CHAPTER 3: IMAGE ENHANCEMENT IN THE SPATIAL DOMAIN

3.1 Background *(page 126)*

- **Subjective:** Perceptions differ from person to person
- **OVERVIEW**

Spatial domain methods — **Chapter 3**

Direct manipulation of pixels: $g(x, y) = T[f(x, y)]$

- Point processing (1×1 masks): $s = T(r)$
- Mask processing (Spatial filtering): 3×3, 5×5 masks
- $g(x, y) = T[\text{set of input images}]$

$f(x, y)$ ⟶ Filter ⟶ $g(x, y)$

Frequency domain methods — **Chapter 4**

Modify Fourier transform

$f(x, y)$ ⟶ Transform ⟶ Filter ⟶ Inverse transform ⟶ $g(x, y)$

Connection between above methods: Convolution theorem

Combined methods: Spatial/frequency domain

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

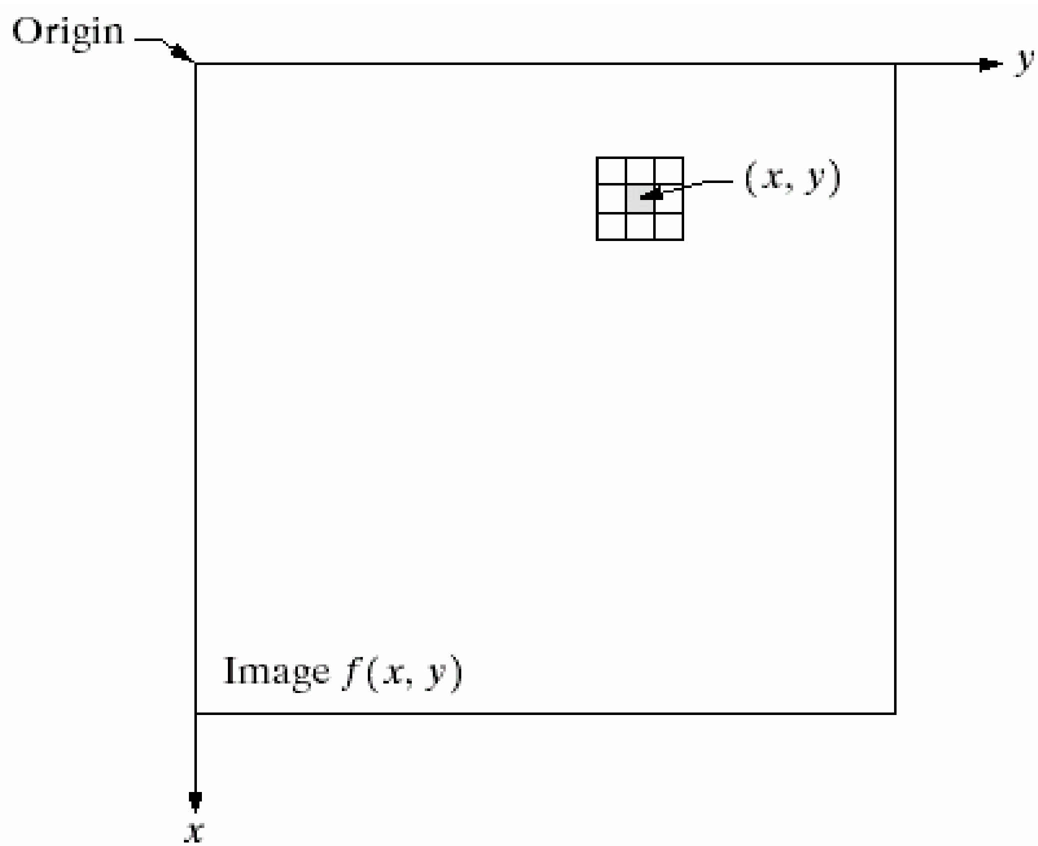
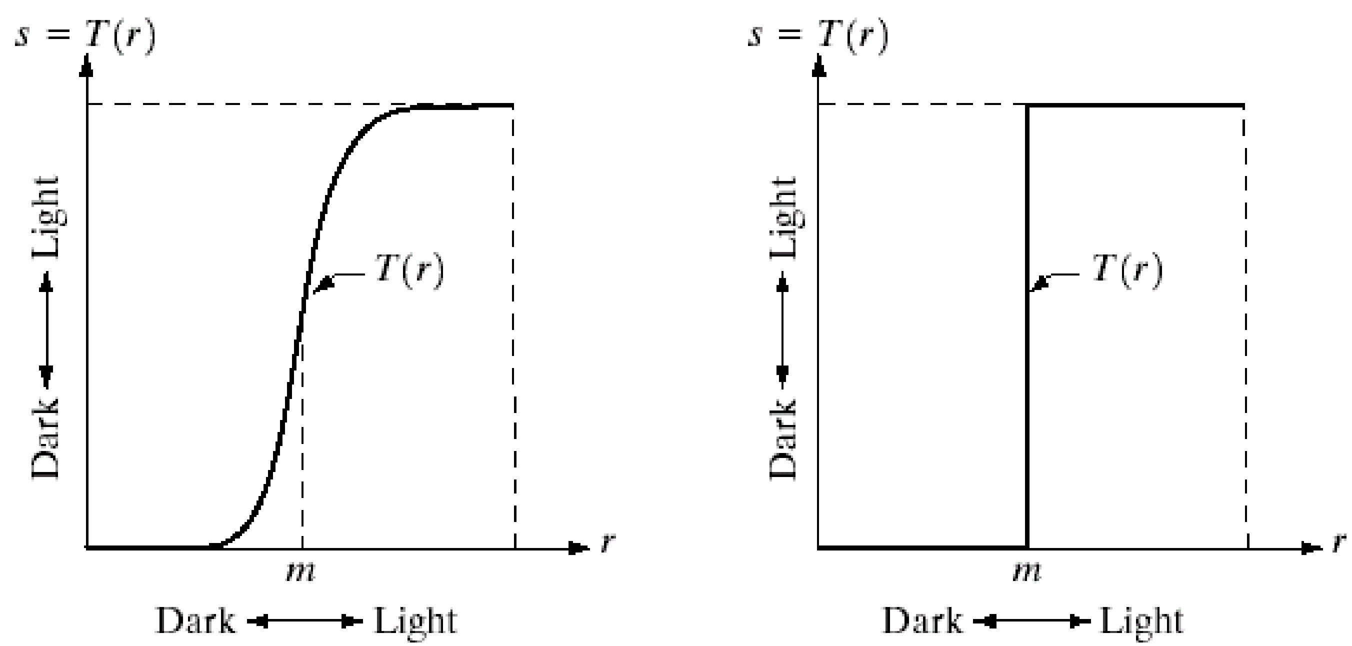


FIGURE 3.1 A 3 × 3 neighborhood about a point (x, y) in an image.

POINT PROCESSING: $s = T(r)$



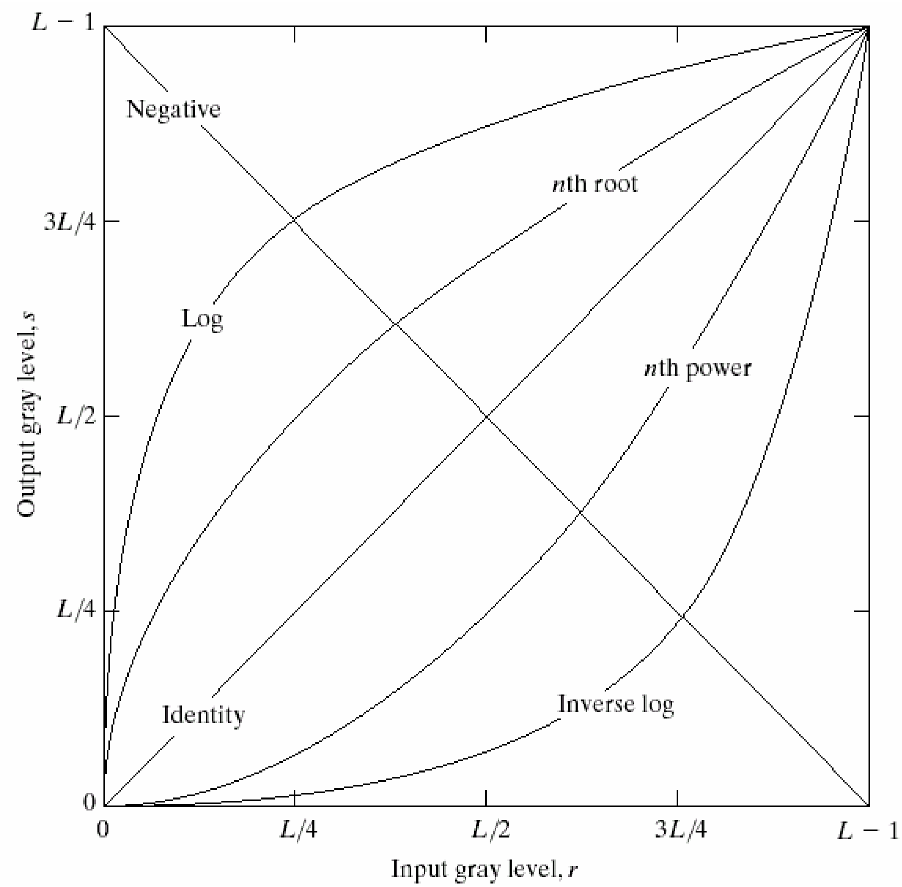
a b

FIGURE 3.2 Gray-level transformation functions for contrast enhancement.

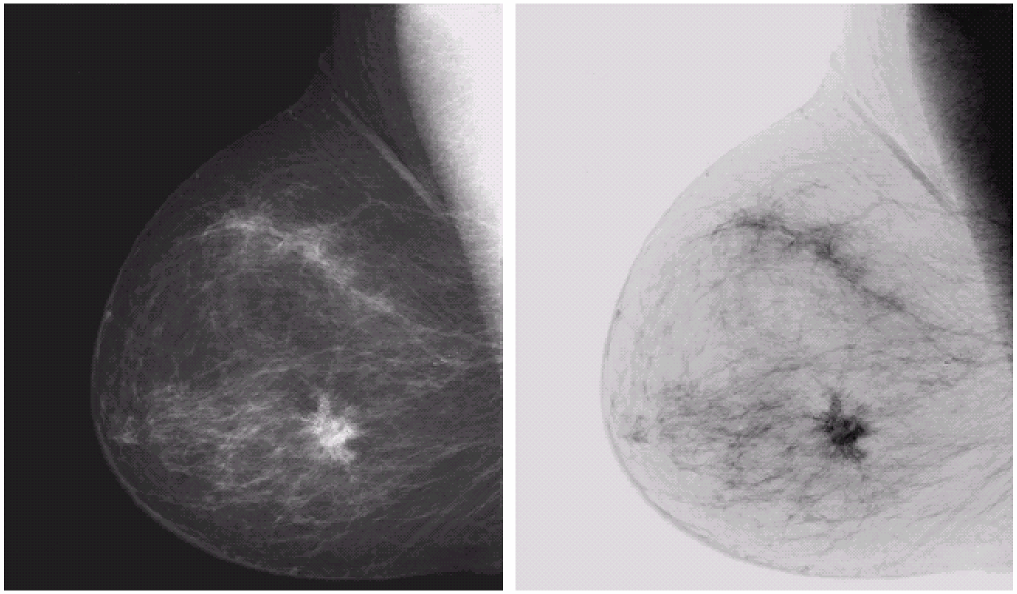
POINT PROCESSING: $s = T(r)$

- **Linear: identity, negative**
- **Logarithmic: log, inverse-log**
- **Power-law: nth power, nth root**

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



3.2 Intensity transformation functions: 3.2.1 Image Negatives: $s = L - 1 - r$



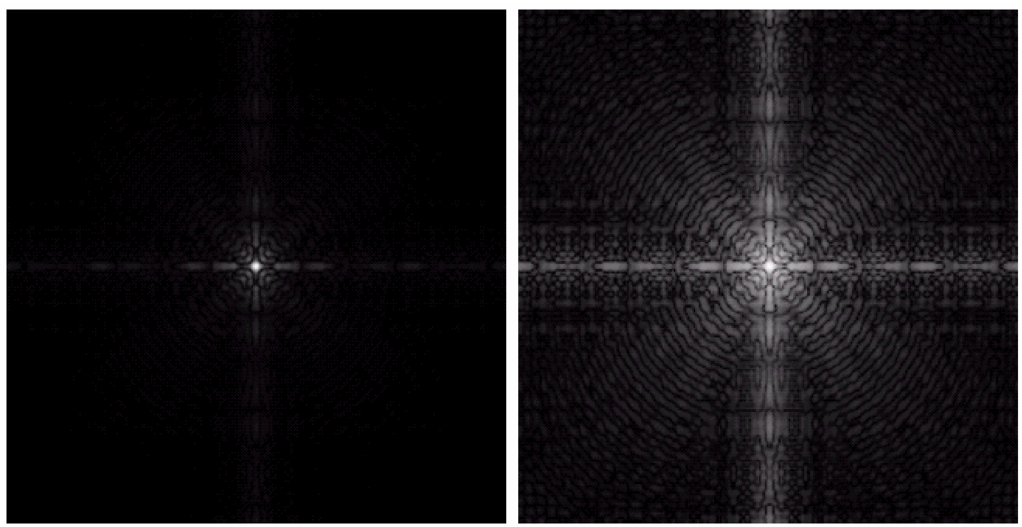
a b

FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

3.2.2 Log Transformations: $s = c\log(1 + r)$

a b

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



3.2.3 Power-Law Transformations: $s = cr^\gamma$

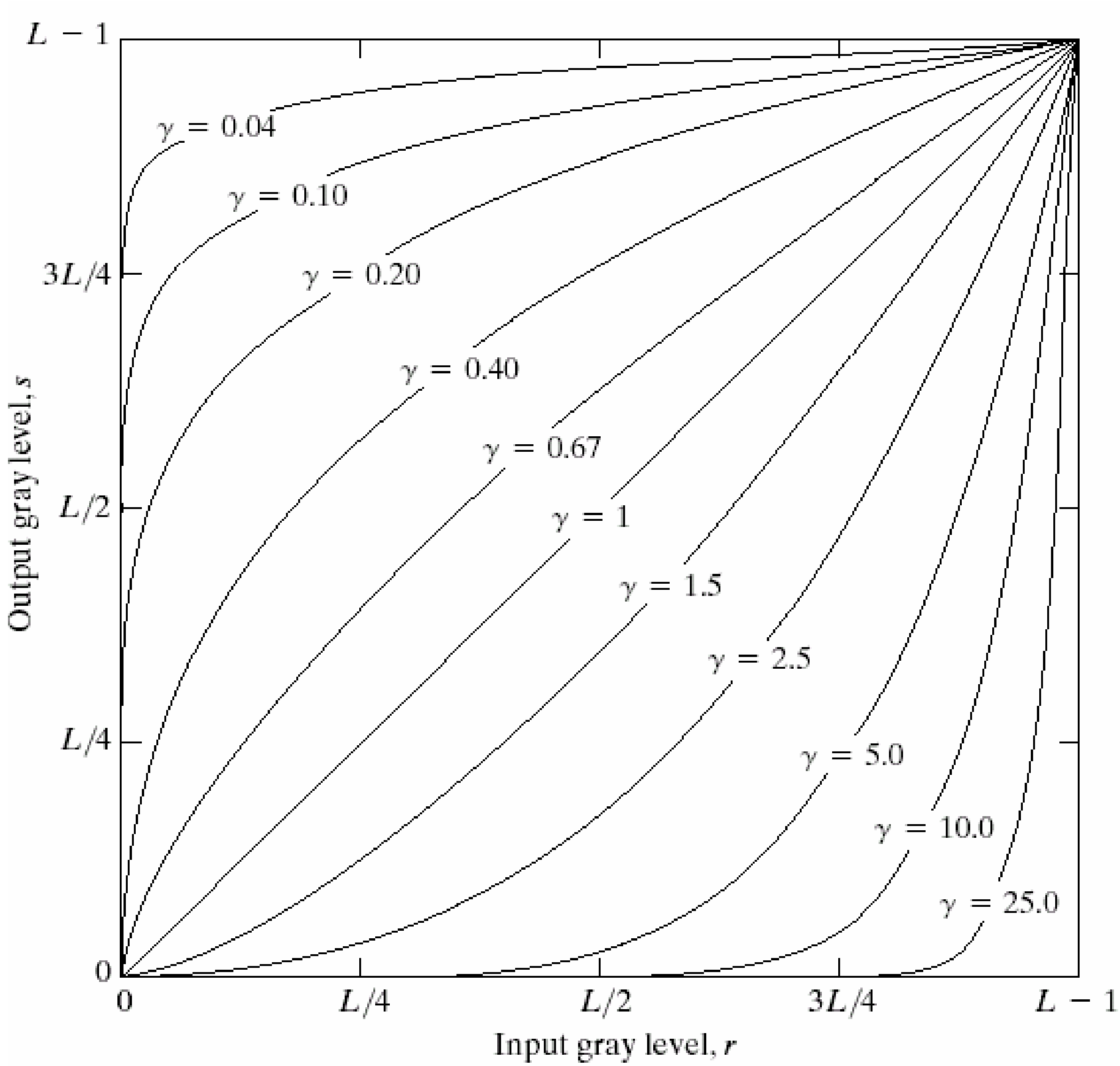
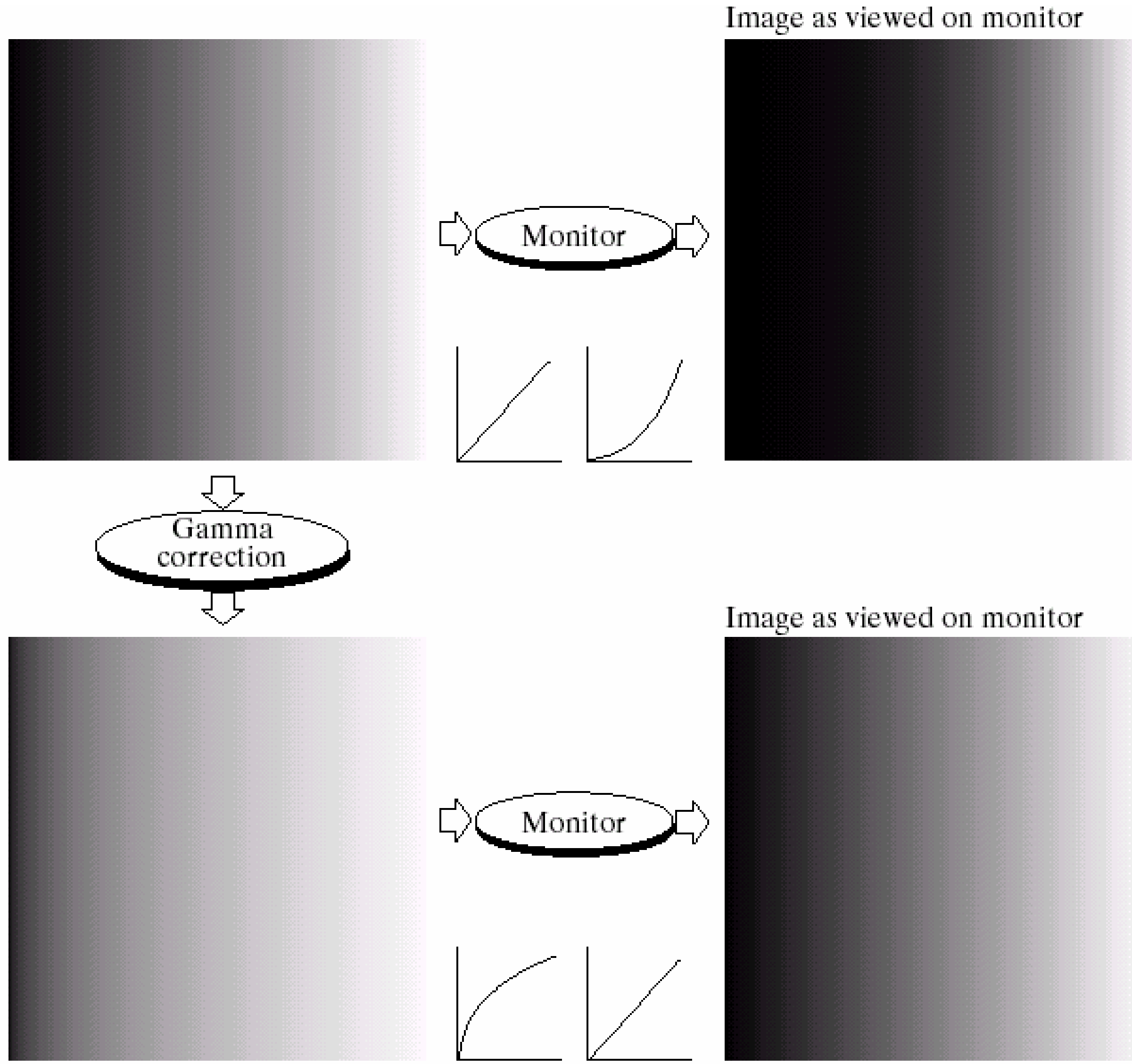


FIGURE 3.6 Plots of the equation $s = cr^\gamma$ for various values of γ ($c = 1$ in all cases).

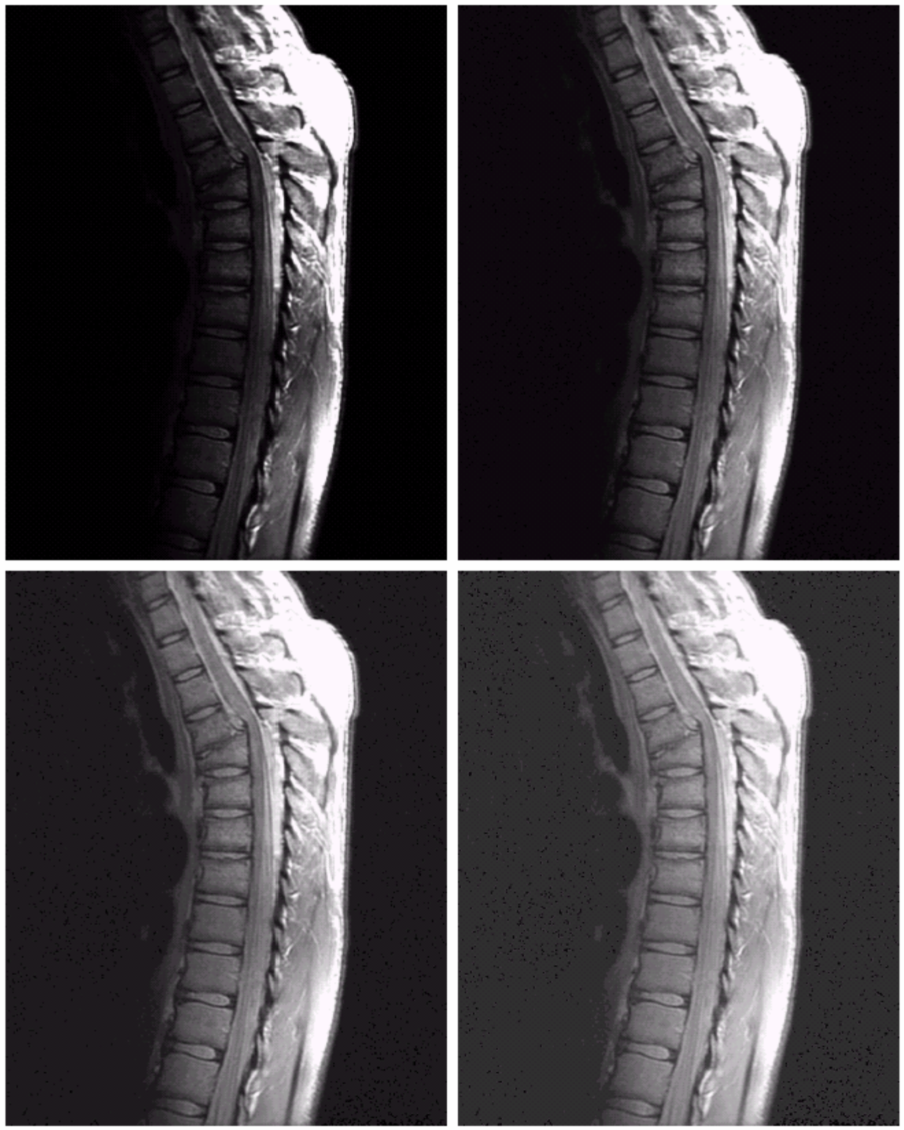
Example: Gamma correction

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.



Example 3.1: Contrast enhancement



a b
c d

FIGURE 3.8 (a) Magnetic resonance (MR) image 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 for this example courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Example 3.2

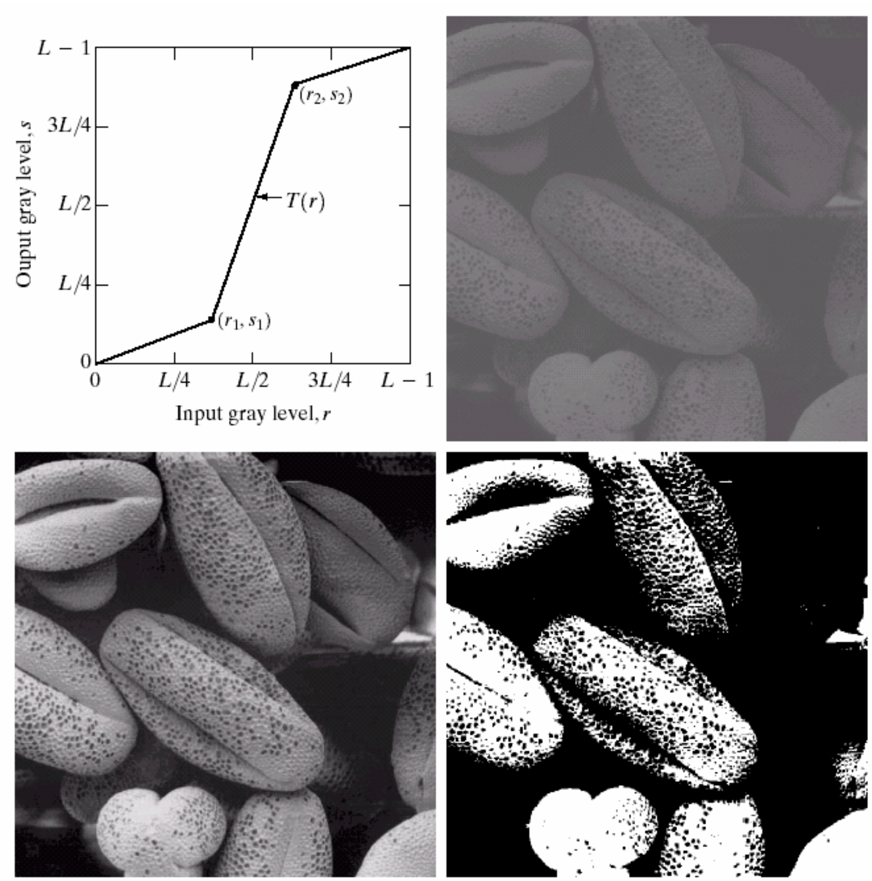
a b
c d

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.)

3.2.4. Piecewise-Linear Transformation Functions

Advantage: Arbitrarily complex
Disadvantage: More user input

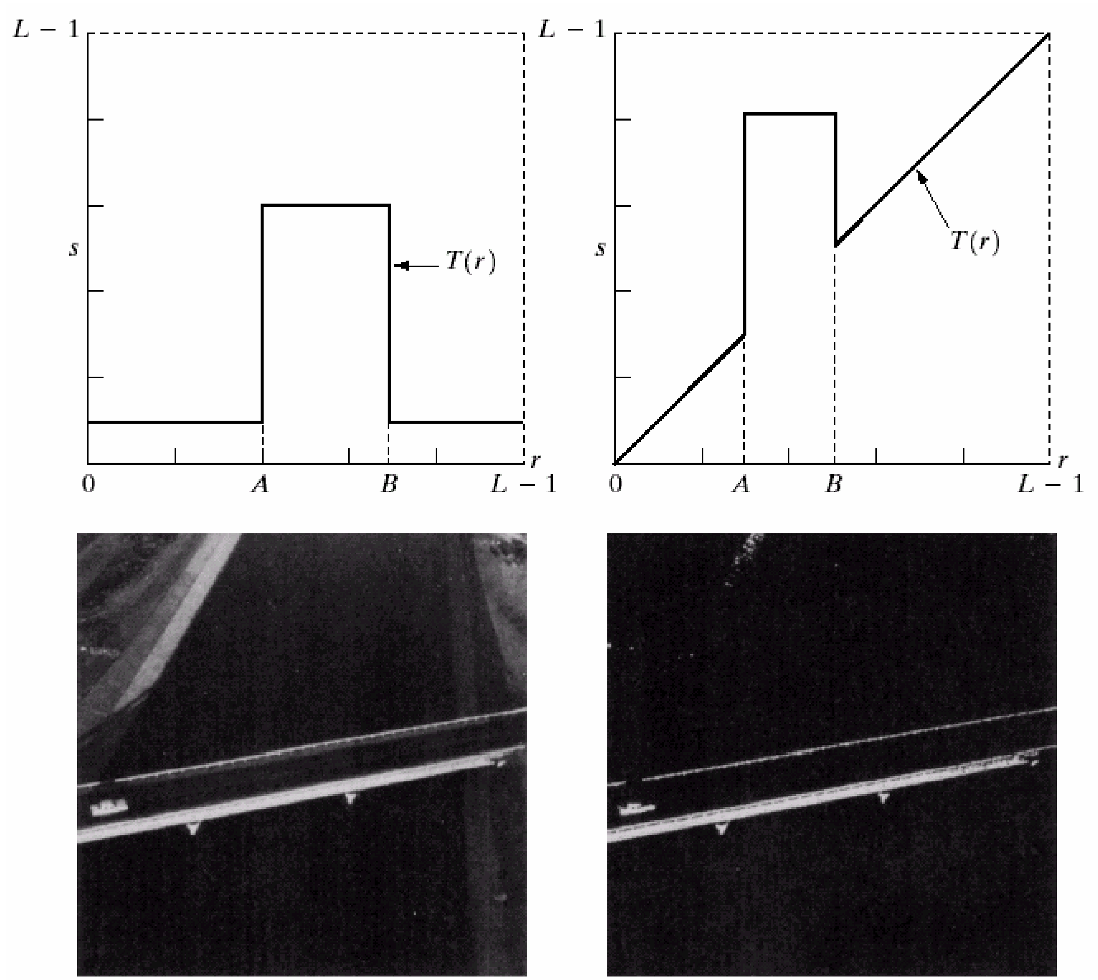
Contrast stretching



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.)

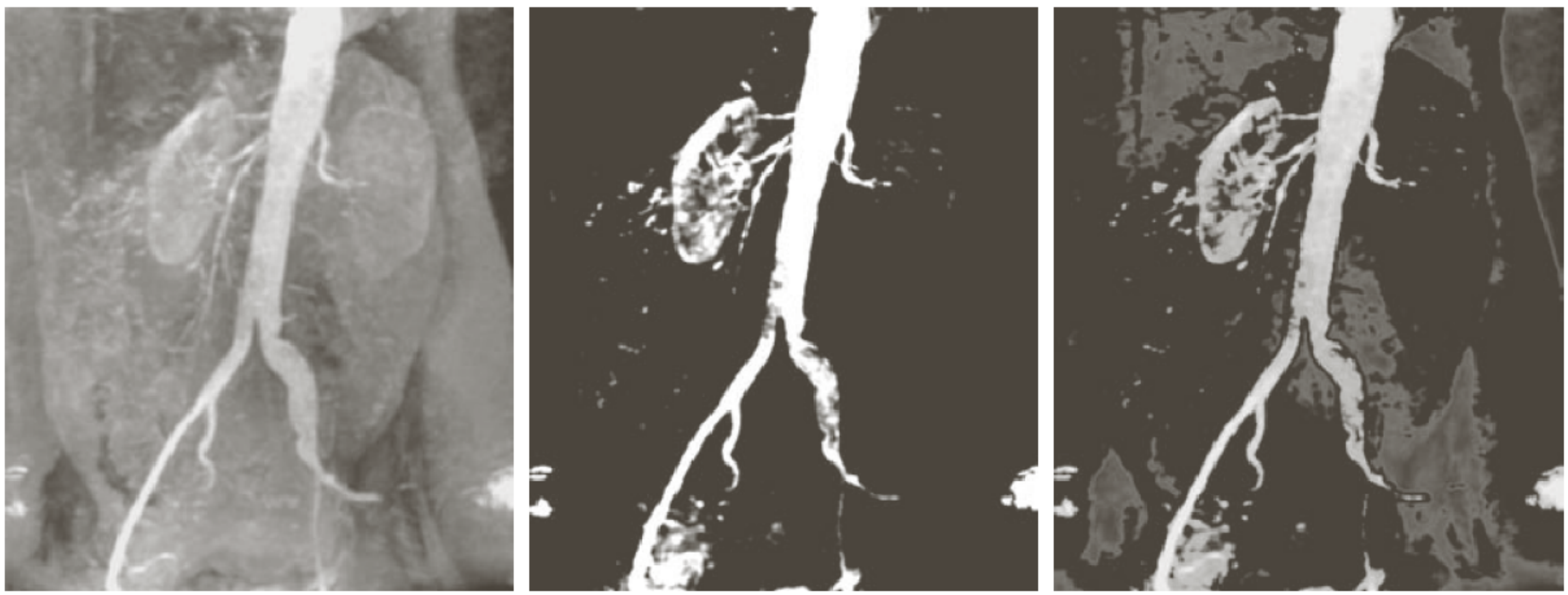
Gray-level slicing



a b
c d

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 slicing



a b c

FIGURE 3.12 (a) Aortic angiogram. (b) Result of using a slicing transformation of the type illustrated in Fig. 3.11(a), with the range of intensities of interest selected in the upper end of the gray scale. (c) Result of using the transformation in Fig. 3.11(b), with the selected area set to black, so that grays in the area of the blood vessels and kidneys were preserved. (Original image courtesy of Dr. Thomas R. Gest, University of Michigan Medical School.)

Bit-plane slicing

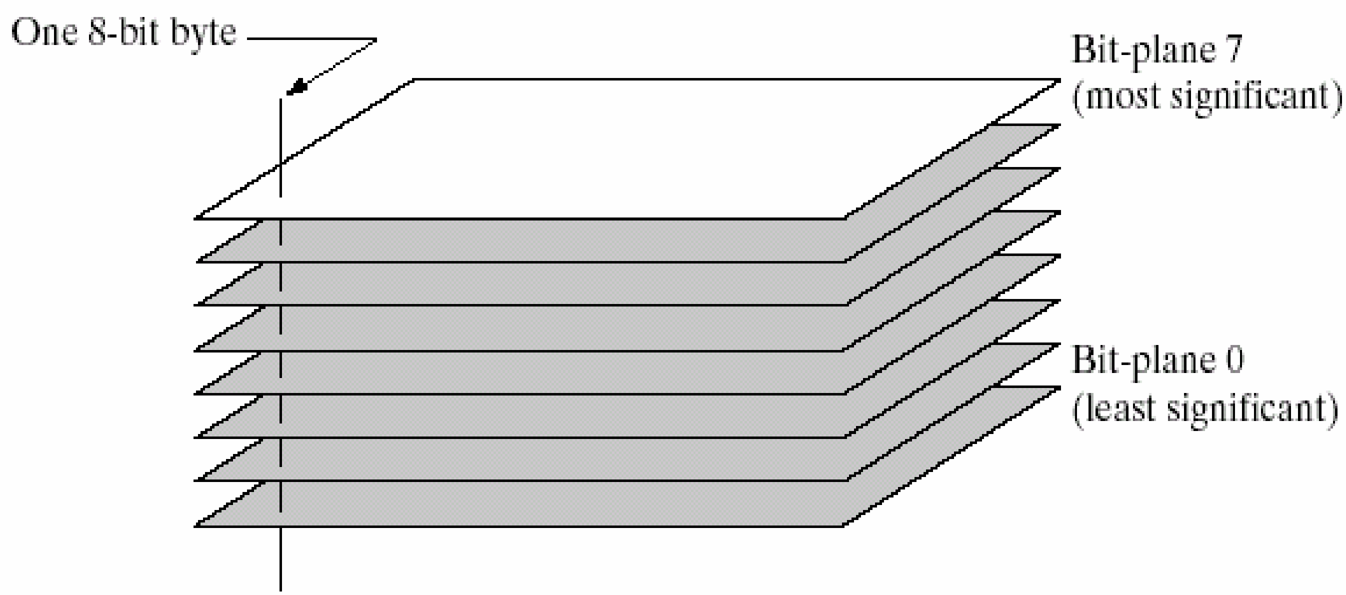


FIGURE 3.12 Bit-plane representation of an 8-bit image.

Bit-plane slicing

a	b	c
d	e	f
g	h	i

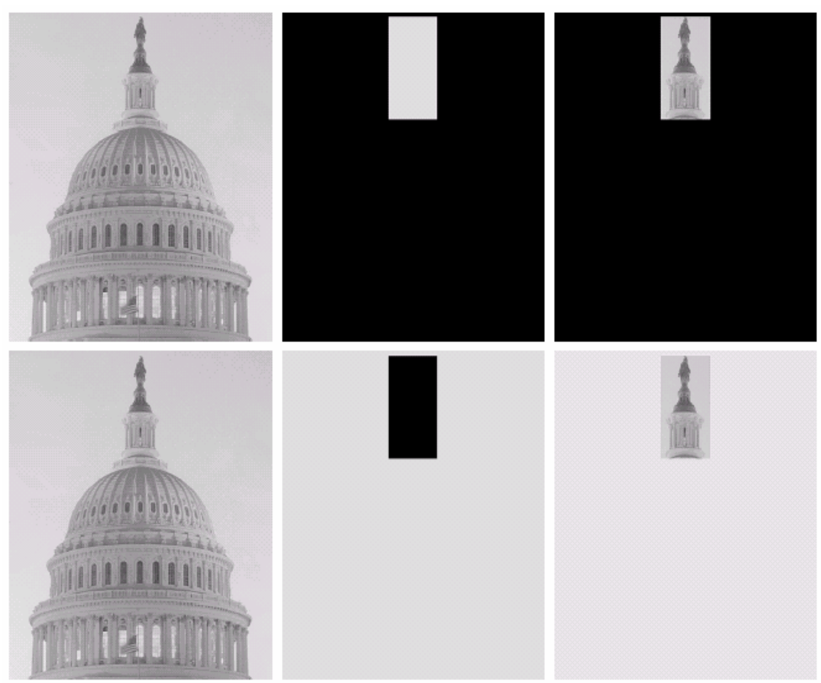
FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

a	b	c

FIGURE 3.15 Images reconstructed using (a) bit planes 8 and 7; (b) bit planes 8, 7, and 6; and (c) bit planes 8, 7, 6, and 5. Compare (c) with Fig. 3.14(a).

Arithmetic/Logic operations *(Previous version of textbook)*

- **Pixel-by-pixel between 2 or more images (NOT: 1 image)**
- **Logic operations: AND, OR, NOT**
  - **Operate on strings of binary numbers**
  - **NOT: performs negative transformation**
  - **AND, OR: masking, region of interest (ROI) processing**



a b c
d e f

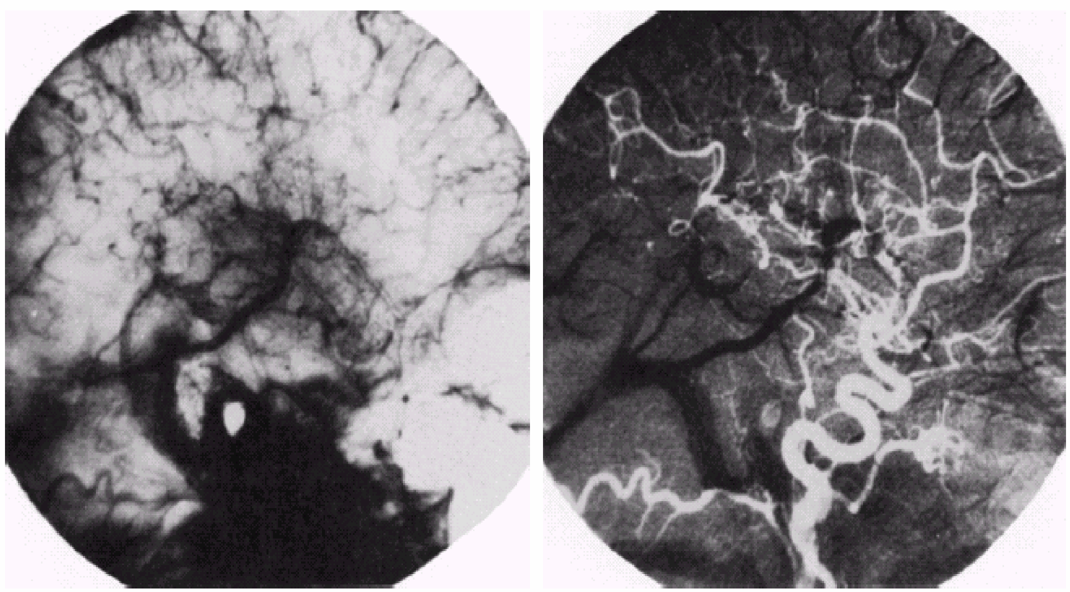
FIGURE 3.27 (a) Original image. (b) AND image mask. (c) Result of the AND operation on images (a) and (b). (d) Original image. (e) OR image mask. (f) Result of operation OR on images (d) and (e).

Image Subtraction *(Previous version of textbook)*

$$g(x, y) = f(x, y) - h(x, y)$$

- **Enhancement of differences between images**

- $f(x, y)$: **Dynamic TV image with dye injected**
- $h(x, y)$: **Mask: Still TV image without dye**
- $g(x, y)$: **Dynamic TV image with mask subtracted out**



a b

FIGURE 3.29 Enhancement by image subtraction. (a) Mask image. (b) An image (taken after injection of a contrast medium into the bloodstream) with mask subtracted out.