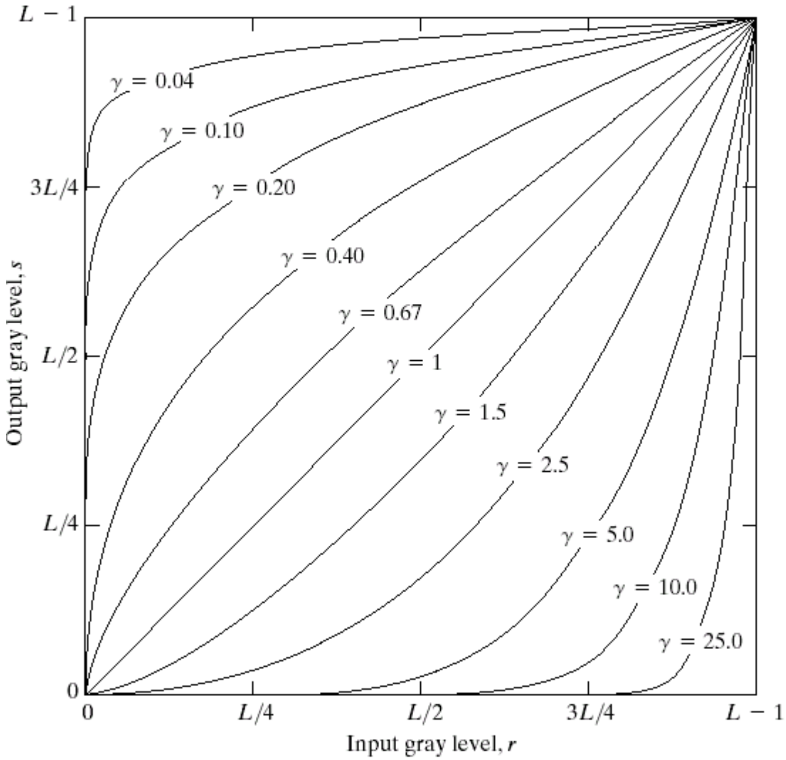


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Power Function

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.)

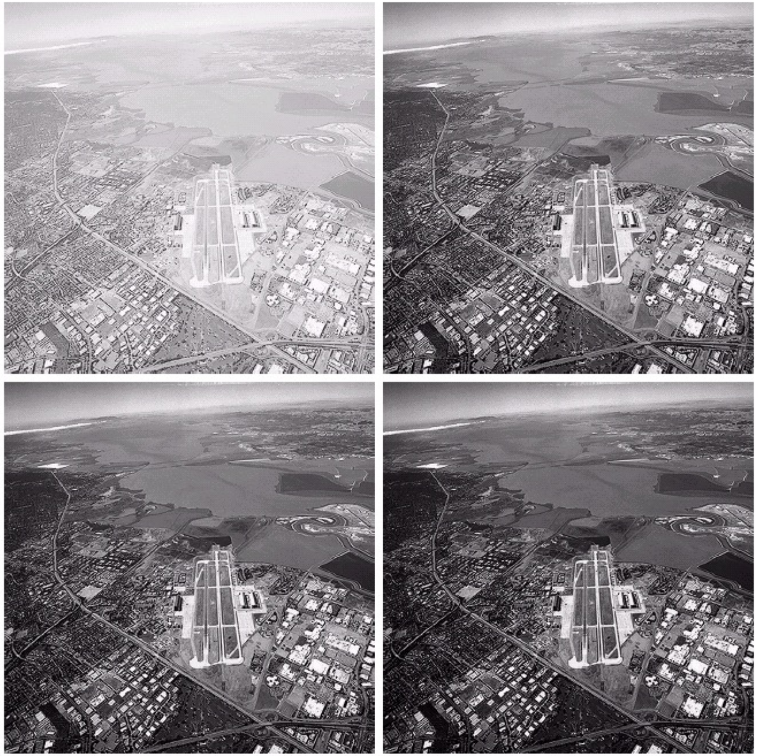


Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Power Function

a b
c d

FIGURE 3.7
(a) Linear-wedge gray-scale image.
(b) Response of monitor to linear wedge.
(c) Gamma-corrected wedge.
(d) Output of monitor.

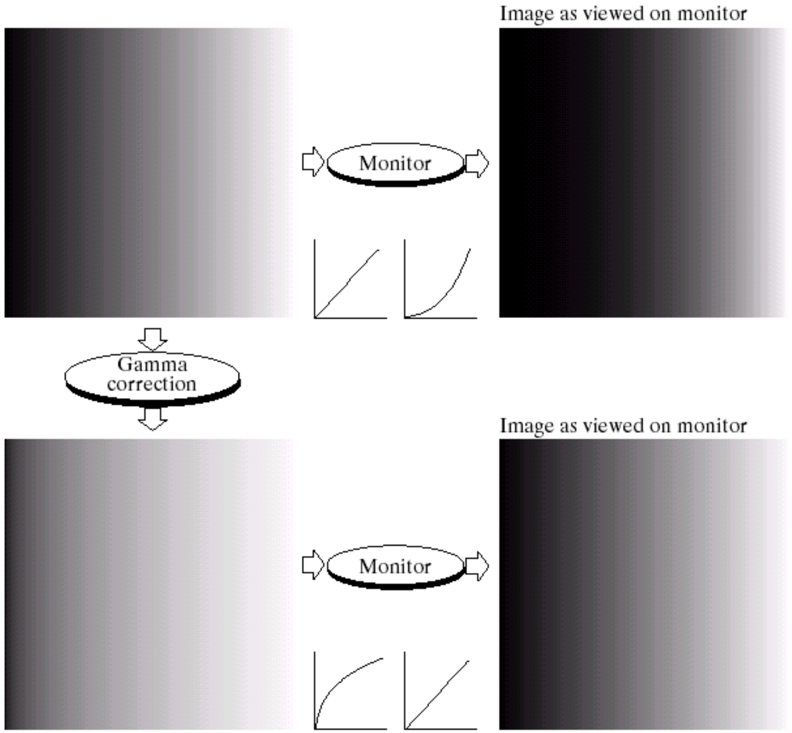
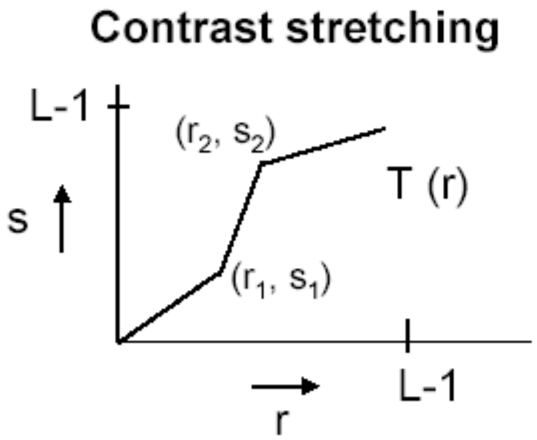


Image Enhancement in Spatial Domain

Gray Level Transformation Functions



$r_1 = s_1$
$r_2 = s_2$ no change

$r_1 = r_2$
$s_1 = 0$
$s_2 = L-1$ Thresholding at r_1

Image Enhancement in Spatial Domain

Gray Level Transformation Functions

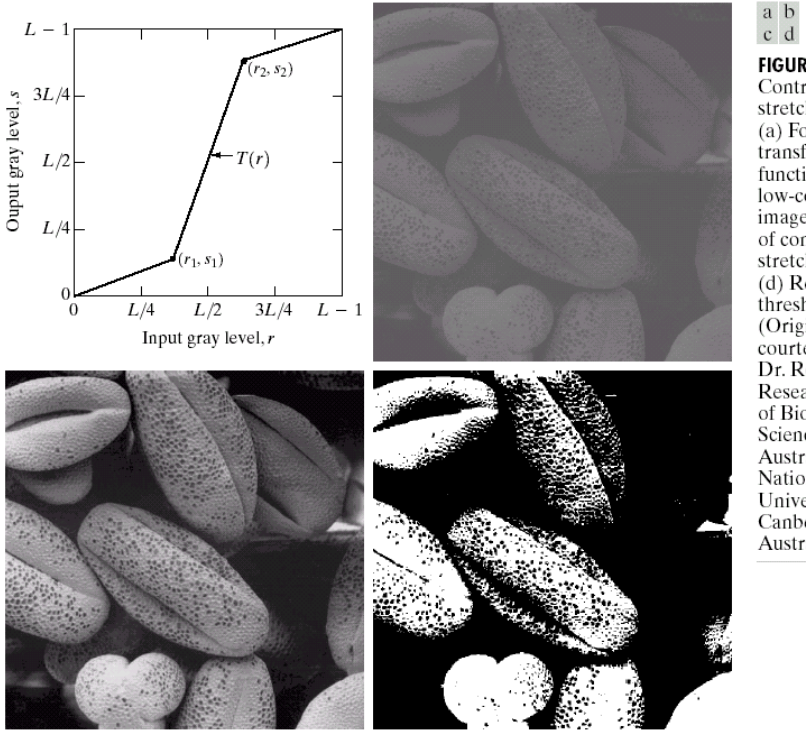
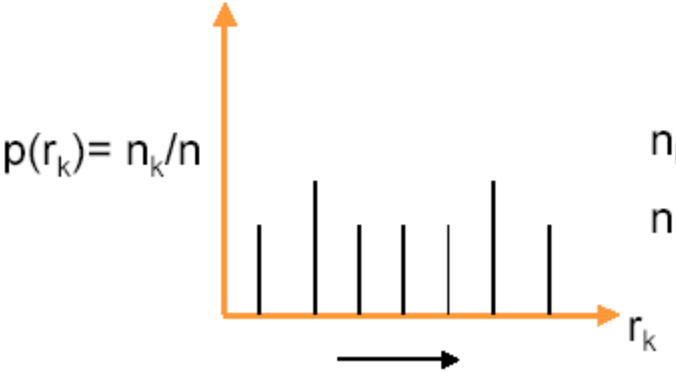


FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Image Enhancement in Spatial Domain

Histogram Processing



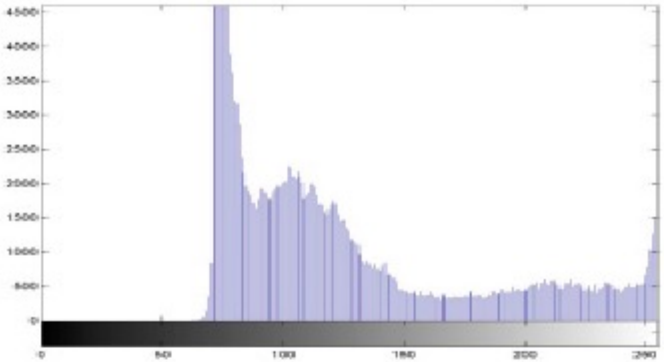
$r_k \in \{0, 1, 2, 3...., L-1\}$

n_k : # pixels with gray level r_k

n : # pixels in the image

Image Enhancement in Spatial Domain

Histogram Examples



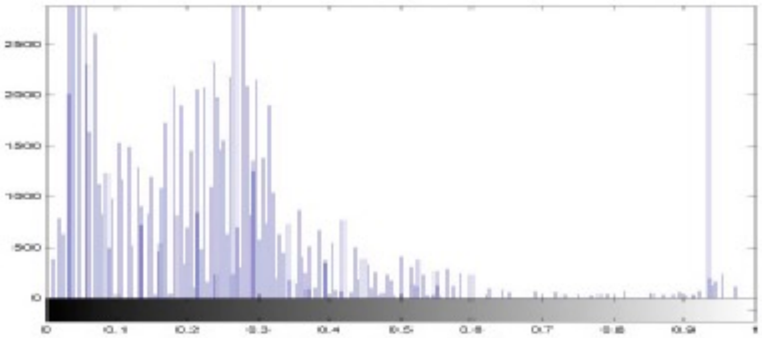


Image Enhancement in Spatial Domain

Histogram Examples

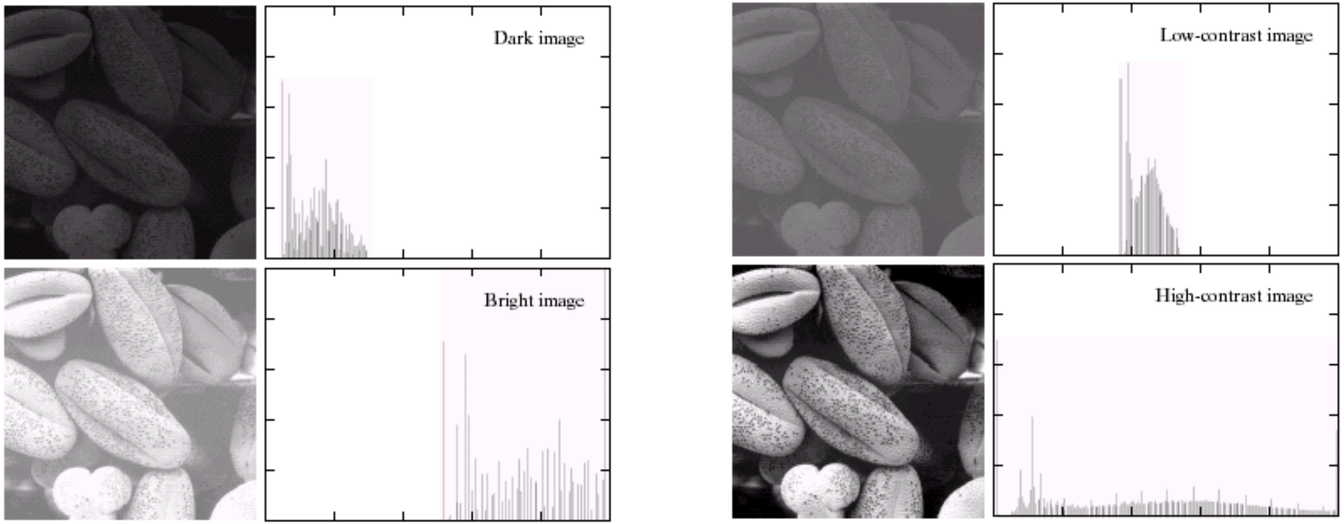


Image Enhancement in Spatial Domain

Histogram Equalization

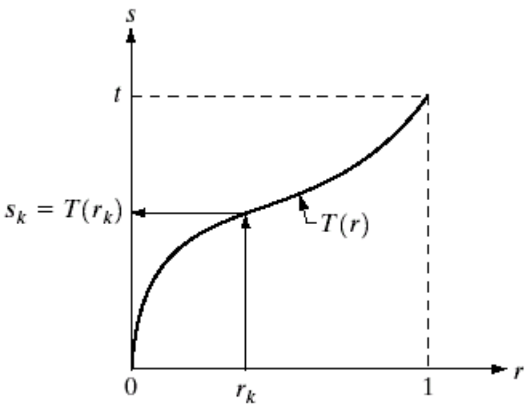


FIGURE 3.16 A gray-level transformation function that is both single valued and monotonically increasing.

Image Enhancement in Spatial Domain

Histogram Equalization

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

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

$$[0,\ 1] \xrightarrow{T} [0, 1]$$

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

$T^{-1}(s)$ also satisfies (i) and (ii)

The gray levels in the image can be viewed as random variables taking values in the range [0,1].

Let $p_r(r)$: p.d.f. of input level r and let $p_s(s)$: p.d.f. of s

Image Enhancement in Spatial Domain

Histogram Equalization

r : Input gray level $\in$ [0, 1]

s : Transformed gray level $\in$ [0, 1]

$s = T(r)$ T : Transformation function

We are interested in obtaining a transformation function T( ) which transforms an arbitrary p.d.f. to an uniform distribution

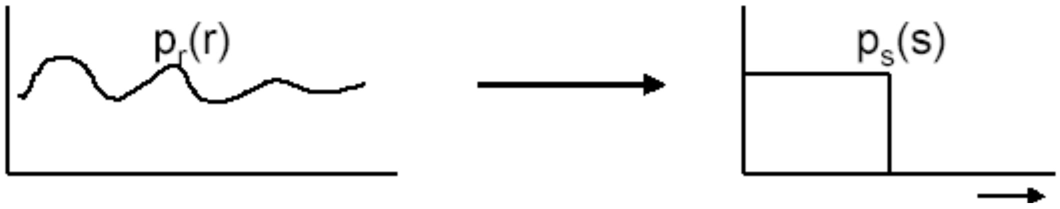


Image Enhancement in Spatial Domain

Histogram Equalization

$$\text{Consider } \; s = T(r) = \int_0^r p_r(w)\, dw \quad 0 \le r \le 1$$

$$\text{(Cumulative distribution function of r)}$$

$$p_s(s) = p_r(r) \, {}^{dr}\!/_{ds} \Big|_{r=T^{-1}(s)} \; ;$$

$$\frac{ds}{dr} = \frac{d}{dr}\left[\int_r^0 p_r(w) dw \right] = p_r(r)$$

$$\therefore \; p_s(s) = p_r(r) \frac{1}{p_r(r)} \Bigg|_{r=T^{-1}(s)} \equiv 1 \qquad 0 \le s \le 1$$

Image Enhancement in Spatial Domain

Histogram Equalization

$$p_r(r_k) = \frac{n_k}{n} \qquad 0 \le r_k \le 1 \quad ; \quad k = 0,1,\ldots,L-1$$

$L \rightarrow$ Number of levels

$$s_k = T(r_k) \quad = \sum_{j=0}^{k} p_r(r_j) \quad = \quad \sum_{j=0}^{k} {}^{n_j}\!/_{n}$$

Image Enhancement in Spatial Domain

Histogram Equalization

$$\begin{bmatrix} 52 & 55 & 61 & 66 & 70 & 61 & 64 & 73 \\ 63 & 59 & 55 & 90 & 109 & 85 & 69 & 72 \\ 62 & 59 & 68 & 113 & 144 & 104 & 66 & 73 \\ 63 & 58 & 71 & 122 & 154 & 106 & 70 & 69 \\ 67 & 61 & 68 & 104 & 126 & 88 & 68 & 70 \\ 79 & 65 & 60 & 70 & 77 & 68 & 58 & 75 \\ 85 & 71 & 64 & 59 & 55 & 61 & 65 & 83 \\ 87 & 79 & 69 & 68 & 65 & 76 & 78 & 94 \end{bmatrix}$$

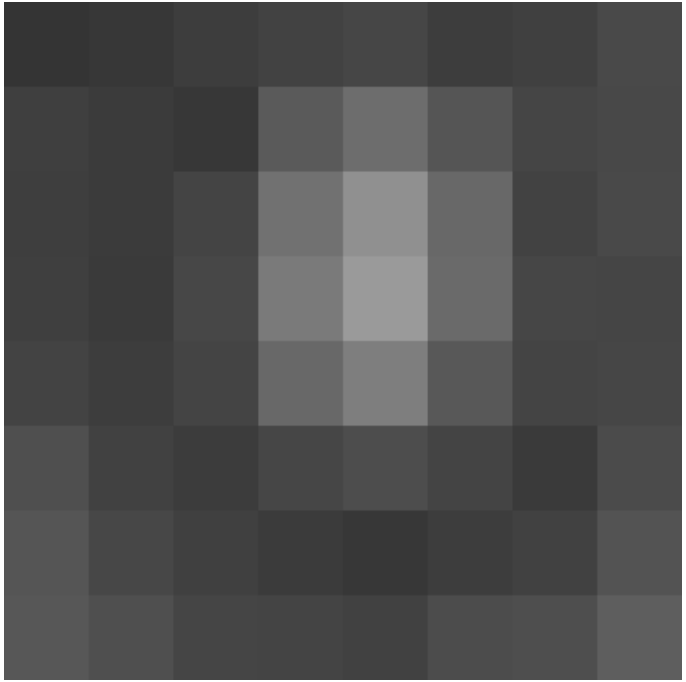


Image Enhancement in Spatial Domain

Histogram Equalization

52	1
55	3
58	2
59	3
60	1
61	4
.	
.	
.	
144	1
154	1

52	1
55	4
58	6
59	9
60	10
61	14
144	63
154	64

Image Enhancement in Spatial Domain

Histogram Equalization

$$h(v) = \mathrm{round}\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L-1)\right)$$

$$h(v) = \mathrm{round}\left(\frac{cdf(v) - 1}{63} \times 255\right)$$

Image Enhancement in Spatial Domain

Histogram Equalization

$$\begin{bmatrix} 0 & 12 & 53 & 93 & 146 & 53 & 73 & 166 \\ 65 & 32 & 12 & 215 & 235 & 202 & 130 & 158 \\ 57 & 32 & 117 & 239 & 251 & 227 & 93 & 166 \\ 65 & 20 & 154 & 243 & 255 & 231 & 146 & 130 \\ 97 & 53 & 117 & 227 & 247 & 210 & 117 & 146 \\ 190 & 85 & 36 & 146 & 178 & 117 & 20 & 170 \\ 202 & 154 & 73 & 32 & 12 & 53 & 85 & 194 \\ 206 & 190 & 130 & 117 & 85 & 174 & 182 & 219 \end{bmatrix}$$

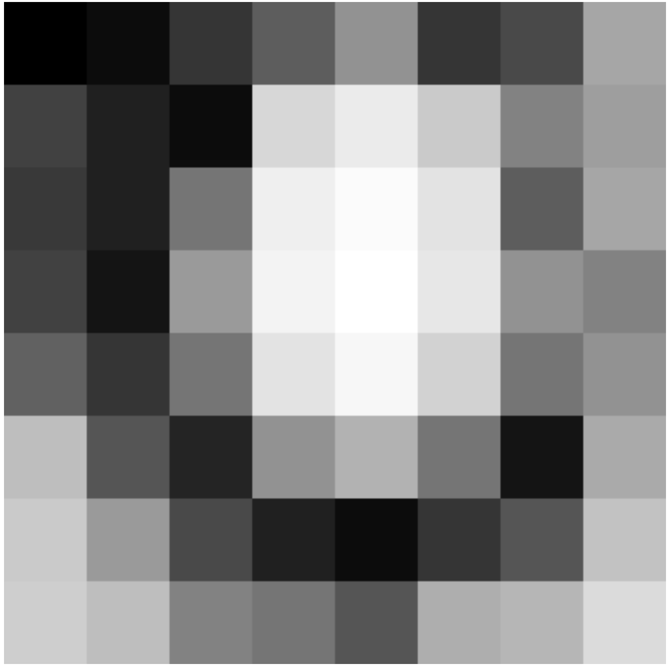
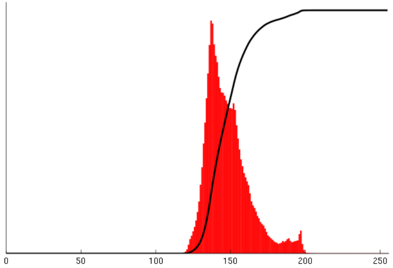


Image Enhancement in Spatial Domain

Histogram Equalization



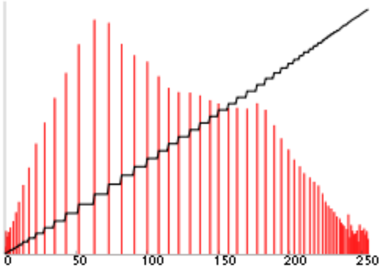
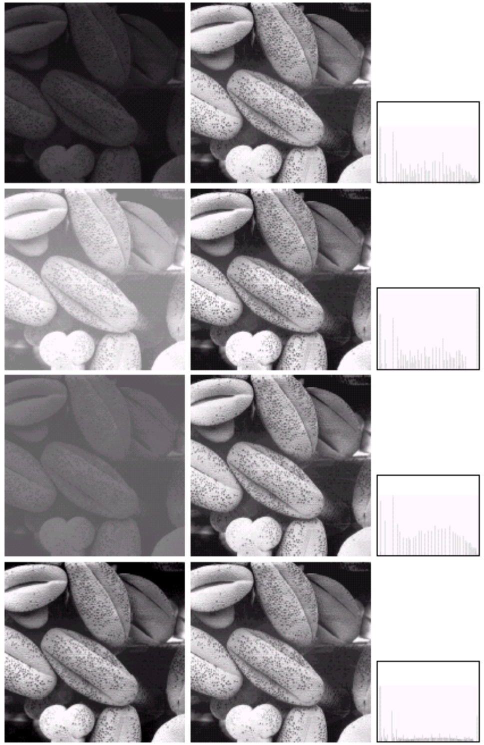


Image Enhancement in Spatial Domain

Histogram Equalization



Histogram Equalization
: Examples

a b c

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

Image Enhancement in Spatial Domain

Histogram Equalization