جَامعة
المَـنارة
MANARA UNIVERSITY

DIGITAL IMAGE PROCESSING

CHAPTER 3

IMAGE ENHANCEMENT IN THE SPATIAL DOMAIN

Image Enhancement

- To process an image so that the result is more suitable than the original image for a *specific* application.

- Spatial domain methods and frequency domain methods.

Image Enhancement Example

Original image

Image after processing
Gamma correction

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Spatial Domain Methods

- Procedures that operate directly on the aggregate of pixels composing an image

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

Where

- *f(x,y)* is the input image
- *g(x,y)* is the processed image and
- *T[ ]* is operator on *f* defined over some neighborhood of *(x,y)*

A neighborhood about (x,y) is defined by using a square (or rectangular) subimage area centered at (x,y).

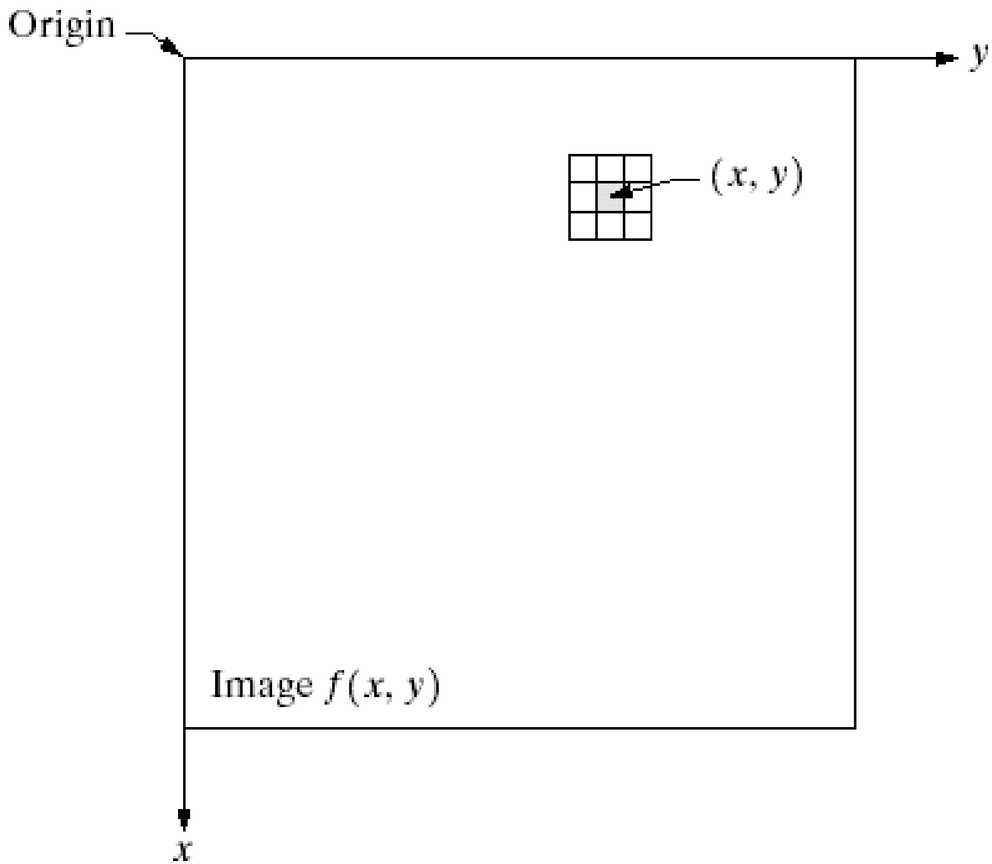


FIGURE 3.1 A 3×3 neighborhood about a point (x, y) in an image.

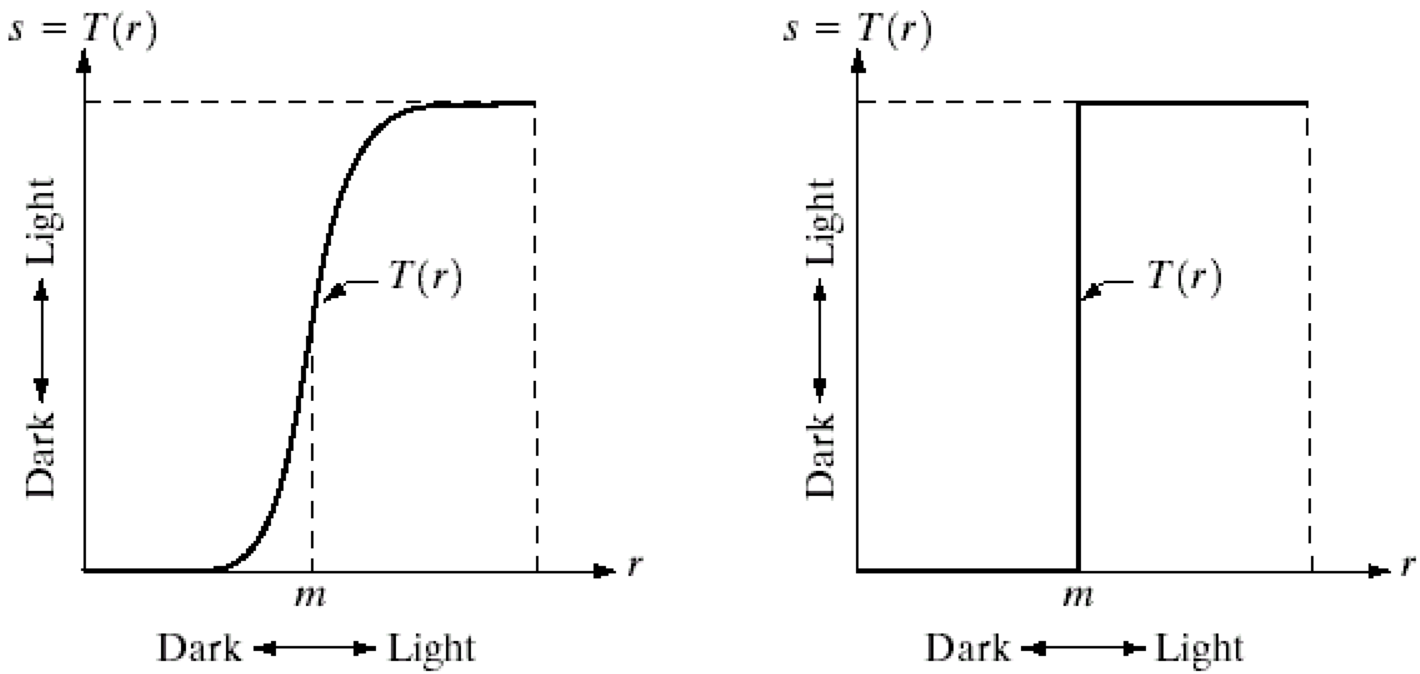
Spatial Domain Methods

- When the neighborhood is 1 x 1 then g depends only on the value of *f* at (x , y) and *T* becomes a gray-level transformation (or mapping) function:

$$s = T(r)$$

r,s: gray levels of f(x,y) and g(x,y) at (x,y)

- Point processing techniques (e.g. contrast stretching, thresholding)



a b

FIGURE 3.2 Gray-level transformation functions for contrast enhancement.

Contrast Stretching

Thresholding

Spatial Domain Methods

- **Mask processing or filtering**: when the values of f in a predefined neighborhood of (x,y) determine the value of g at (x,y).
  - Through the use of masks (or kernels, templates, or windows, or filters).

Enhancement by Point Processing

- These are methods based only on the intensity of single pixels.

$$s = T(r)$$

  - r denotes the pixel intensity before processing.
  - s denotes the pixel intensity after processing.

Some Simple Intensity Transformations

- Image negatives
- Piecewise-Linear Transformation Functions:
  - Contrast stretching
  - Gray-level slicing
  - Bit-plane slicing

➢ Implemented via Look-Up Tables (LUT) where values of *T* are stored in a 1-D array (for 8-bit, LUT will have 256 values)

Some basic gray-level transformation functions used for image enhancement

Linear: Negative, Identity

Logarithmic: Log, Inverse Log

Power-Law: *n*th power, *n*th root

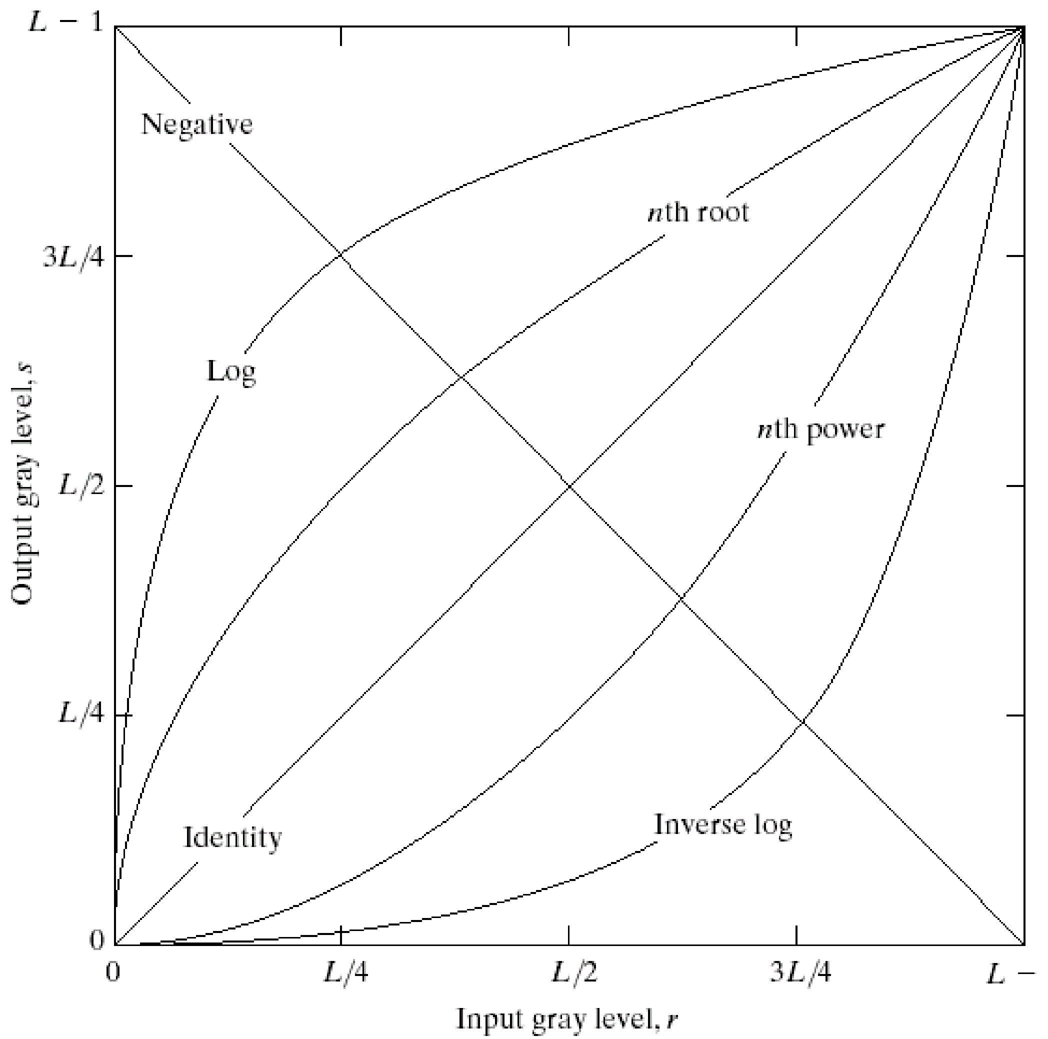
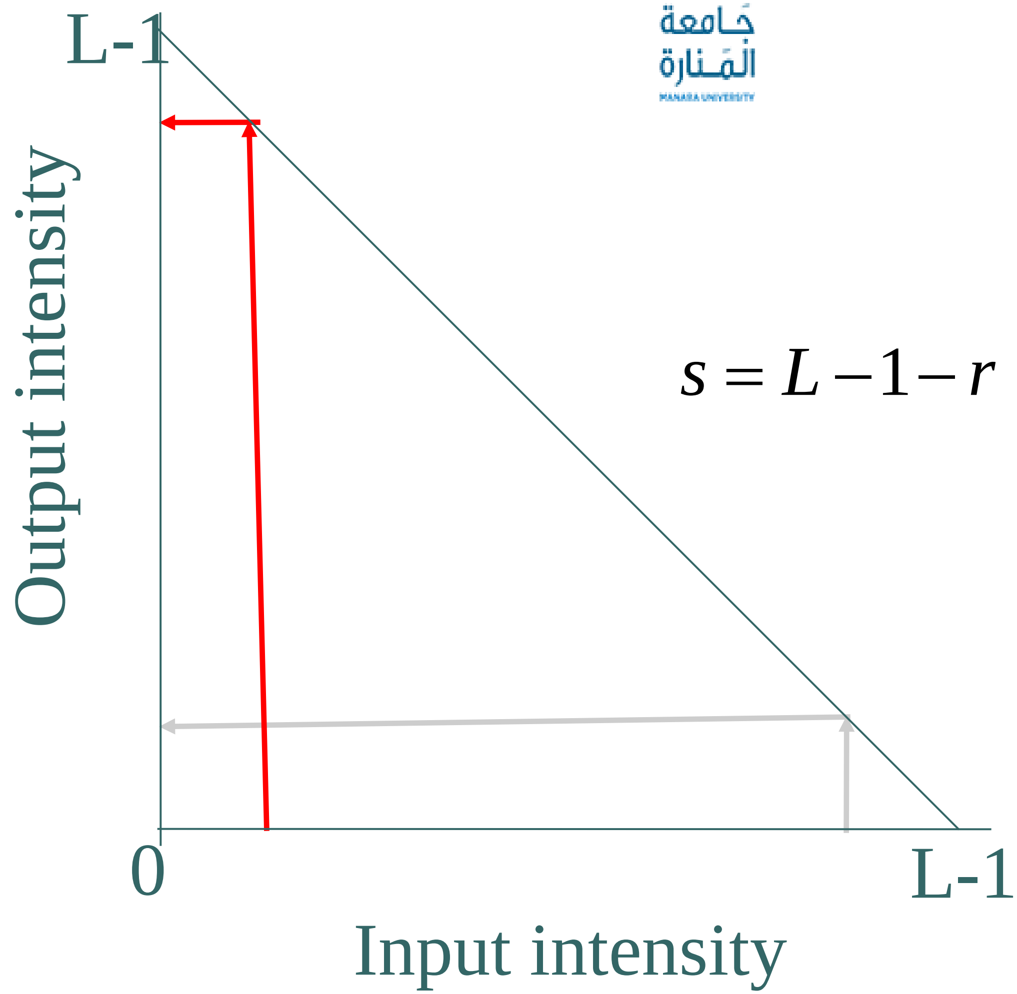


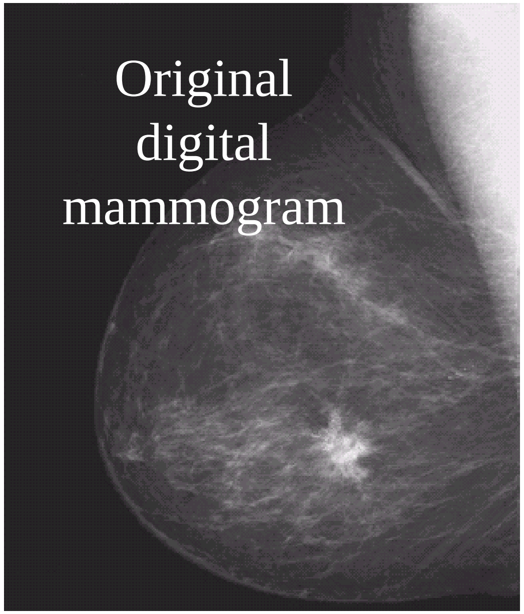
Image Negatives

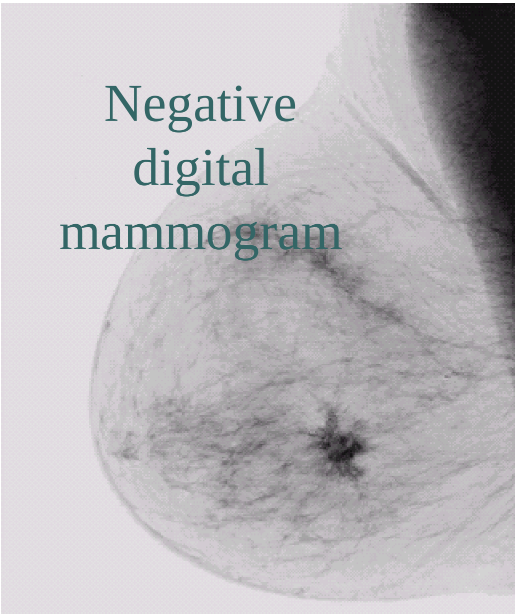
- Function reverses the order from black to white so that the intensity of the output image decreases as the intensity of the input increases.
- Used mainly in medical images and to produce slides of the screen.
- Note: *Because the eye responds logarithmically to brightness changes, subtle brightness changes in the bright regions of an image may be undetectable. With the complement operation these subtle brightness changes are transformed to dark regions so that they become more clearly visible.*

Image Negative



$$s = L - 1 - r$$





[0,L-1] the range of gray levels

$s = L - 1 - r$

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Log Transformations

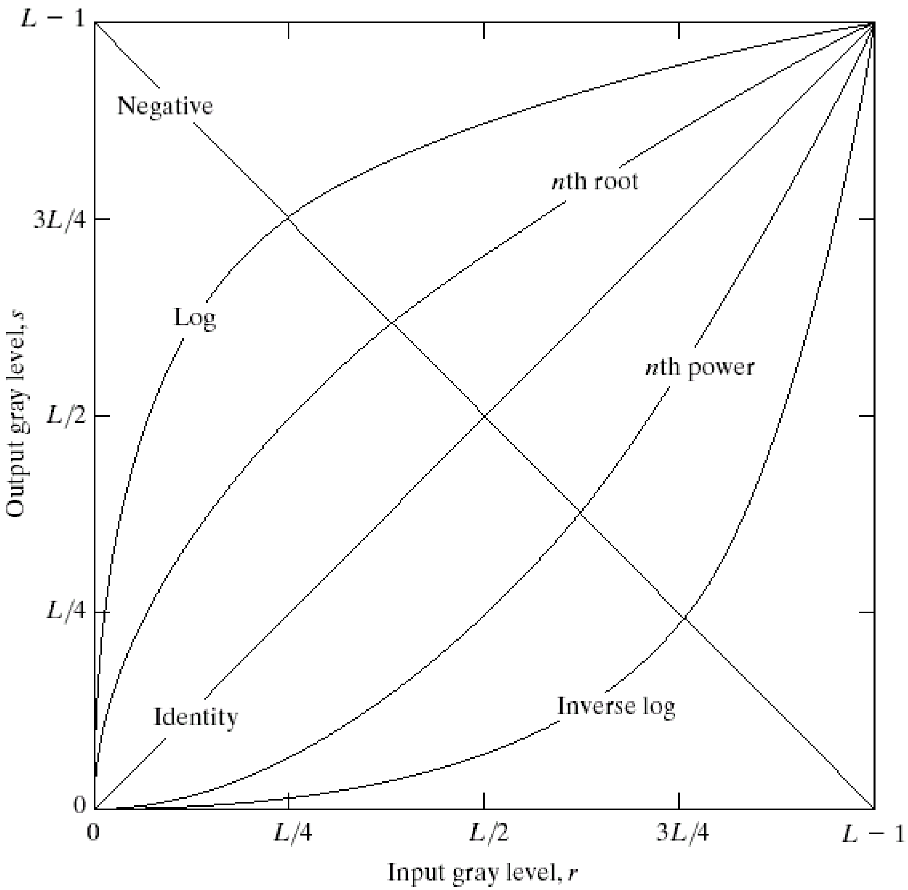
$$s = c \log(1+r)$$

c: constant

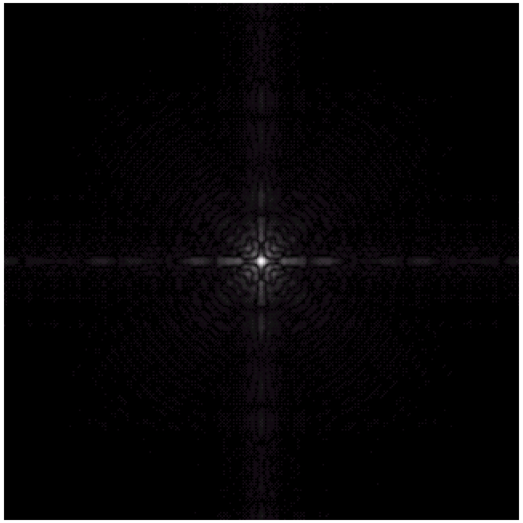
- Compresses the dynamic range of images with large variations in pixel values

Application: the display of the Fourier spectrum of an image

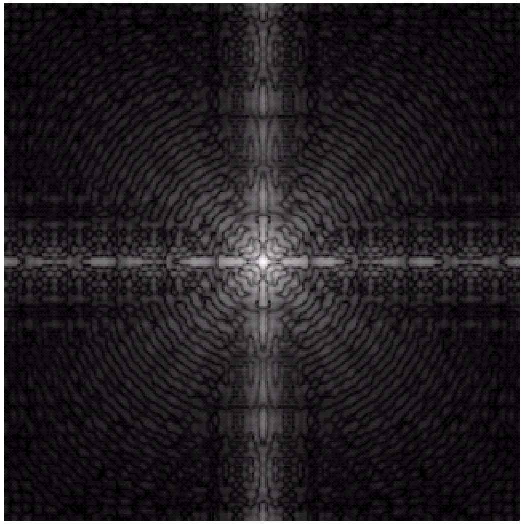
$$s = c\log(r+1)$$



Fourier spectrum "Image with large dynamic range (pixel values ranging from 0 to 2.5 x 10^6)"



Log Tr. of Fourier Spectrum (Significant increase in visible detail)



(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Power-Law Transformations

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

c, γ : positive constants

- Gamma correction

Power-Law Transformations

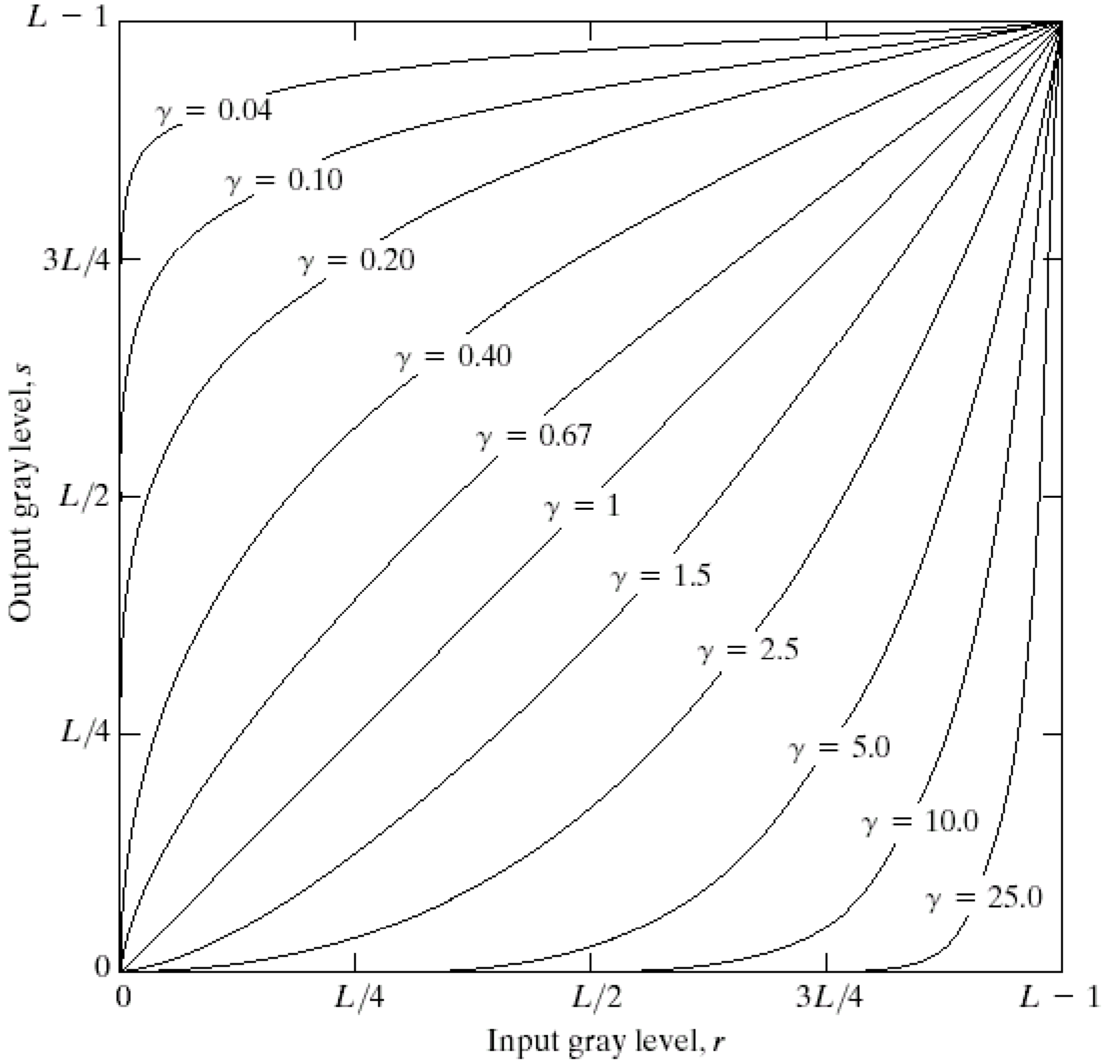


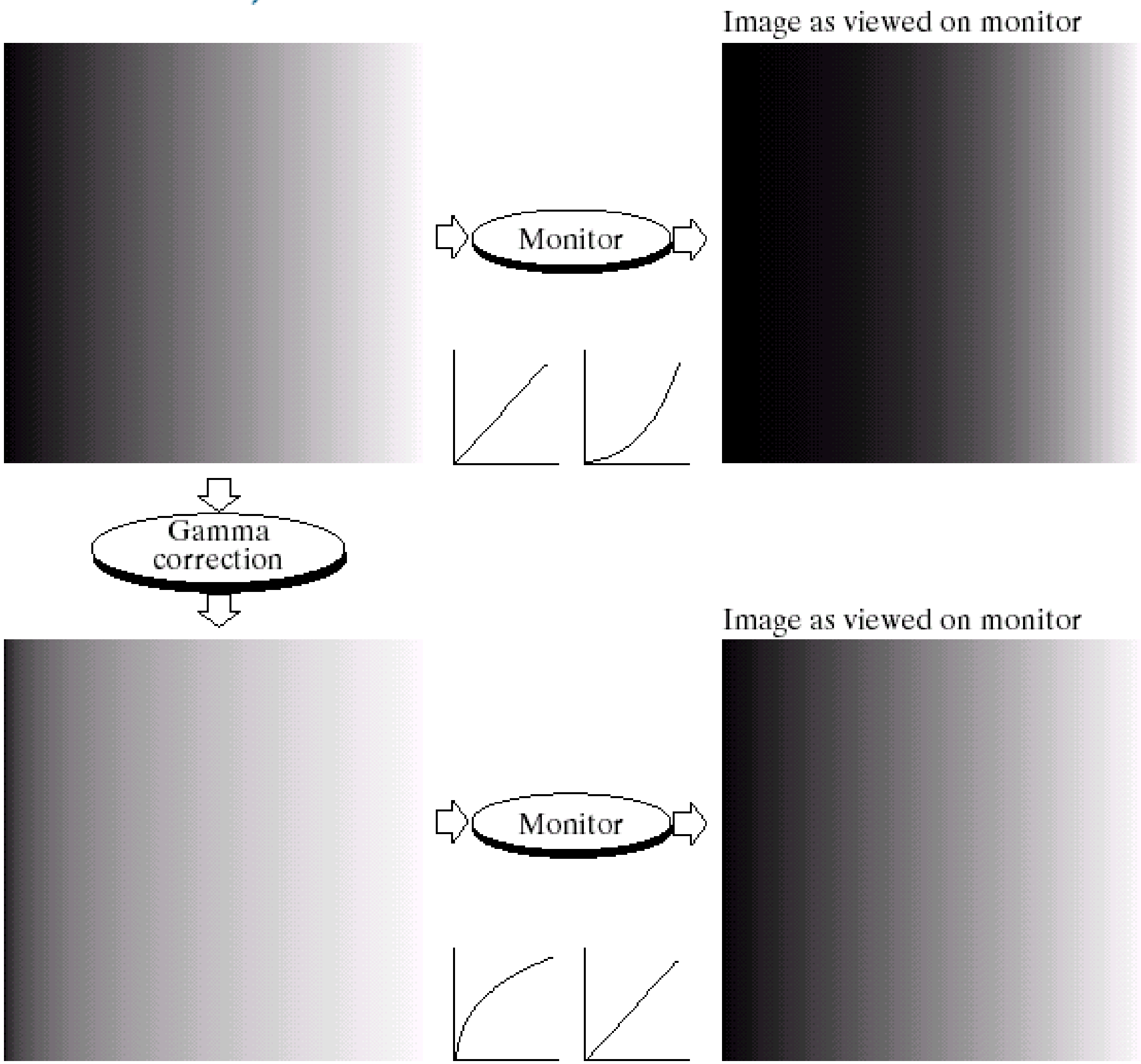
FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

$\gamma = c = 1$: identity

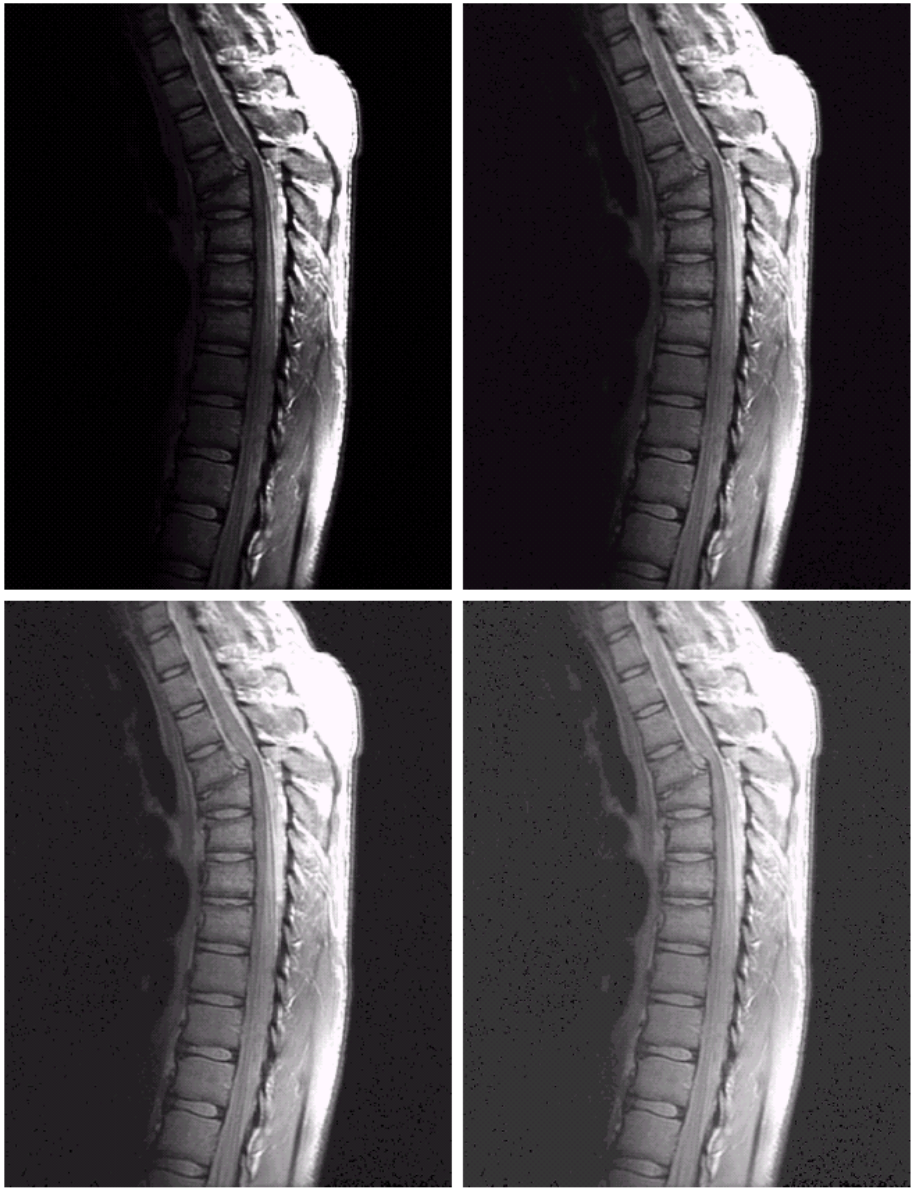
Power-Law Transformations : Gamma Correction Application

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.



Power-Law Transformations : Gamma Correction Application



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.

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

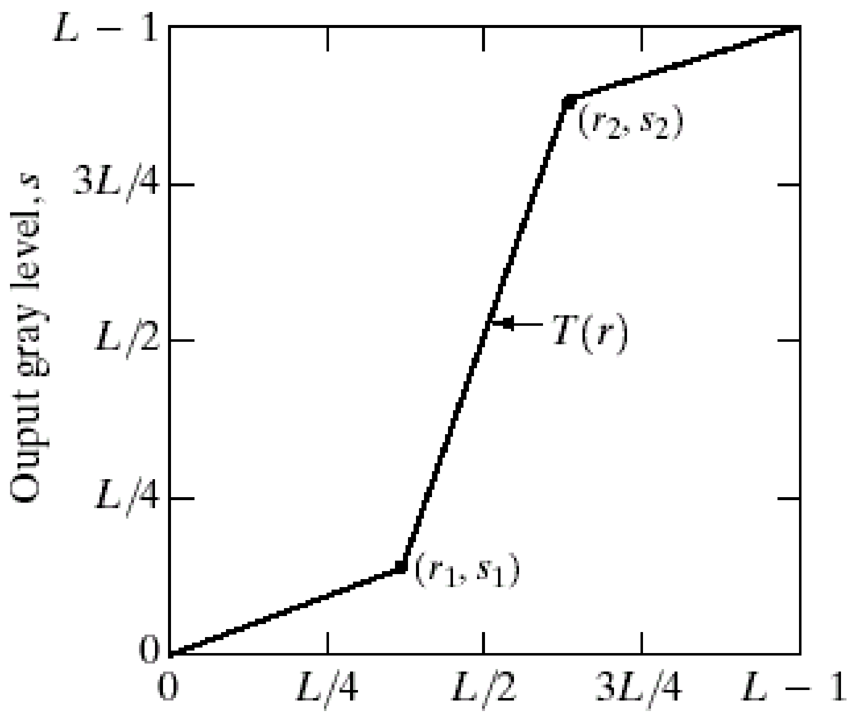
(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

a	b
c	d

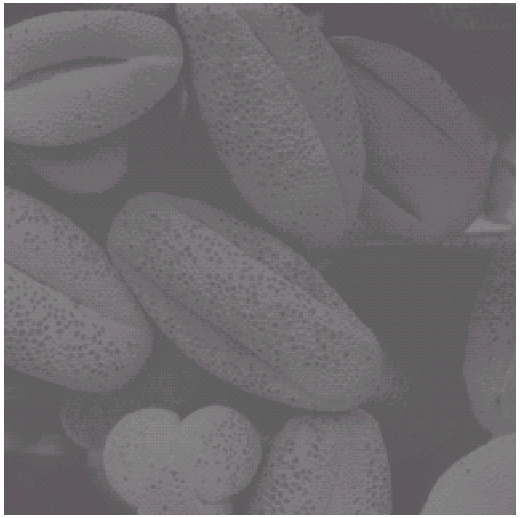
FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively.

Piecewise-Linear Transformation Functions

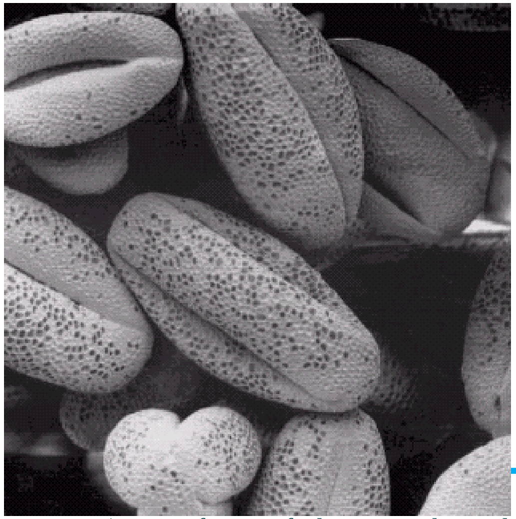
- To increase the dynamic range of the gray levels in the image being processed.



Before contrast enhancement



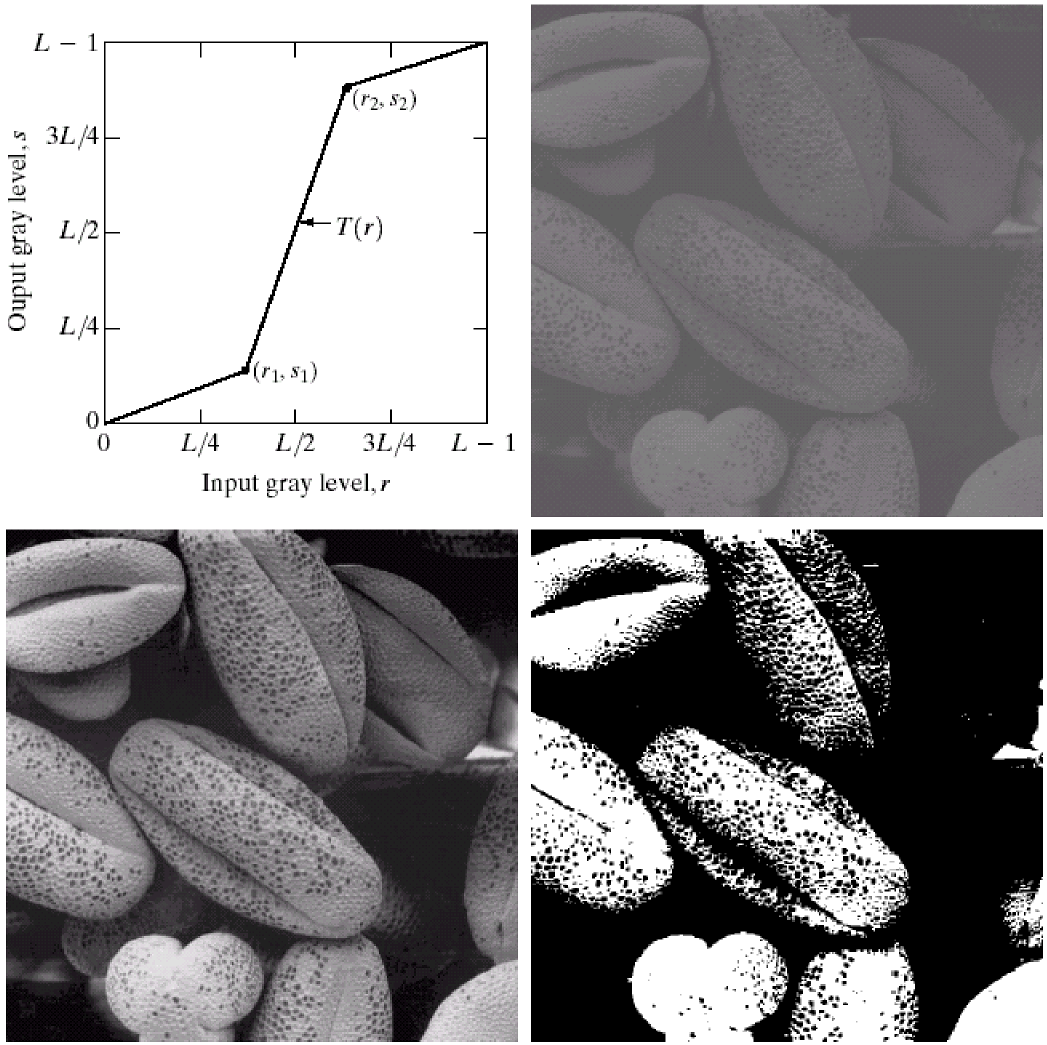
After



(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Contrast Stretching

- The locations of (r_1,s_1) and (r_2,s_2) control the shape of the transformation function.
  - If $r_1= s_1$ and $r_2= s_2$ the transformation is a linear function and produces no changes.
  - If $r_1=r_2$, $s_1=0$ and $s_2=L-1$, the transformation becomes a thresholding function that creates a binary image.



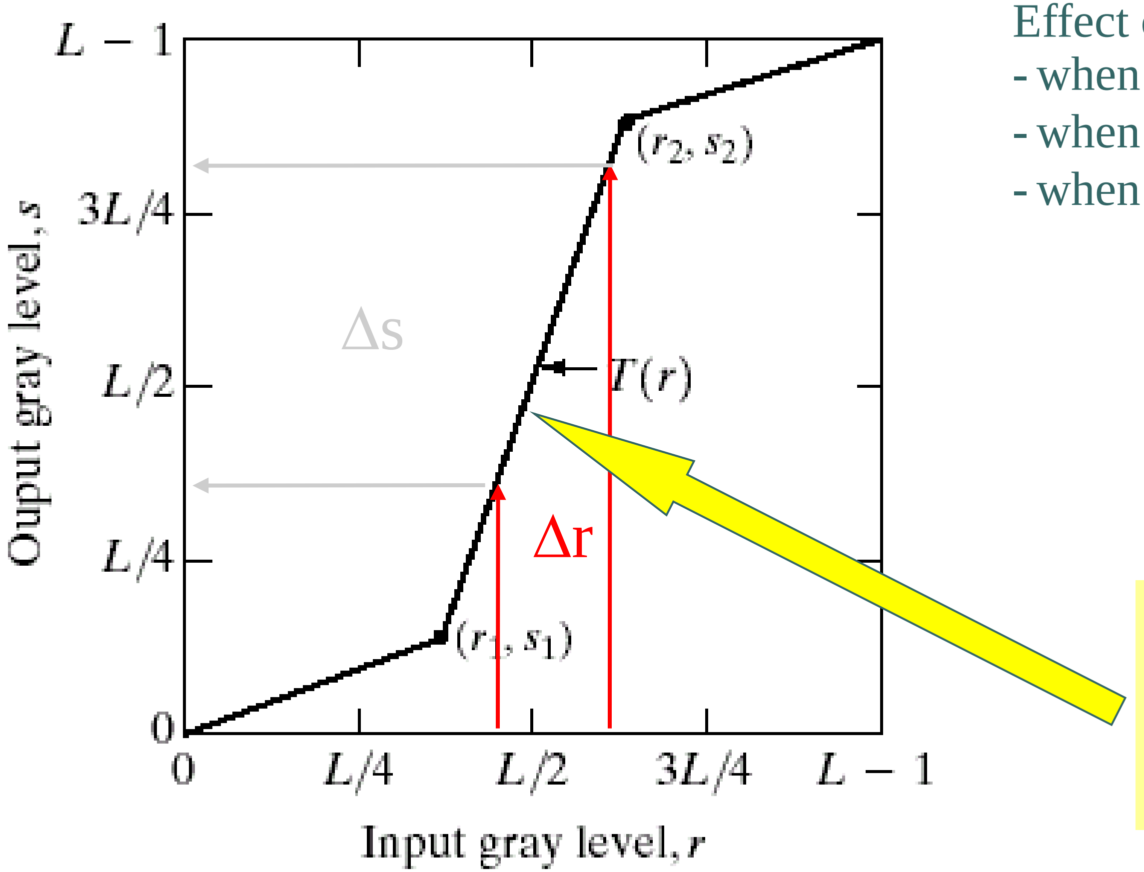
a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding.

Contrast Stretching

- More on function shapes:
  - Intermediate values of (r_1,s_1) and (r_2,s_2) produce various degrees of spread in the gray levels of the output image, thus affecting its contrast.
  - Generally, $r_1 \leq r_2$ and $s_1 \leq s_2$ is assumed.

How to know where the contrast is enhanced ?



Effect of Slope on T(r)

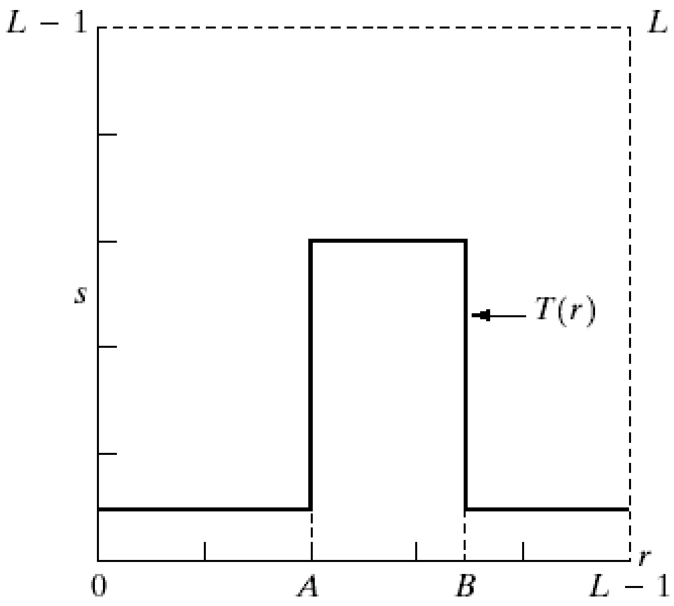
- when Slope > 1 → Contrast increase
- when Slope < 1 → Contrast decrease
- when Slope = 1 → Contrast same

Δr is narrow compared to Δs and leads to Contrast increase

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Gray-Level Slicing

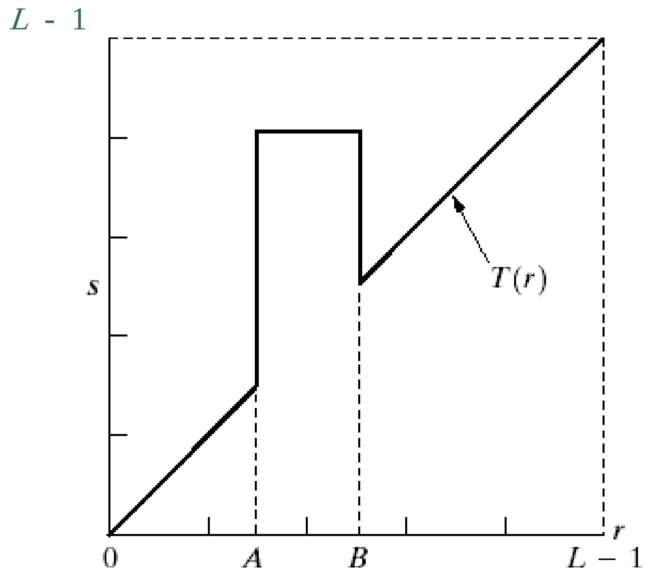
- To highlight a specific range of gray levels in an image (e.g. to enhance certain features).

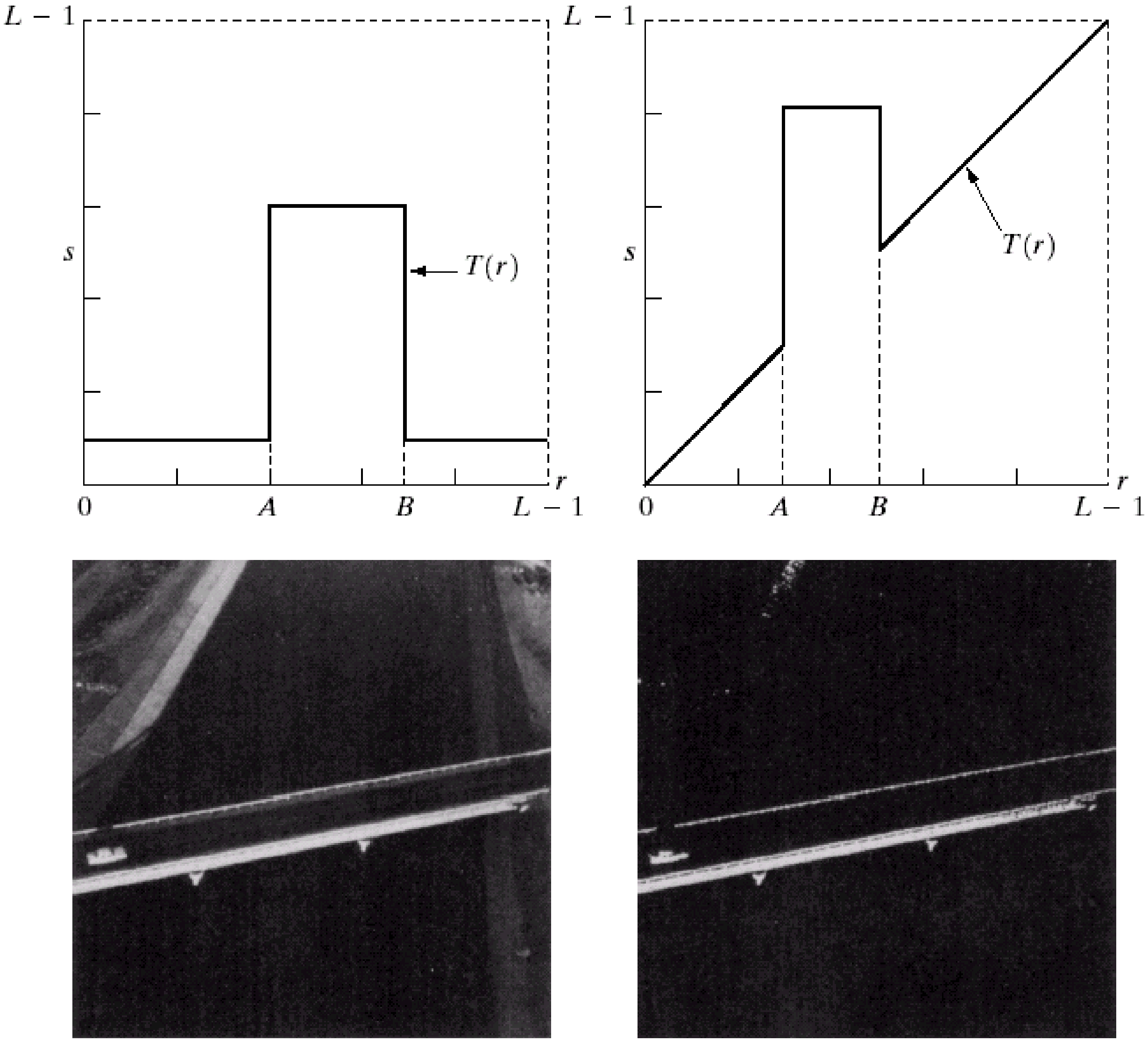


One way is to display a high value for all gray levels in the range of interest and a low value for all other gray levels (binary image).

Gray-Level Slicing

- The second approach is to brighten the desired range of gray levels but preserve the background and gray-level tonalities in the image:





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).

Bit-Plane Slicing

- To highlight the contribution made to the total image appearance by specific bits.
  - i.e. Assuming that each pixel is represented by 8 bits, the image is composed of 8 1-bit planes.
  - Plane 0 contains the least significant bit and plane 7 contains the most significant bit.

Bit-Plane Slicing

- More on bit planes:
  - Only the higher order bits (top four) contain visually significant data. The other bit planes contribute the more subtle details.
  - Plane 7 corresponds exactly with an image thresholded at gray level 128.

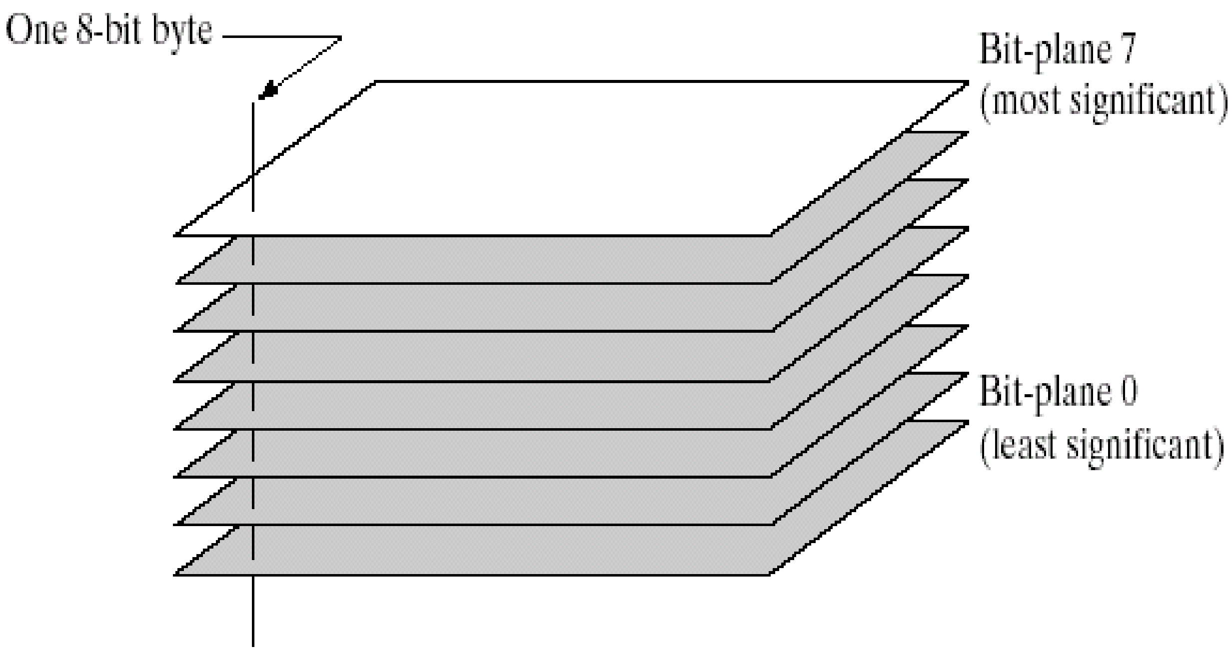


FIGURE 3.12 Bit-plane representation of an 8-bit image.

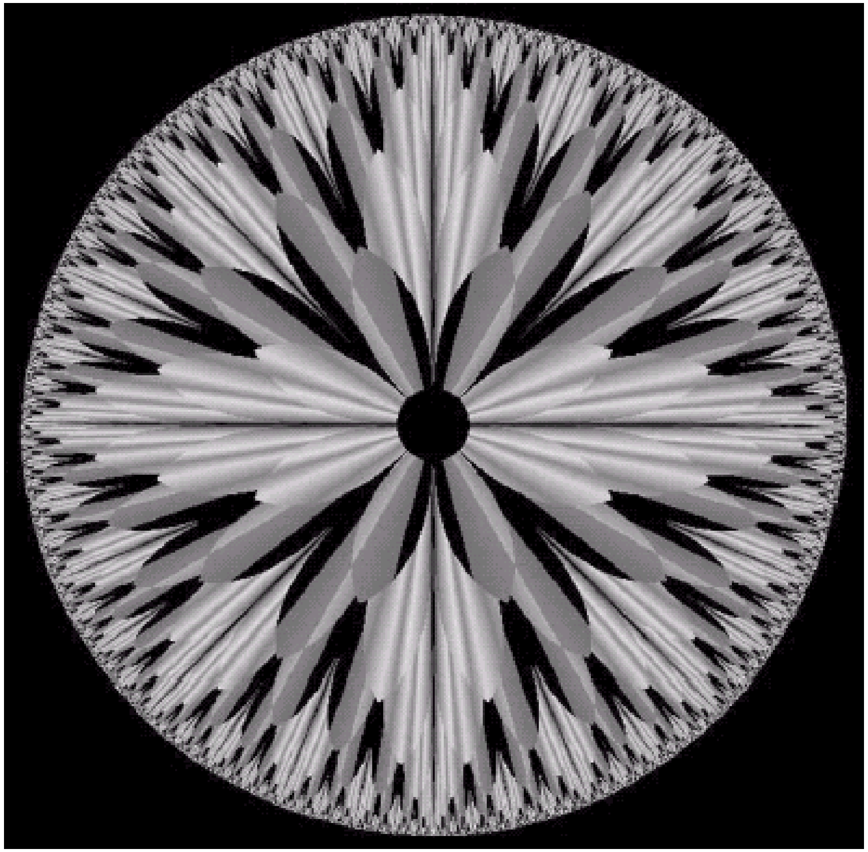


FIGURE 3.13 An 8-bit fractal image. (A fractal is an image generated from mathematical expressions). (Courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA.)

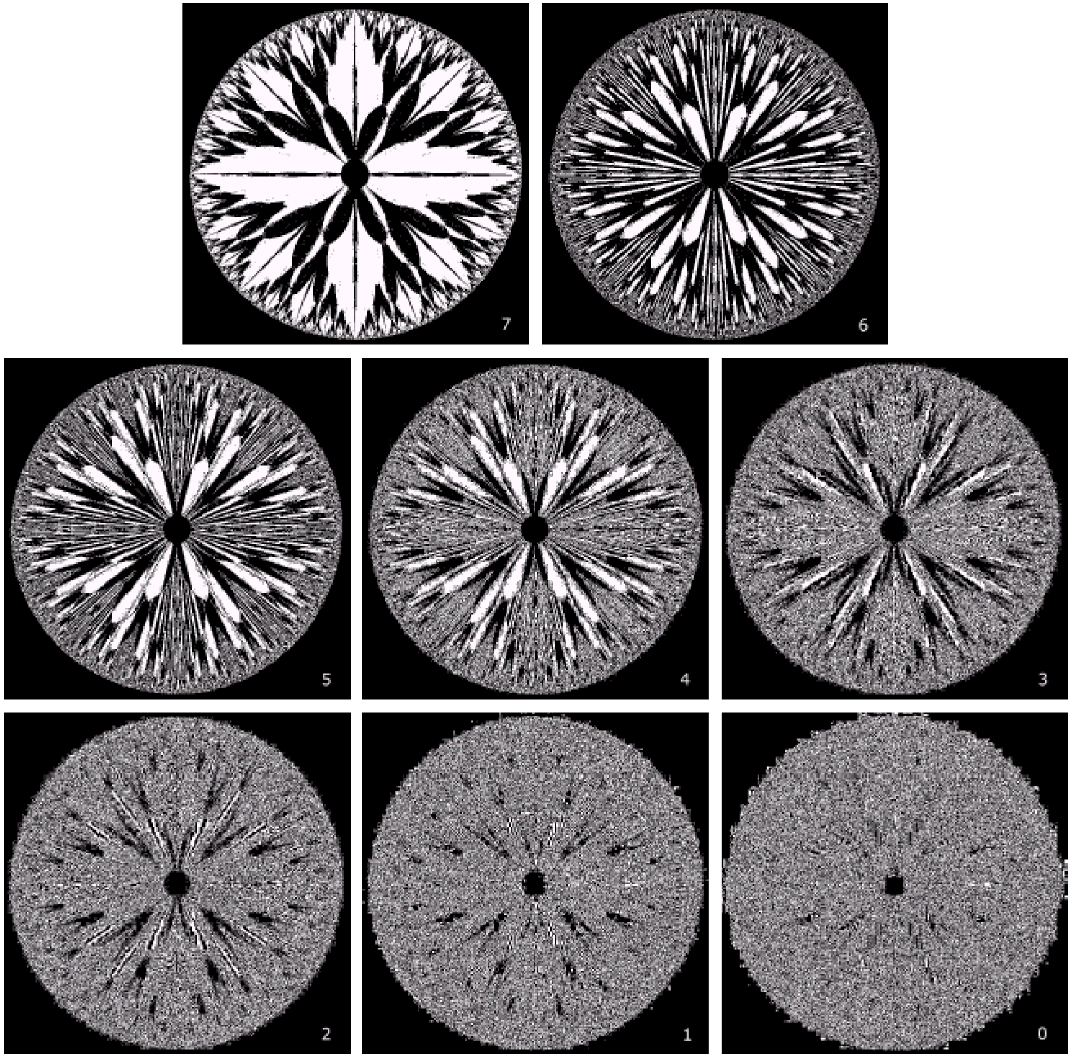


 FIGURE 3.14 The eight bit planes of the image in Fig. 3.13. The number at the bottom, right of each image identifies the bit plane.