

COL783: Digital Image Processing

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Recap

General Information

Evaluation (Tentative):

Exams:

Minor, Major, Quizes (70%)

Assignments >= 3 (30%)

TA

On Request

Rohan

Course Page

<http://www.cse.iitd.ac.in/~pkalra/col783>

Digital Image Processing

Image
Segmentation

Image
Restoration

Image
Enhancement

Feature
Description

Course Contents (Tentative)

Basic
Representation

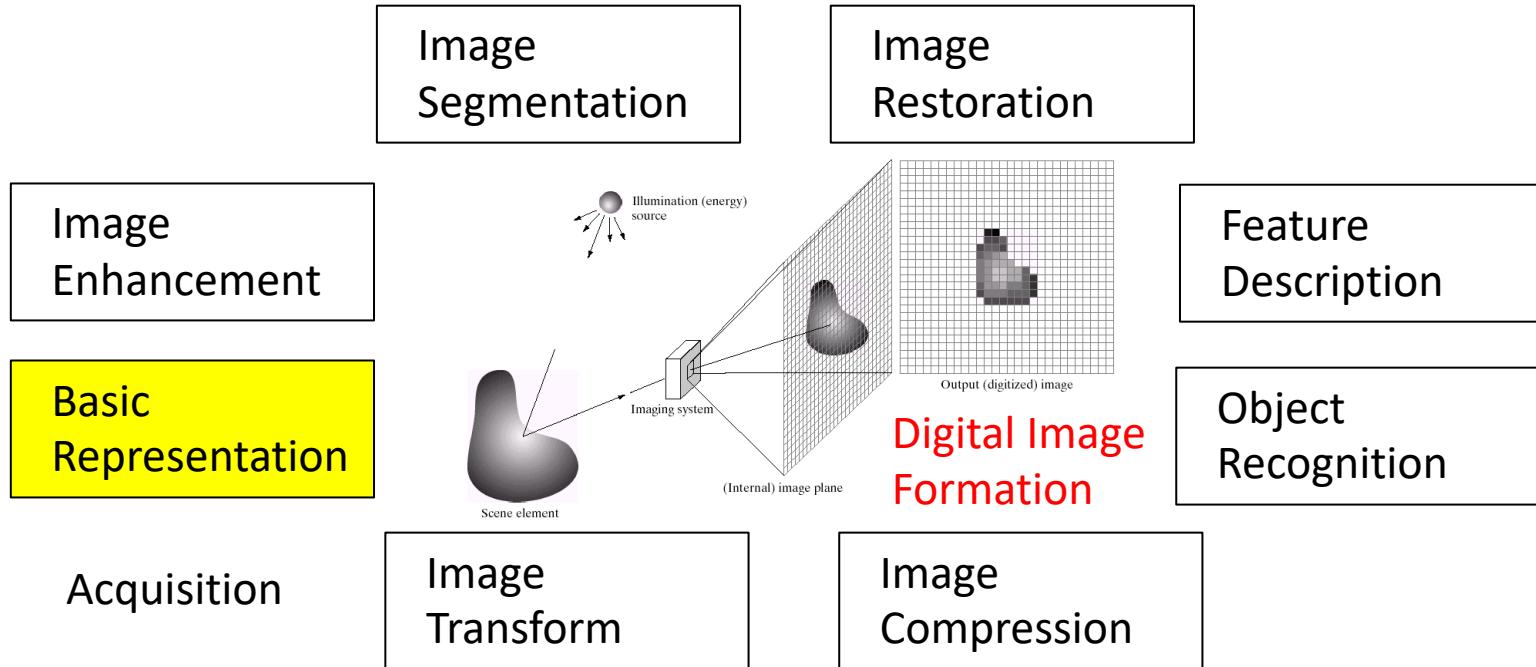
Object
Recognition

Acquisition

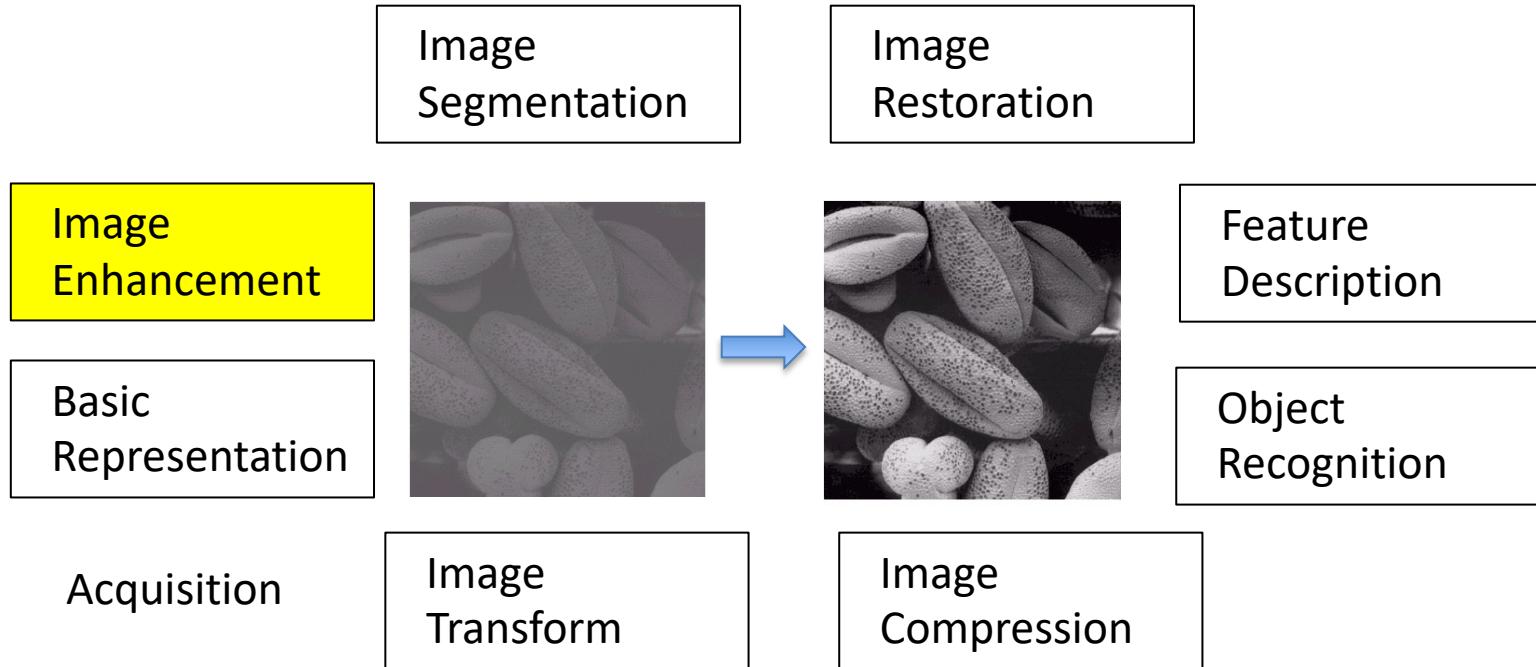
Image
Transform

Image
Compression

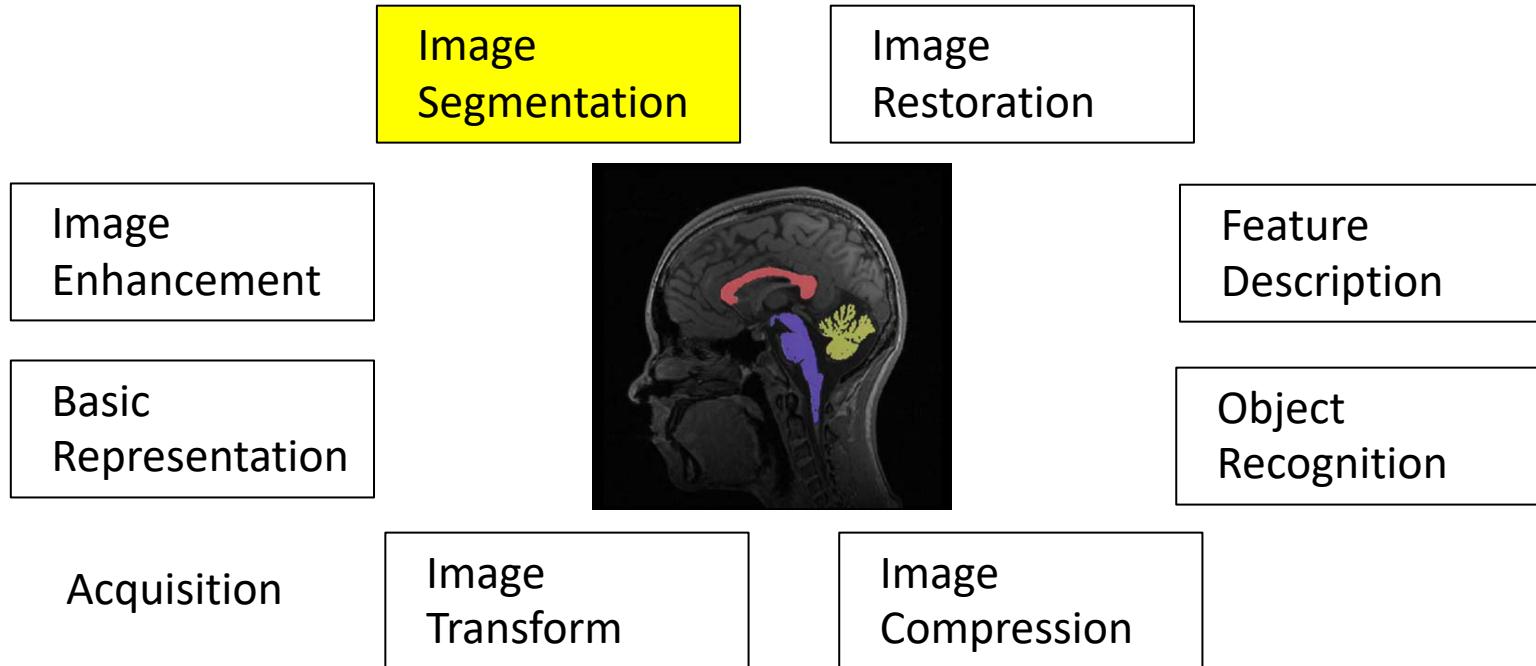
Digital Image Processing



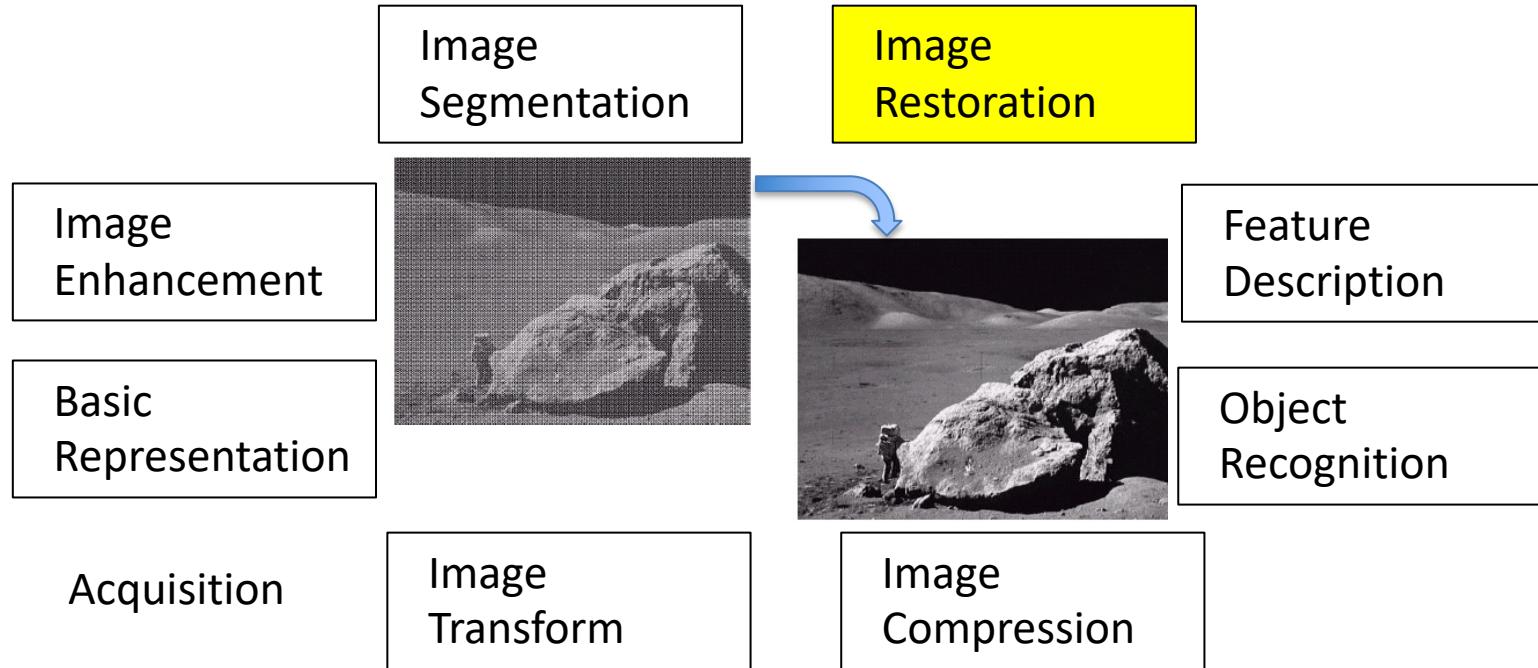
Digital Image Processing



Digital Image Processing



Digital Image Processing



Digital Image Processing

Image Segmentation

Image Restoration

Image Enhancement

Feature Description

Basic Representation

Object Recognition

Acquisition

Image Transform

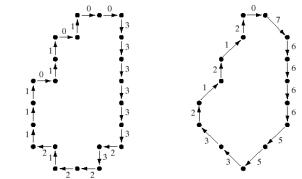
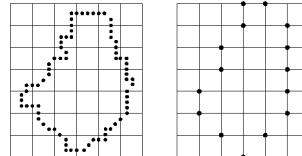


Image Compression

Digital Image Processing

Image
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Basic
Representation



Feature
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Compression

Fundamentals

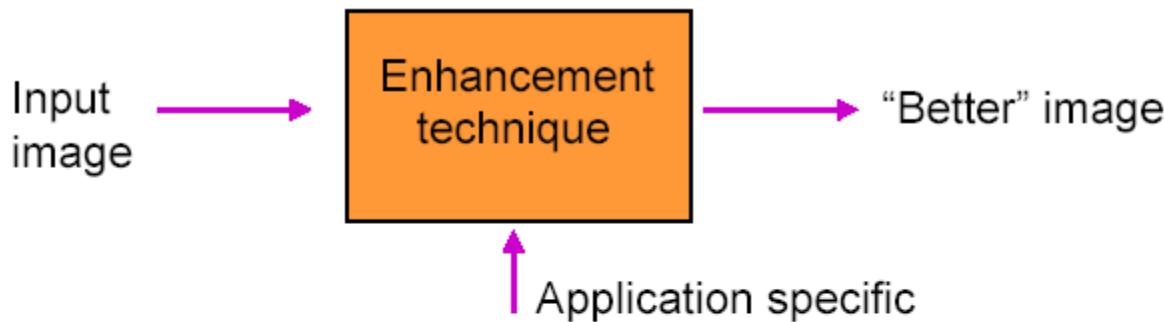
Assignment 0

Image Expansion



Image Enhancement

Image Enhancement



- No general theory

Spatial domain

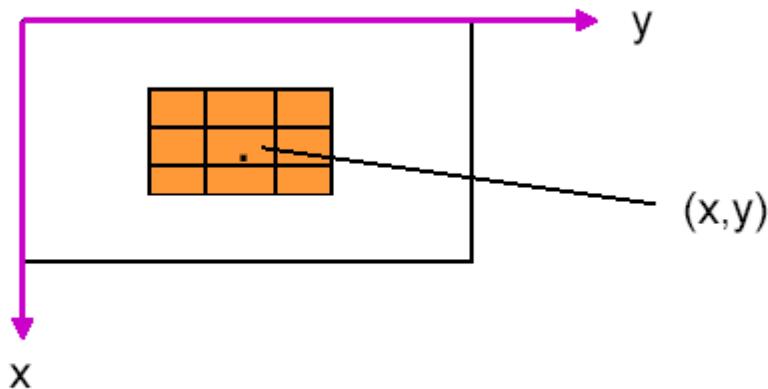
Manipulate pixel intensity directly

Frequency domain

Modify the Fourier transform

Image Enhancement in Spatial Domain

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

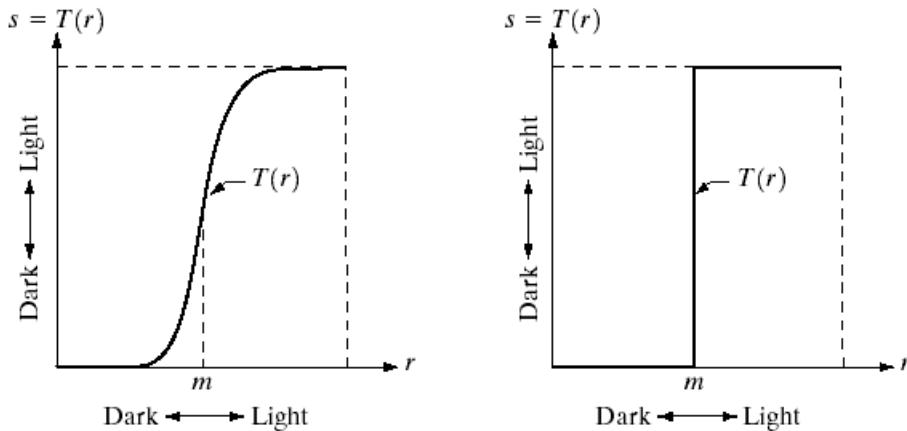


Simplest case: Neighbourhood is (x,y)

[$g(\cdot)$ 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.

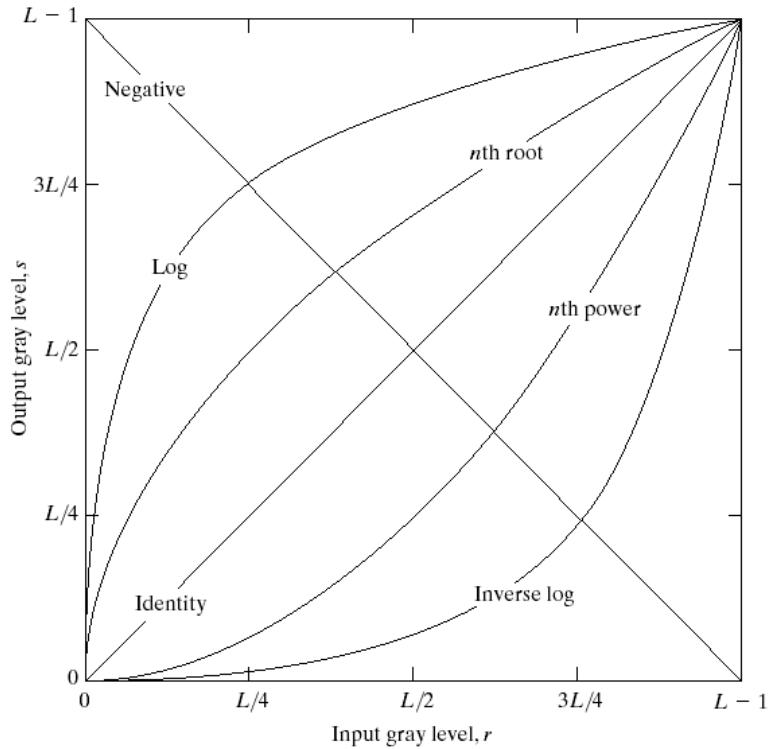


Image Enhancement in Spatial Domain

Gray Level Transformation Functions

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

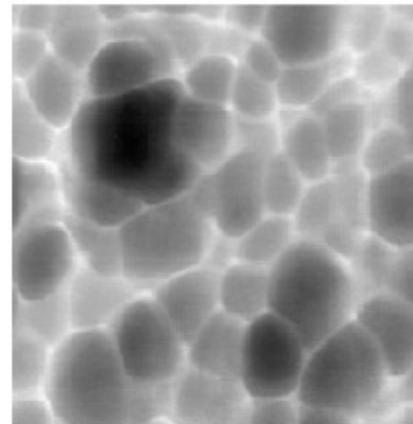
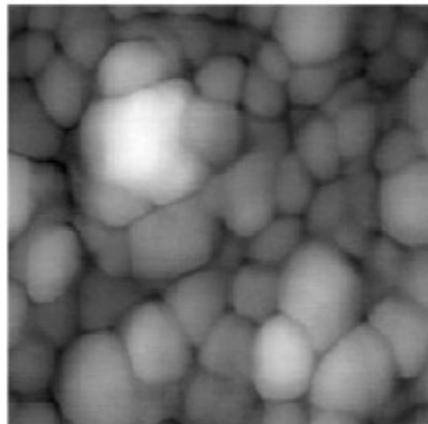


Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Compressing dynamic range

$$s = c \log (1 + |r|) \quad c \rightarrow \text{Scaling factor}$$

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 $c = 1$.

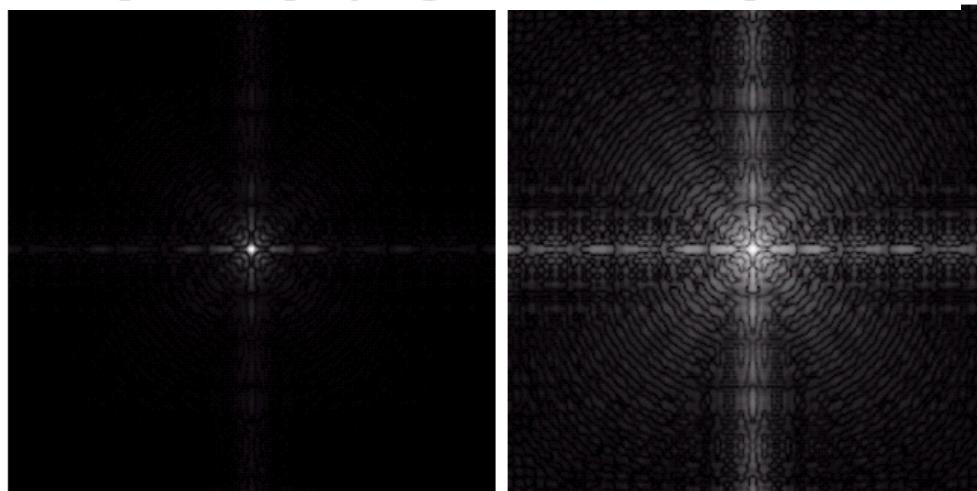


Image Enhancement in Spatial Domain

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

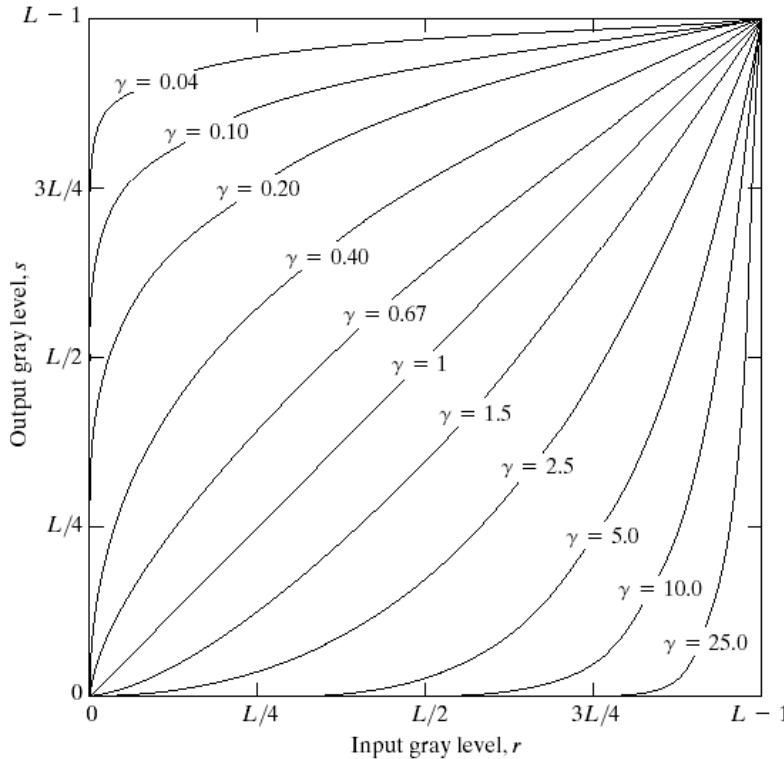


FIGURE 3.6 Plots of the equation $s = cr^\gamma$ for various values of γ ($c = 1$ in all cases).

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.)

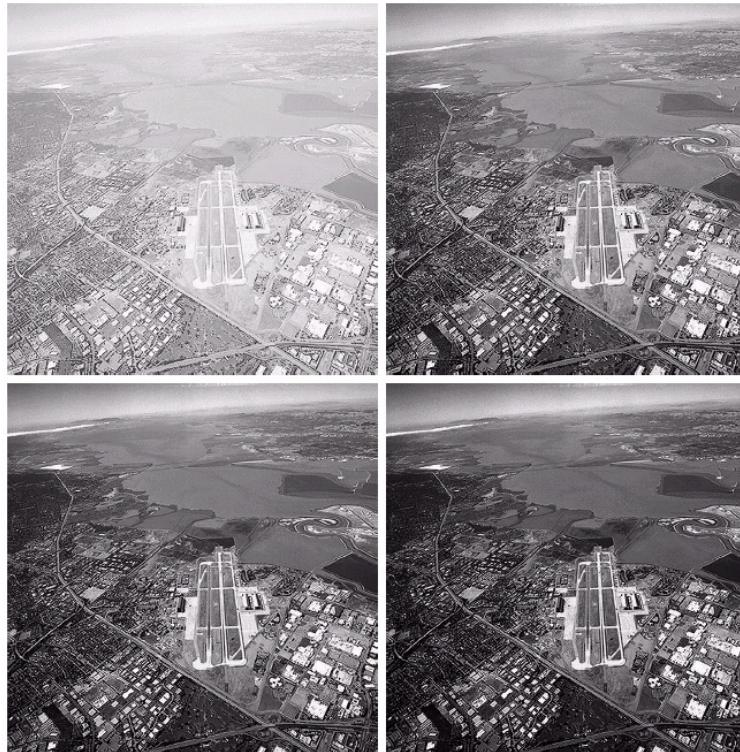


Image Enhancement in Spatial Domain

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.

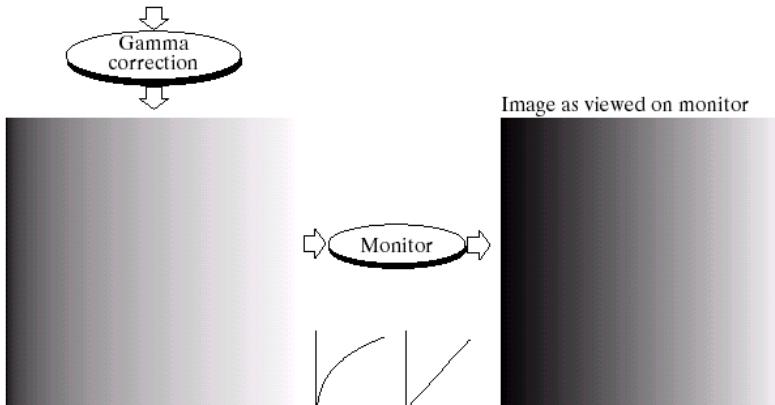
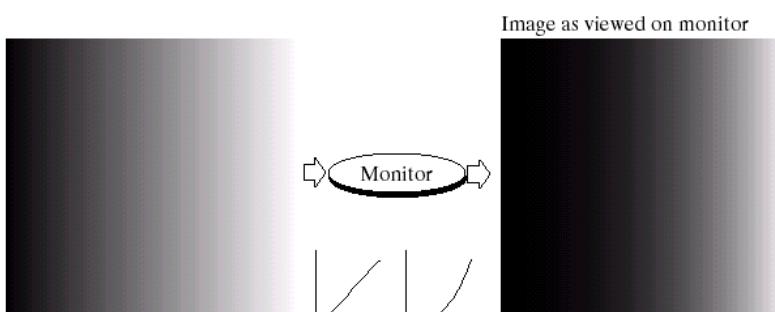
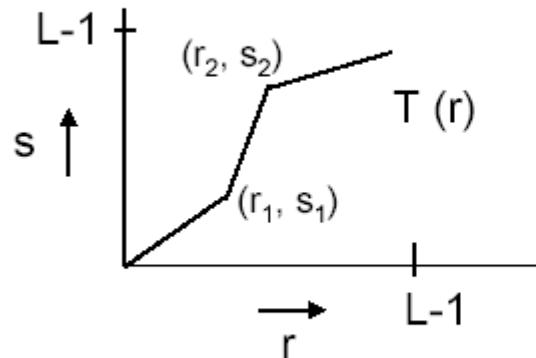


Image Enhancement in Spatial Domain

Gray Level Transformation Functions

Contrast stretching



$$\begin{aligned} r_1 &= s_1 \\ r_2 &= s_2 \end{aligned}$$

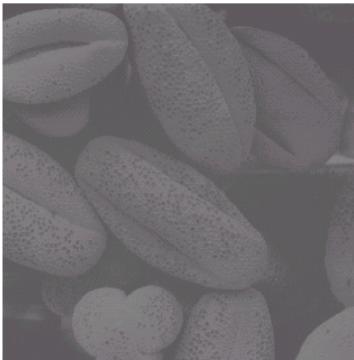
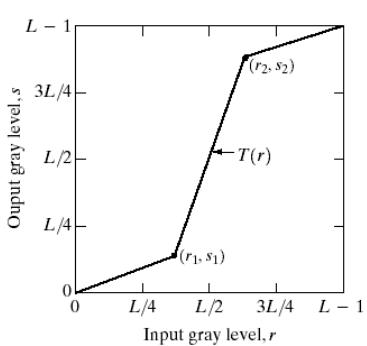
no change

$$\begin{aligned} r_1 &= r_2 \\ s_1 &= 0 \\ s_2 &= L-1 \end{aligned}$$

Thresholding
at r_1

Image Enhancement in Spatial Domain

Gray Level Transformation Functions



a | b
c | d

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

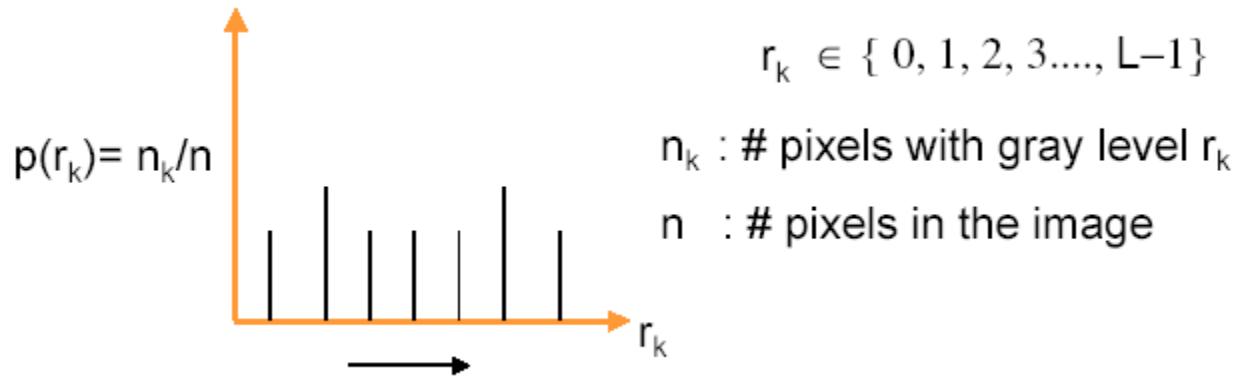


Image Enhancement in Spatial Domain

Histogram Examples

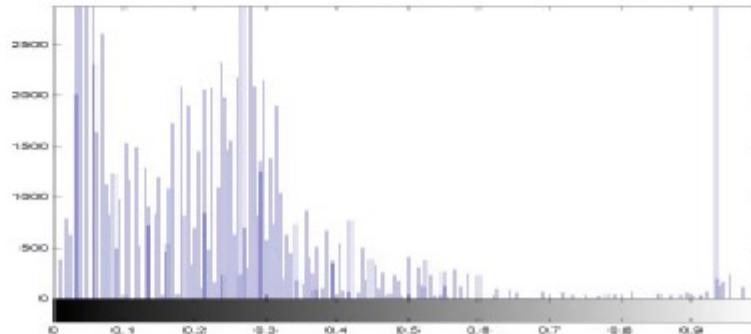
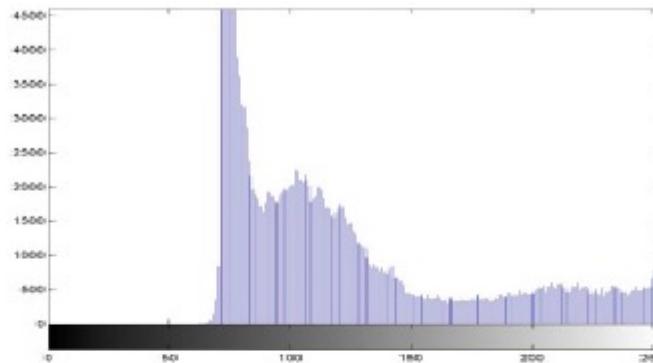


Image Enhancement in Spatial Domain

Histogram Examples

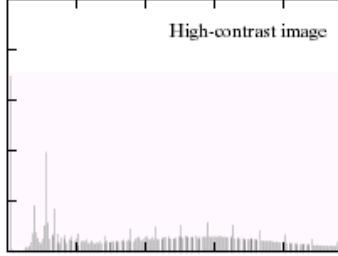
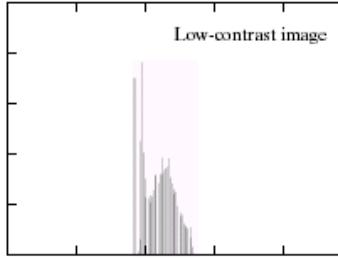
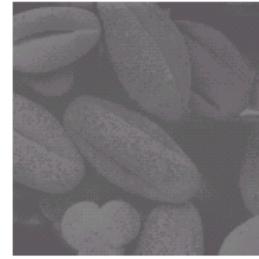
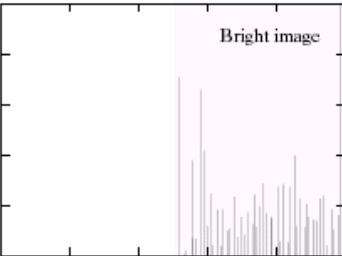
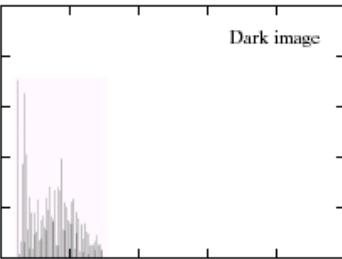
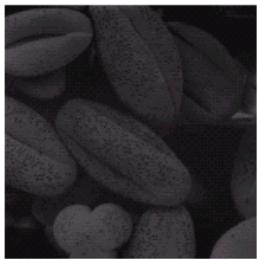


Image Enhancement in Spatial Domain

Histogram Equalization

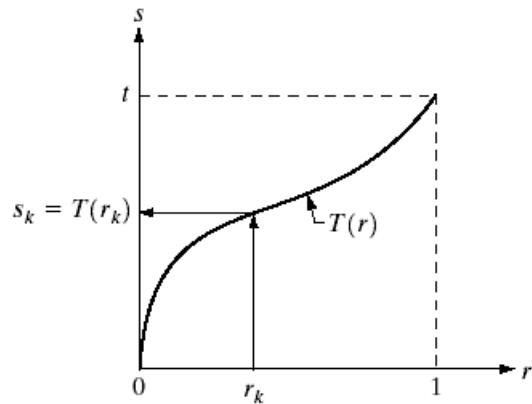


FIGURE 3.16 A gray-level transformation function that is both single valued and monotonically increasing.

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

$T^{-1}(s)$ 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 $\in [0, 1]$

$$s = T(r) \quad T : \text{Transformation function}$$

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

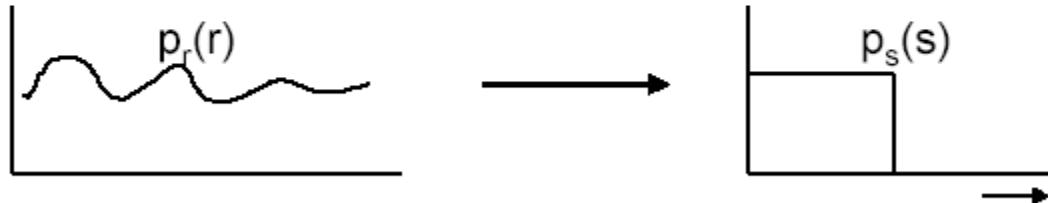


Image Enhancement in Spatial Domain

Histogram Equalization

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

(Cumulative distribution function of r)

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

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

$$\therefore p_s(s) = p_r(r) \frac{1}{p_r(r)} \Big|_{r=T^{-1}(s)} \equiv 1 \quad 0 \leq s \leq 1$$

Image Enhancement in Spatial Domain

Histogram Equalization

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

$L \rightarrow$ Number of levels

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

Image Enhancement in Spatial Domain

Histogram Equalization

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

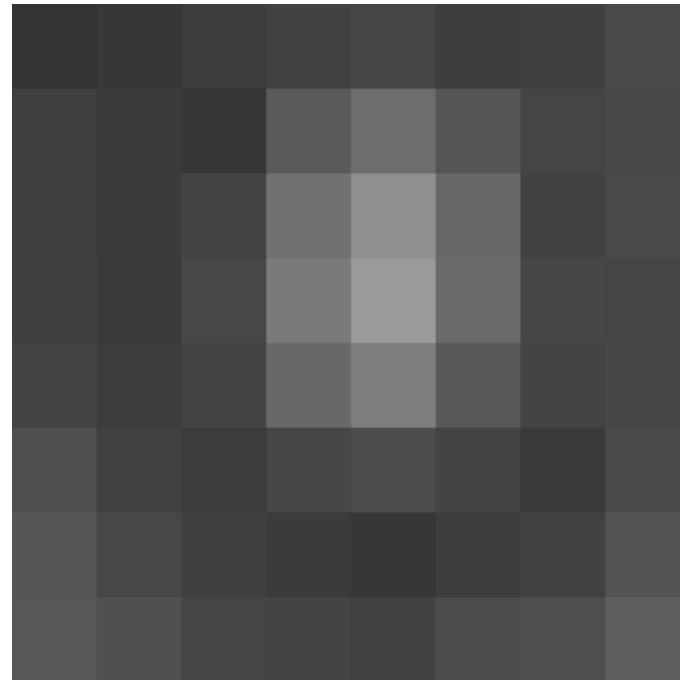


Image Enhancement in Spatial Domain

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

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

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

Image Enhancement in Spatial Domain

Histogram Equalization

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

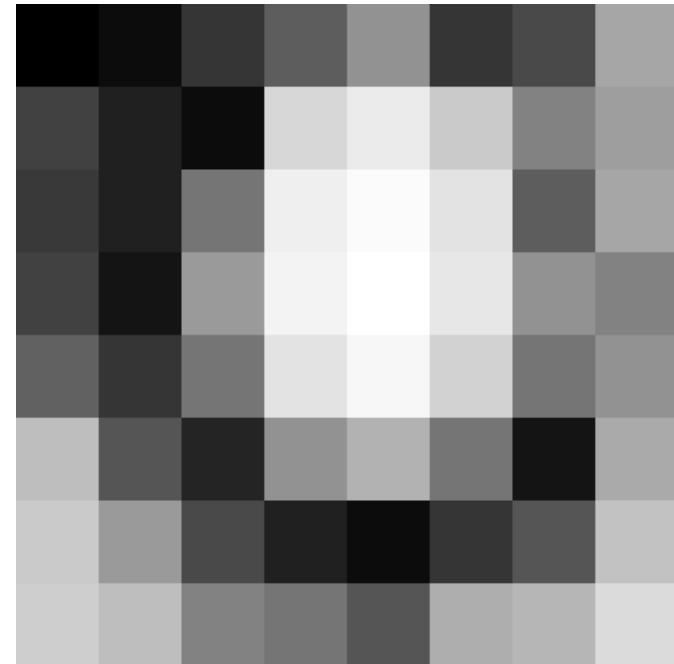


Image Enhancement in Spatial Domain

Histogram Equalization

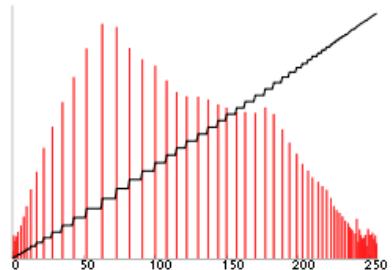
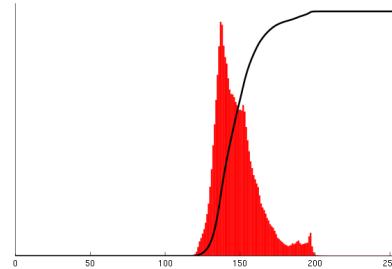
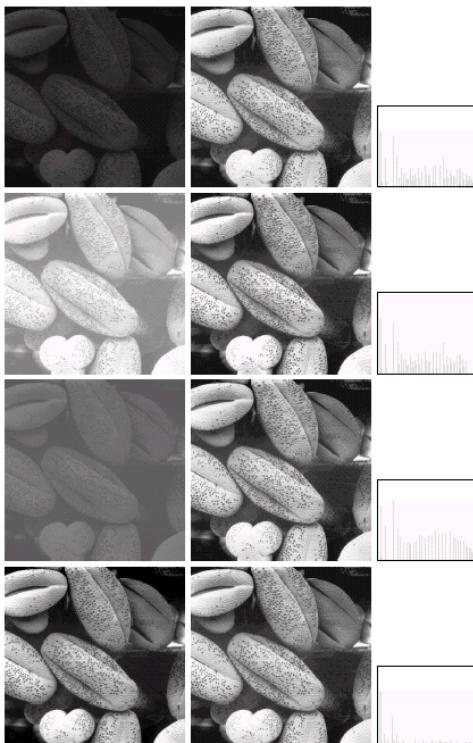


Image Enhancement in Spatial Domain

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

