CHAPTER – 2

IMAGE ENHANCEMENT SPATIAL DOMAIN

Image Enhancement

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

Fall into two broad categories

(a) Spatial domain methods and

(b) Frequency domain methods

Image Enhancement

- Spatial domain methods refers to the image plane itself and approaches are based on direct manipulation of pixels in an image
- Frequency domain methods are based on modifying the Fourier Transform of an Image.

Includes:

- Gray level and Contrast manipulation
- Noise Reduction
- Edge Sharpening and Filtering

Spatial Domain Methods

- The term Spatial domain refers to the aggregate of pixels composing an image.
- These methods are Procedures that operate directly on the aggregate of pixels composing an image

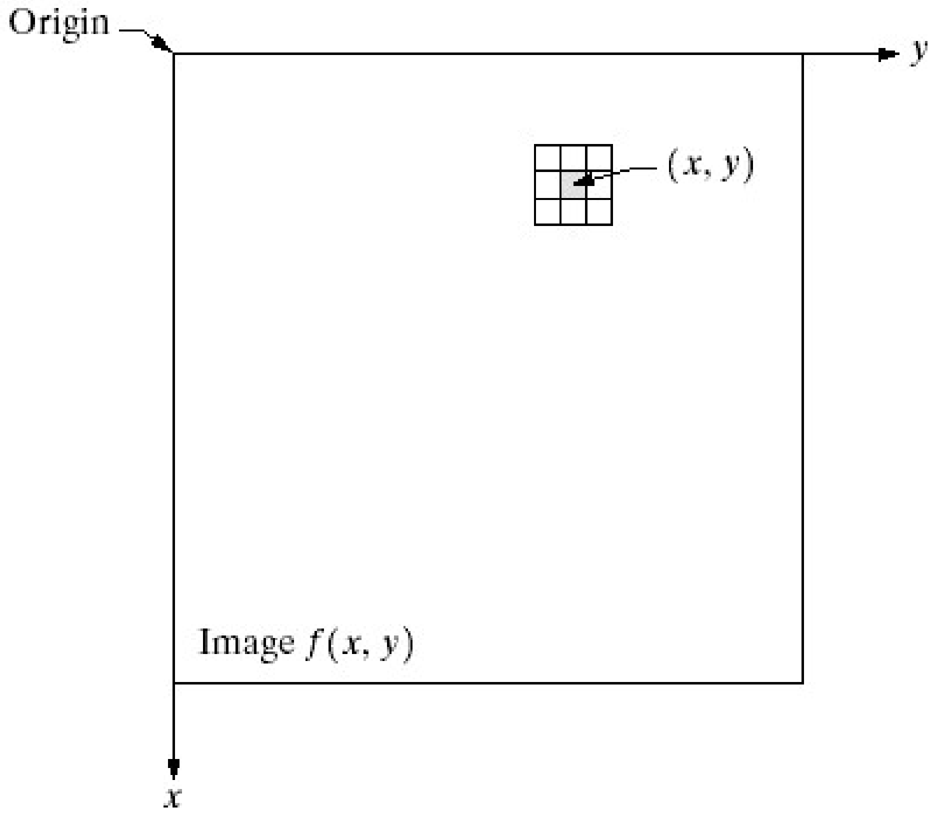
- Image processing function in spatial domain may be expressed as $g(x, y) = T[f(x, y)]$

- Where f(x, y) - Input image,
- g(x, y) – Processed image and
- T - Transform operator on f(x,y)

Image Enhancement in the Spatial Domain

- A neighborhood about (x,y) is defined by using a square (or rectangular) subimage area centered at (x,y) as shown in fig

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



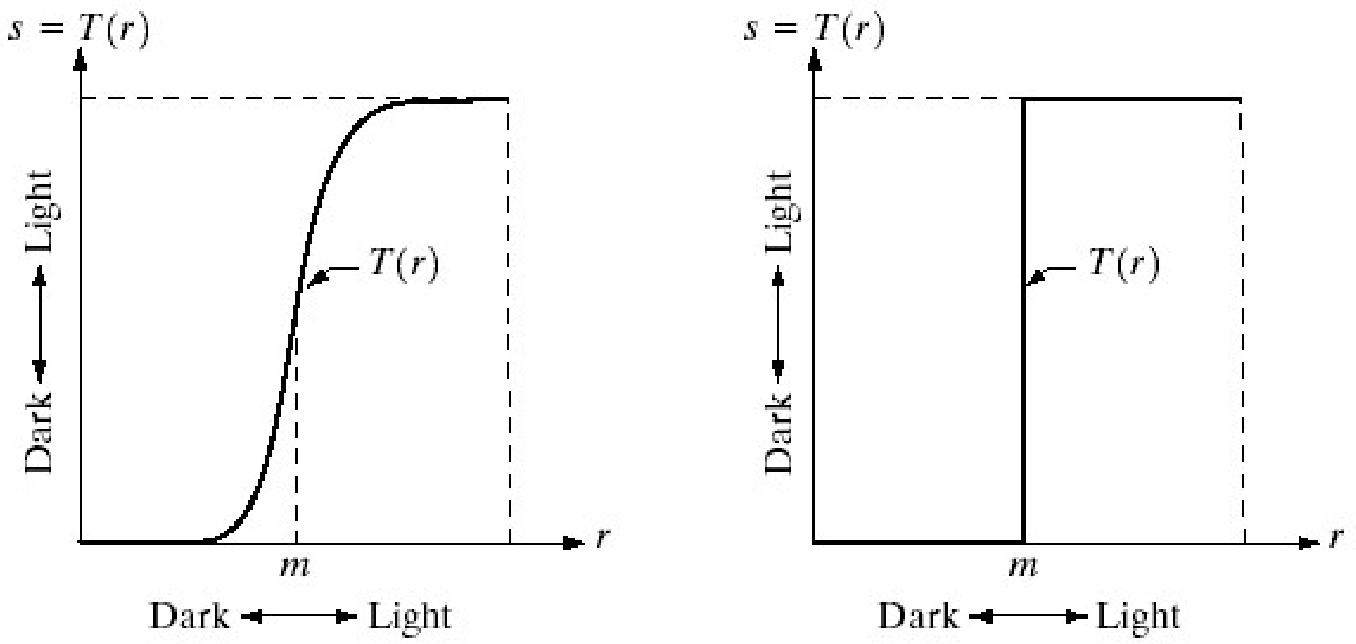
Spatial Domain Methods
Point Processing

- Simplest form of T is when the neighborhood is 1x1
- Then g depends only on the value of f at (x,y) and
- T becomes a gray-level transformation (or mapping) function: $s = T(r)$

  where r = gray level of f(x,y) at (x,y),

  s = gray levels of g(x,y) at (x,y)

Image Enhancement in the Spatial Domain



Contrast Stretching

Thresholding

a b

FIGURE 3.2 Gray-level transformation functions for contrast enhancement.

Spatial Domain Methods

Point processing techniques are

Thresholding: Produce an image of *higher contrast* than the original by darkening the levels below m and brightening the levels above m in the original Image.

Contrast stretching: The value of r below m are compressed by the transformation function into a narrow range of s towards black. Opposite effect takes place for values of r above m.

In the limiting case *T(r)* produces a two level Image

Spatial Domain Methods

Larger neighborhoods allow variety of processing functions that go beyond just Image Enhancement.

The Principal approach in this formulation is based on the use of so-called MASKS

Enhancement techniques based on this type of approach often are referred to as Mask processing or filtering:

Frequency Domain Methods

Techniques are based on Convolution theorem.

Let g(x,y) is formed by the convolution of an image f(x,y) and a linear and position invariant operator h(x,y), i.e.

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

Then from Convolution theorem

$$G(u,v) = H(u,v) \cdot F(u,v)$$

where G,H and F - Fourier Transforms of g, h and f respectively

Enhancement by Point Processing

In this Processing is based on the intensity of single pixels.

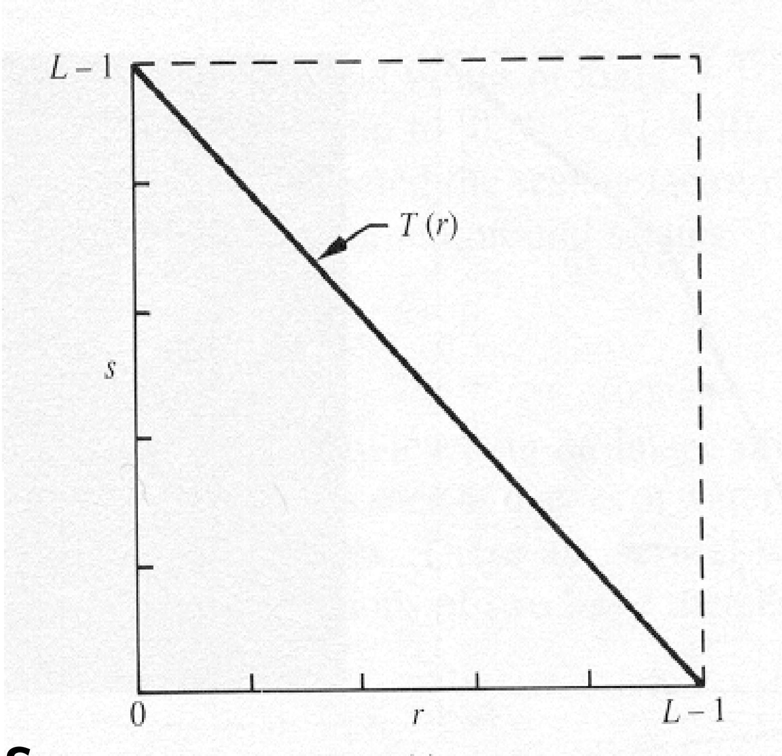
(1) Intensity Transformations

- (i) Image Negatives
- (ii) Compression of dynamic range – log transformations
- (iii) Power Law Transformations
- (iv) Contrast Stretching
- (v) Gray – Level Slicing
- (vi) Bit plane Slicing

Image Negatives

- Are obtained by using the transformation function s=T(r) as shown in fig.

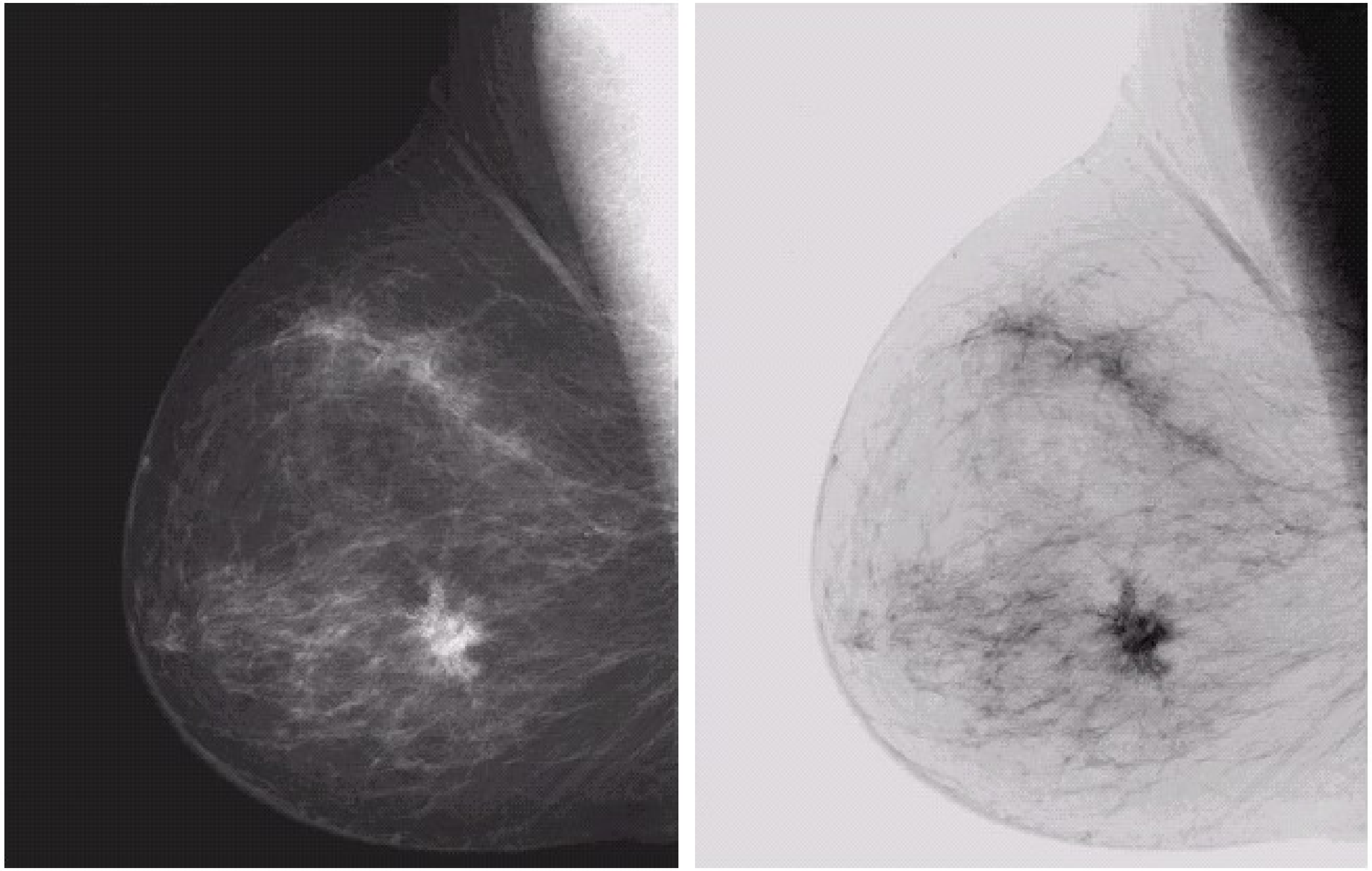
  Where is L is the no. of gray levels



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

$$S = L\text{-}1\text{-}r$$

Image Enhancement in the Spatial Domain



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.)

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.

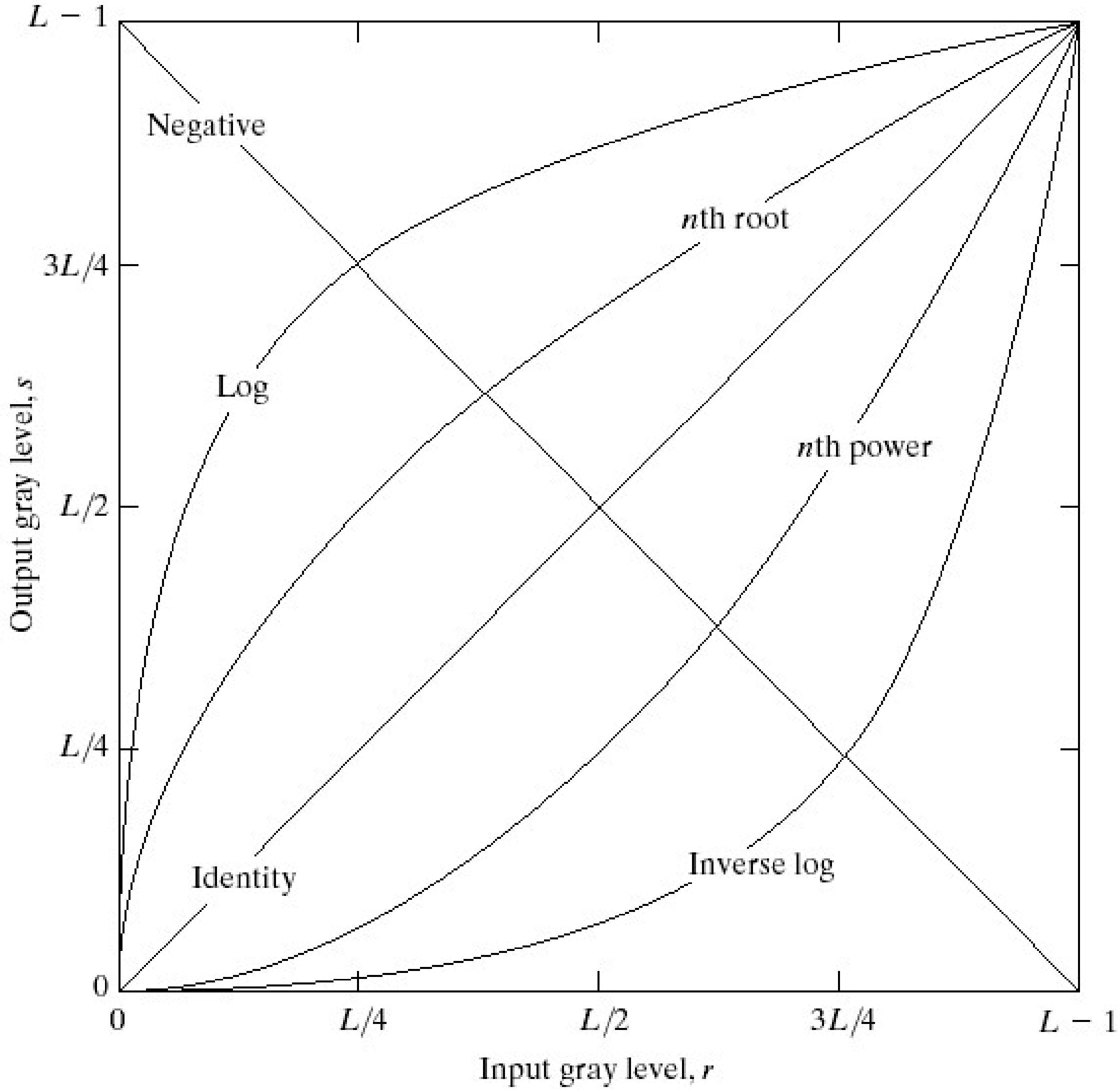
Image Enhancement in the Spatial Domain

FIGURE 3.3 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

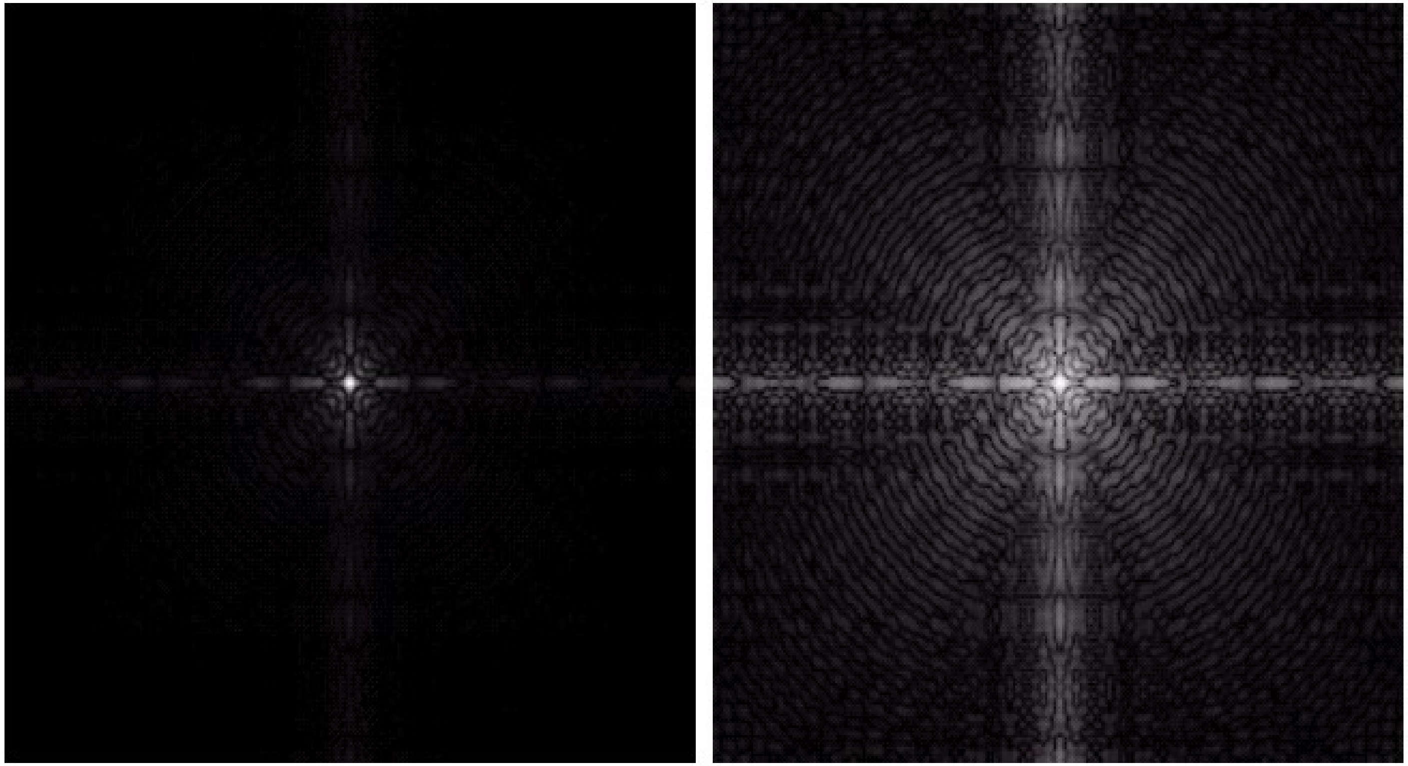


Compression of Dynamic Image

- Some times the dynamic range of a processed image far exceeds the capability of the display device.
- In this case only brightest parts of the image are visible on the display screen
- An effective way to compress the dynamic range of pixel value is to perform Intensity transformation called LOG Transformation

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

Image Enhancement in the Spatial Domain



a b

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

Power-Law Transformations

This is having the basic form $s = cr^{\gamma}$

where C, γ : positive constants

As in the case of Log Transformations, Power Law curves with fractional values of γ map a narrow range of dark i/p value into wider range of o/p values.

The process used to correct this power law response phenomenon is called Gamma correction

Image Enhancement in the Spatial Domain

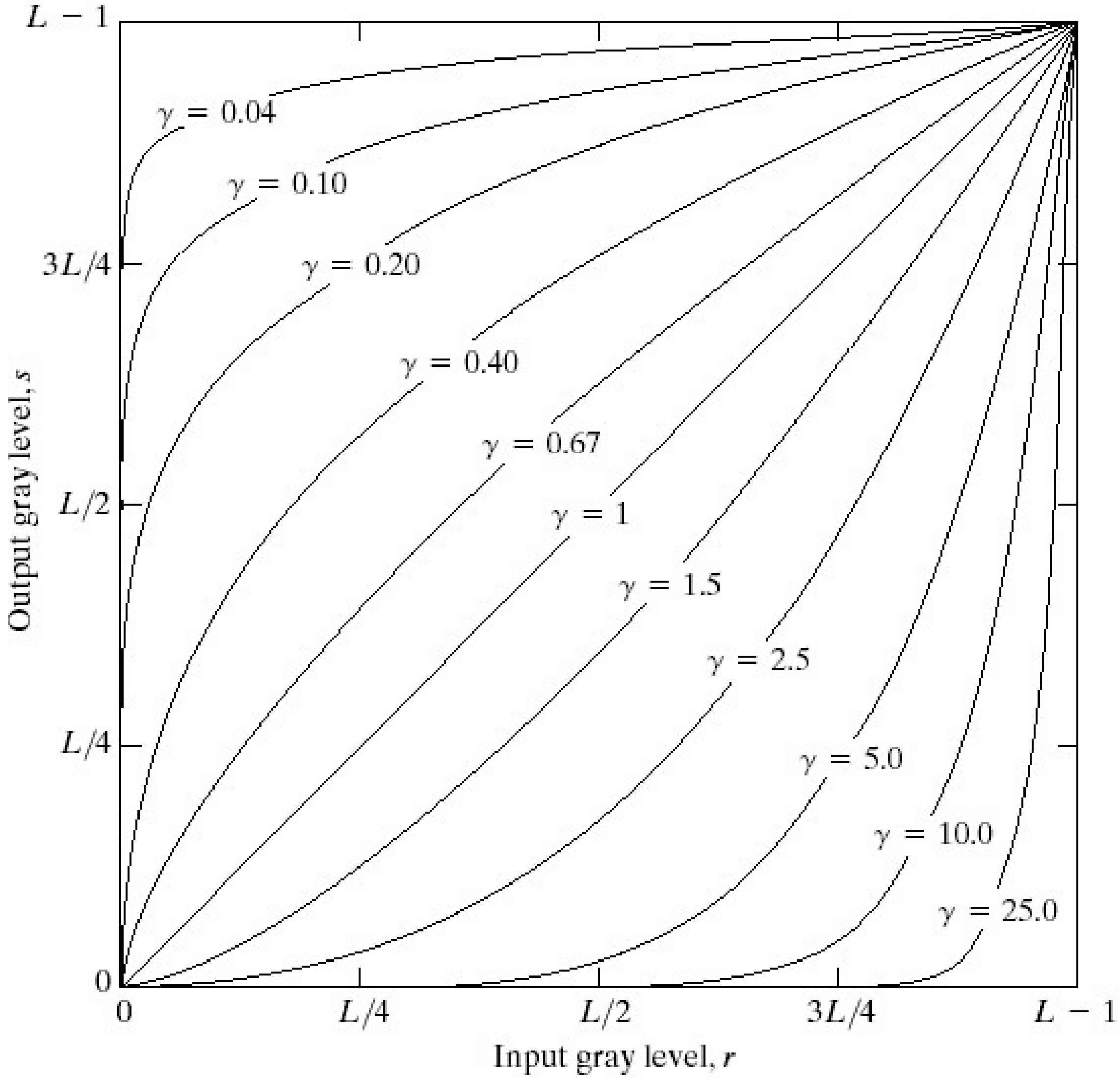
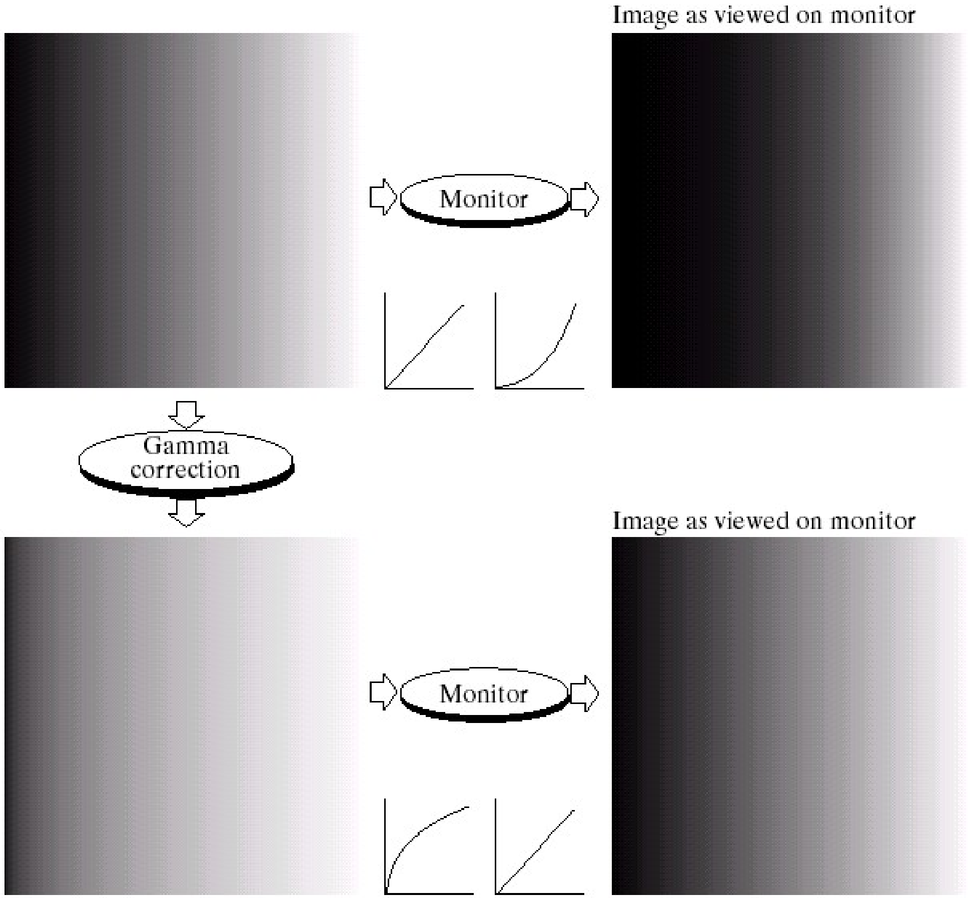


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

$\gamma = c = 1$: identity

Image Enhancement in the Spatial Domain



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 the Spatial Domain

a b
c d

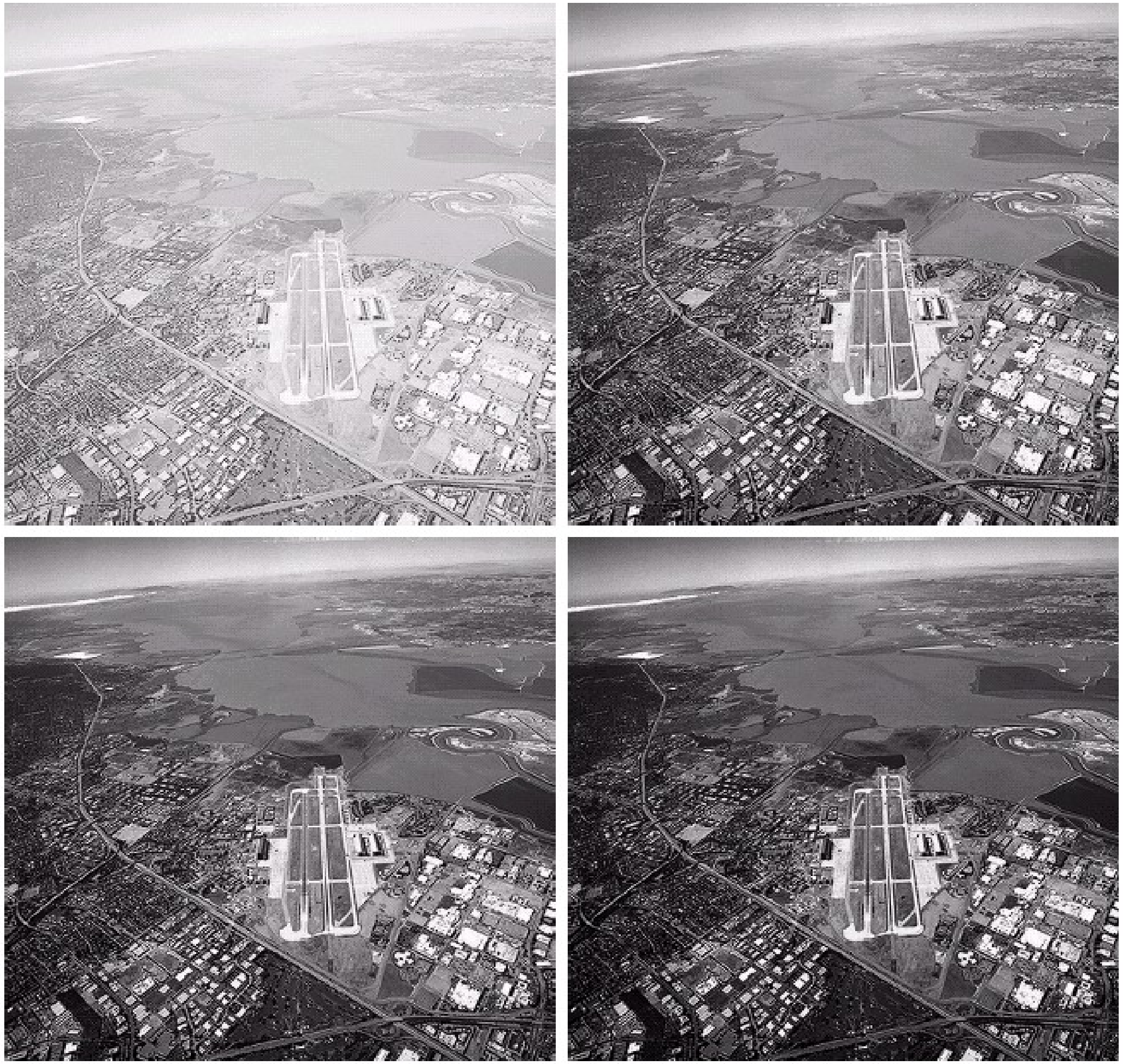


FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively. (Original image for this example courtesy of NASA.)

Piecewise-Linear Transformation Functions

Contrast Stretching

Low contrast images can result from poor illumination

The reasons for this are

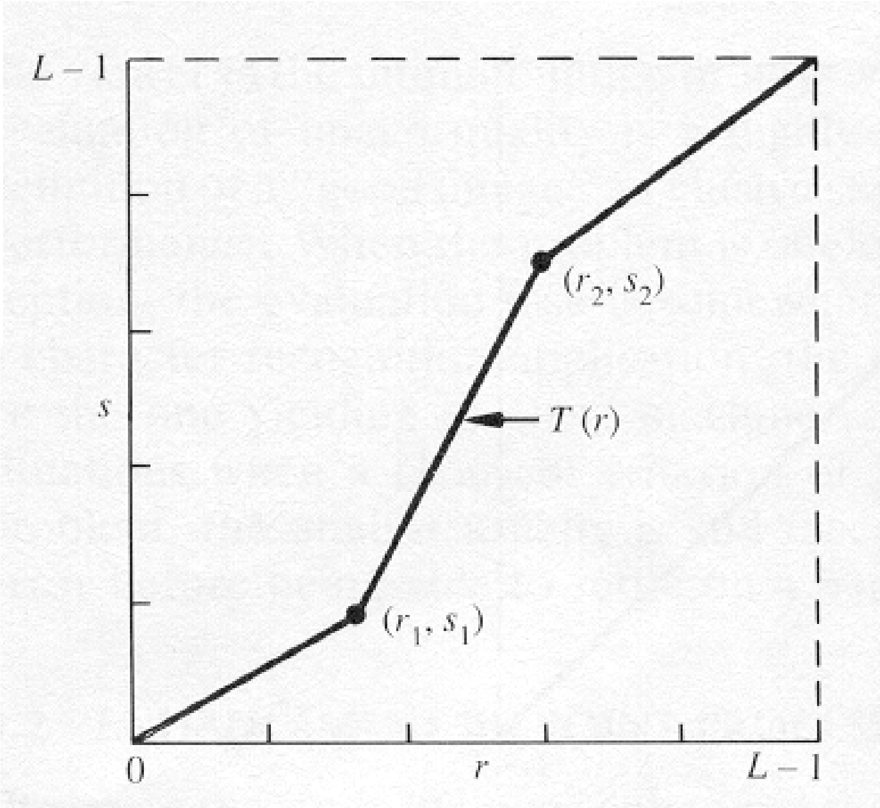
- Lack of Dynamic Range in the image sensor
- Wrong setting of a lens aperture during image acquisition.

Contrast Stretching is used increase the dynamic range of the gray levels in the image being processed.

Contrast Stretching

The transformation used for this is shown in fig

The locations of (r_1,s_1) and (r_2,s_2) control the shape of the transformation function.

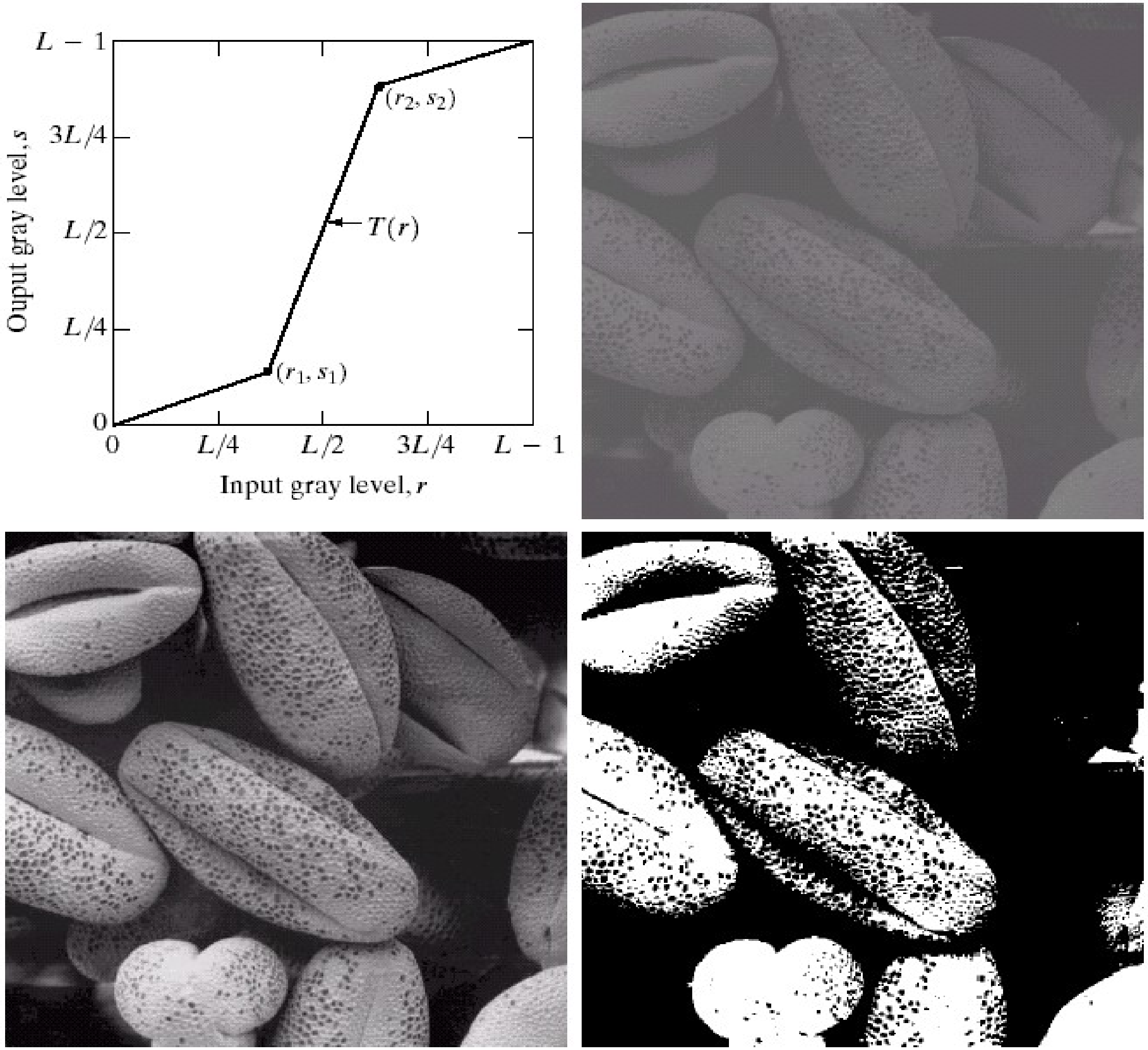


- If $r_1= s_1$ and $r_2= s_2$ the transformation is a linear function and produces no changes.
- If $r_1=r_2$, $s_1=0$ and $s_2=L-1$, the transformation becomes a thresholding function that creates a binary image.

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.

Image Enhancement in the Spatial Domain

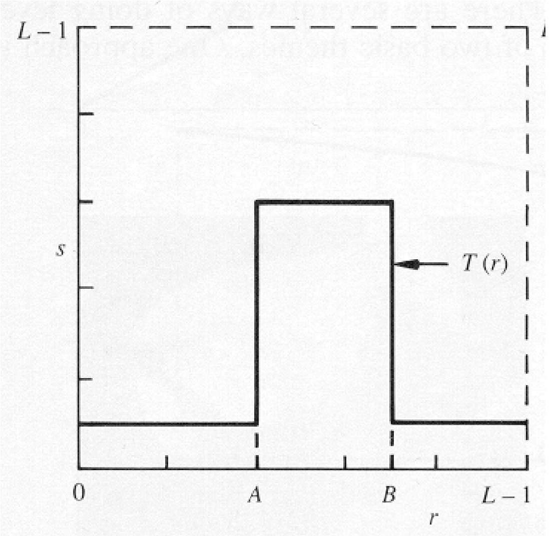


a b
c d

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

- 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:

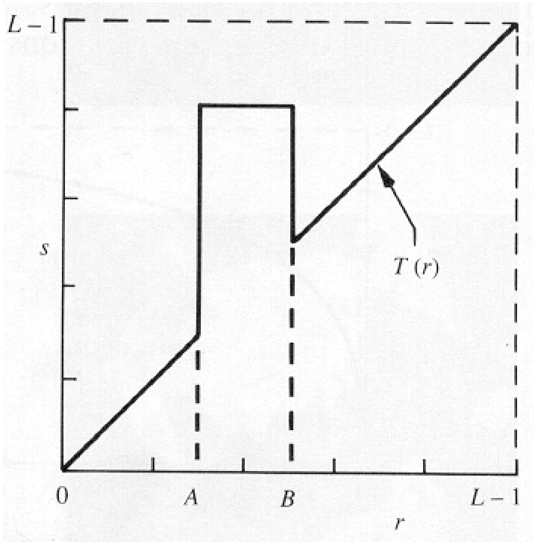
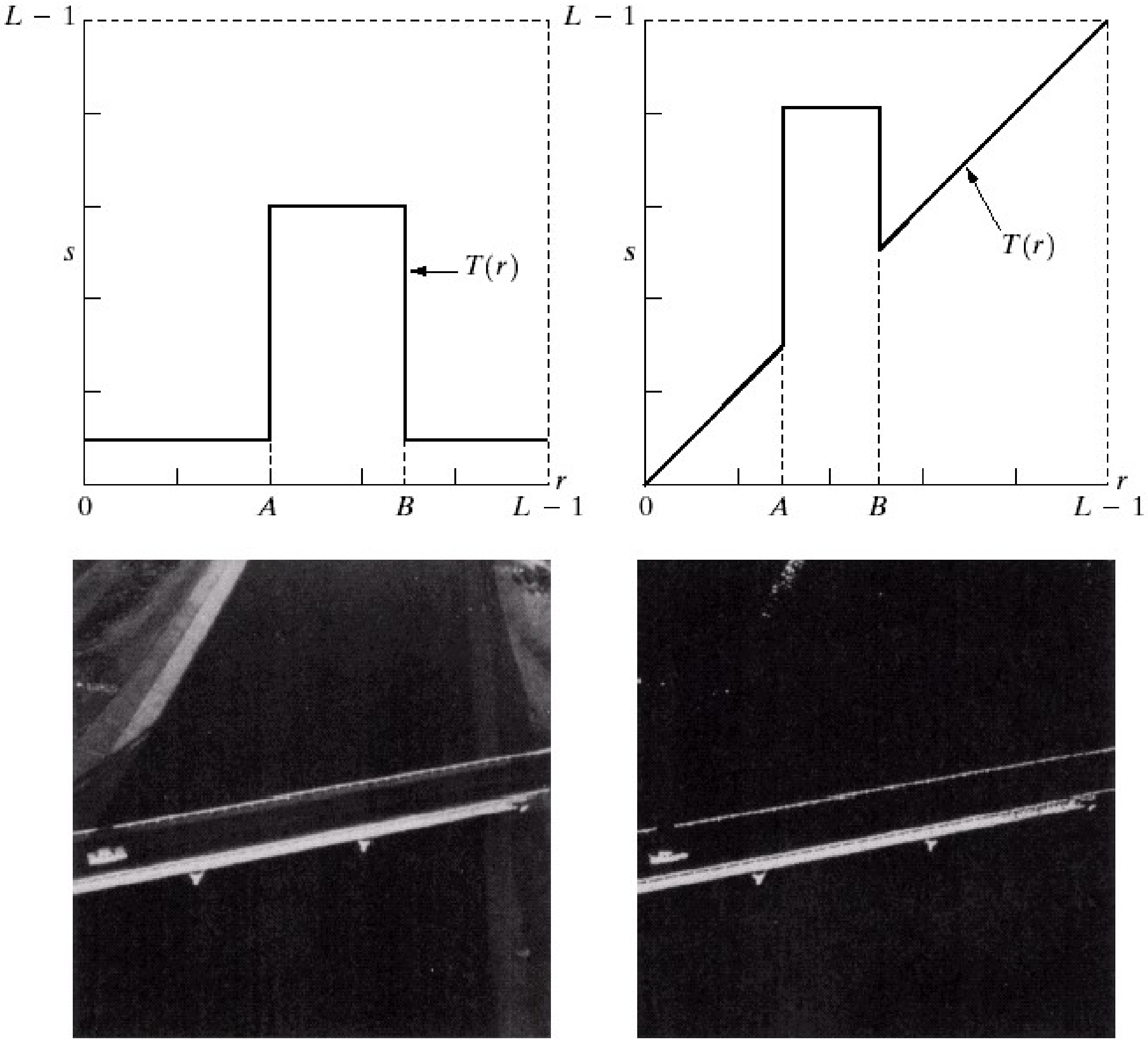


Image Enhancement in the Spatial Domain



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.

Image Enhancement in the Spatial Domain

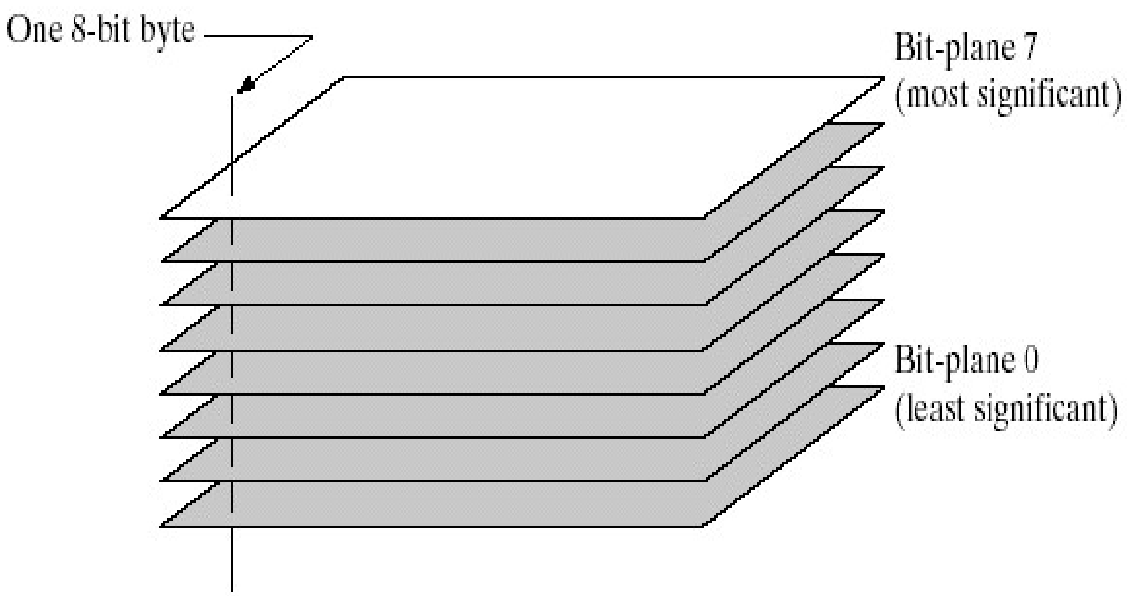


FIGURE 3.12 Bit-plane representation of an 8-bit image.

Image Enhancement in the Spatial Domain

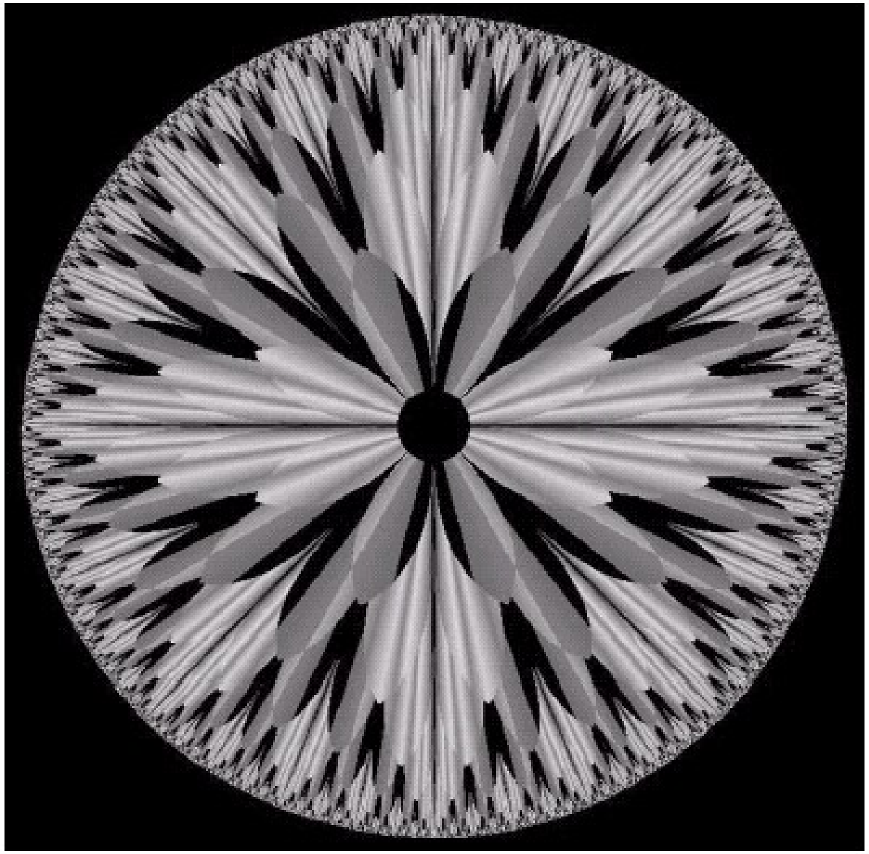


FIGURE 3.13 An 8-bit fractal image. (A fractal is an image generated from mathematical expressions). (Courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA.)

Image Enhancement in the Spatial Domain

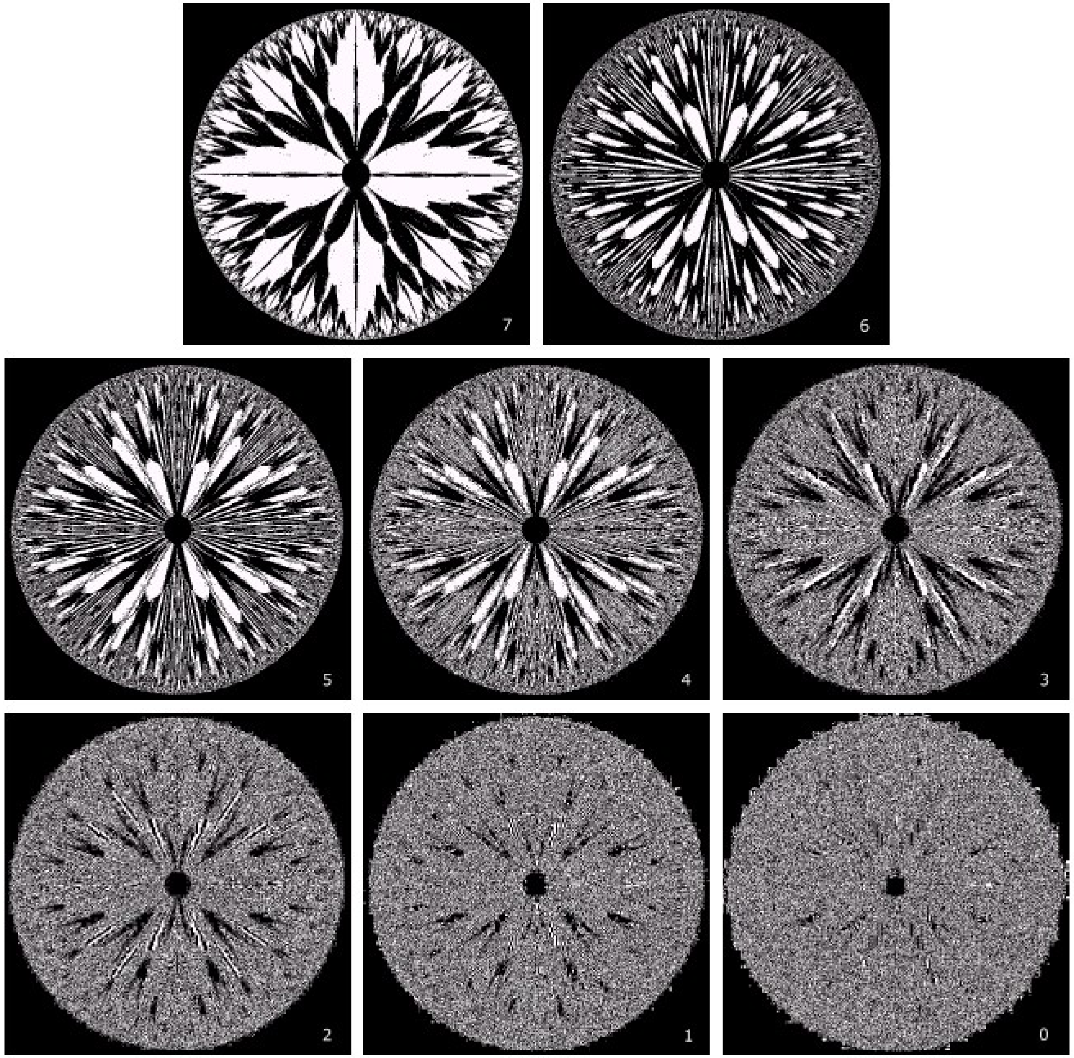


FIGURE 3.14 The eight bit planes of the image in Fig. 3.13. The number at the bottom, right of each image identifies the bit plane.