

# **Digital Image Processing**

## **Image Enhancement**

### **Review of Spatial Domain Methods**

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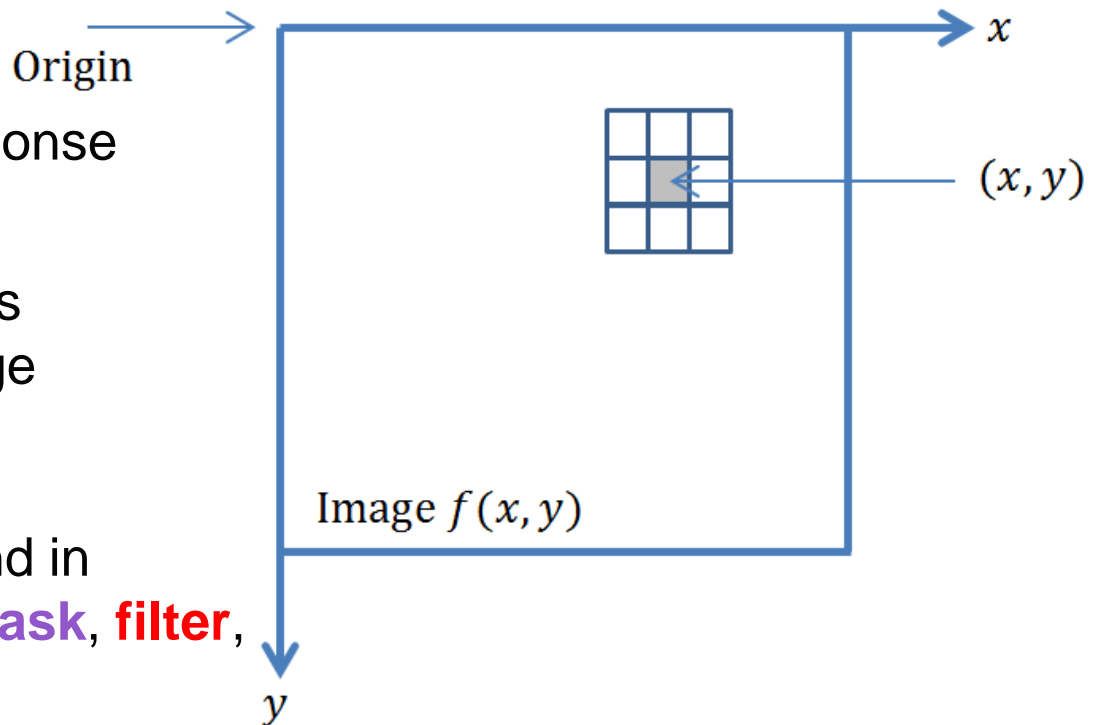
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# Image Enhancement

- The goal of Image Enhancement is to process an image so that the resulting image is:
  - more suitable than the original image for a *specific* application
  - of better quality in terms of some quantitative metric(s)
  - visually better
- Image enhancement method classification:
  - spatial domain methods
  - frequency domain methods

## Spatial Domain Methods: Local neighborhood processing

- A neighborhood around each pixel  $(x, y)$  is defined by using mainly a square (or rectangular) image patch centered at  $(x, y)$ .
- An operator  $T(f(x, y))$  is defined, which manipulates all pixels within the pre-specified neighborhood mentioned above centered at  $(x, y)$  and produces a single response  $g(x, y)$ .
- The original image  $f(x, y)$  is replaced with the new image  $g(x, y) = T[f(x, y)]$ .
- The operator  $T$  can be found in textbooks with the terms **mask**, **filter**, **kernel** and others.



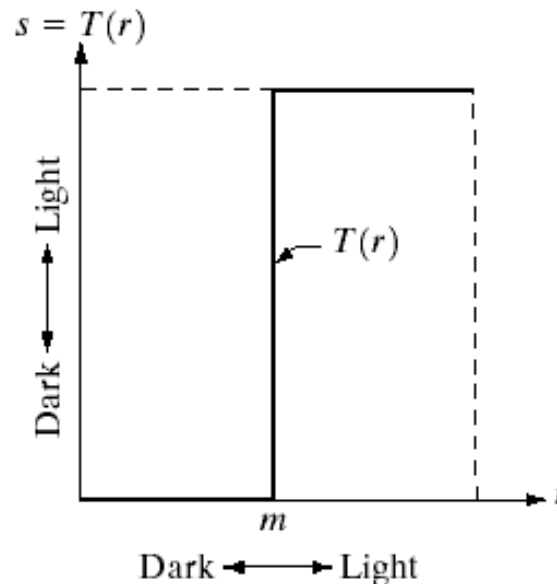
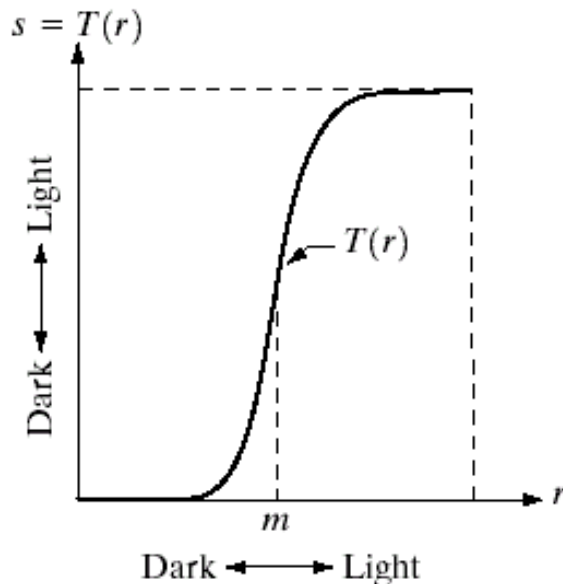
## Spatial Domain Methods: Point processing

- When the previously mentioned neighborhood is of size  $1 \times 1$ ,  $g(x, y)$  depends only on the value of  $f(x, y)$  at  $(x, y)$
- A very important family of transformations of that type are the so called gray level or intensity transformations of the form:
$$s = T(r)$$

$r, s$  are the grey levels of  $f(x, y)$  and  $g(x, y)$  at  $(x, y)$ .
- Observe that the transformation of a pixel depends on its gray level only and not its coordinates  $(x, y)$ .
- These techniques are called point processing techniques. To name a few:
  - **Contrast manipulation (enhancement/stretching/thresholding)**
  - **Image negatives**
  - **Log transformations**
  - **Power log transformations**
  - **Grey-level slicing**
  - **Bit-plane slicing**
  - **Histogram processing**
  - **Others**

## Point Processing: Contrast manipulation

- In the figures below you can see examples of two different intensity transformations which aim at alternating the contrast of an image.
- The figure on the right shows the process of binarization of the image.

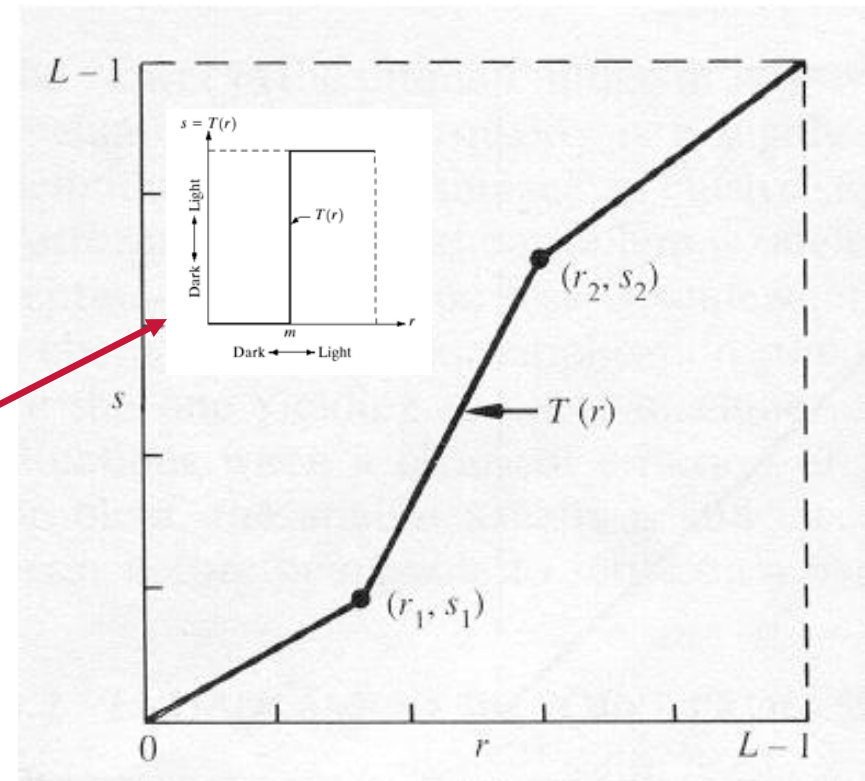


a b

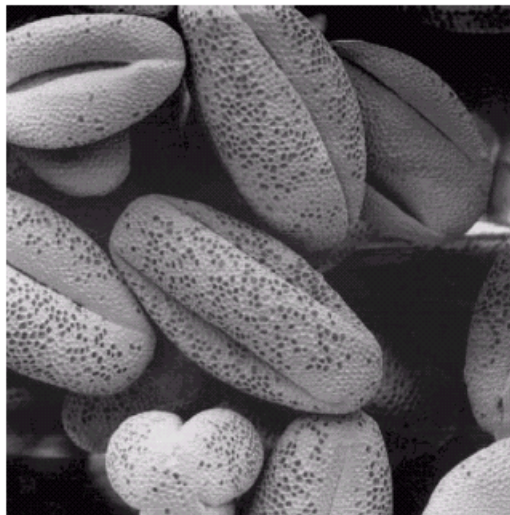
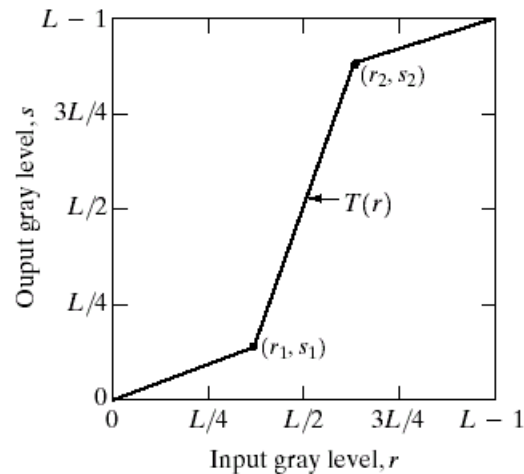
**FIGURE 3.2** Gray-level transformation functions for contrast enhancement.

## Point Processing: Contrast manipulation cont.

- Another type of transformation is a piecewise linear functions shown below.
- Depending on the slope of each straight line, the original local range of intensities is decreased (slope  $< 1$ ) or increased (slope  $> 1$ ).
- 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.



## Point Processing: Contrast manipulation cont.



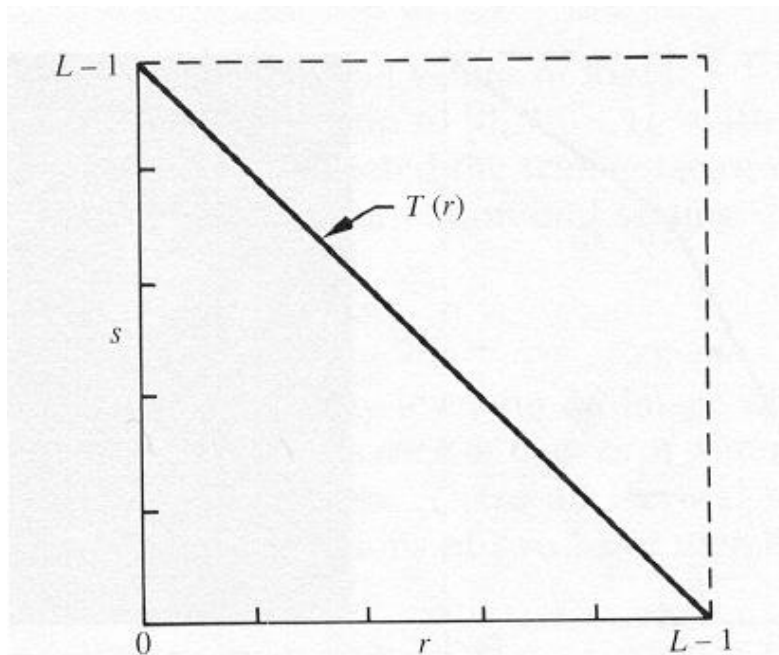
a b  
c d

**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.)

## Point processing: Image negatives

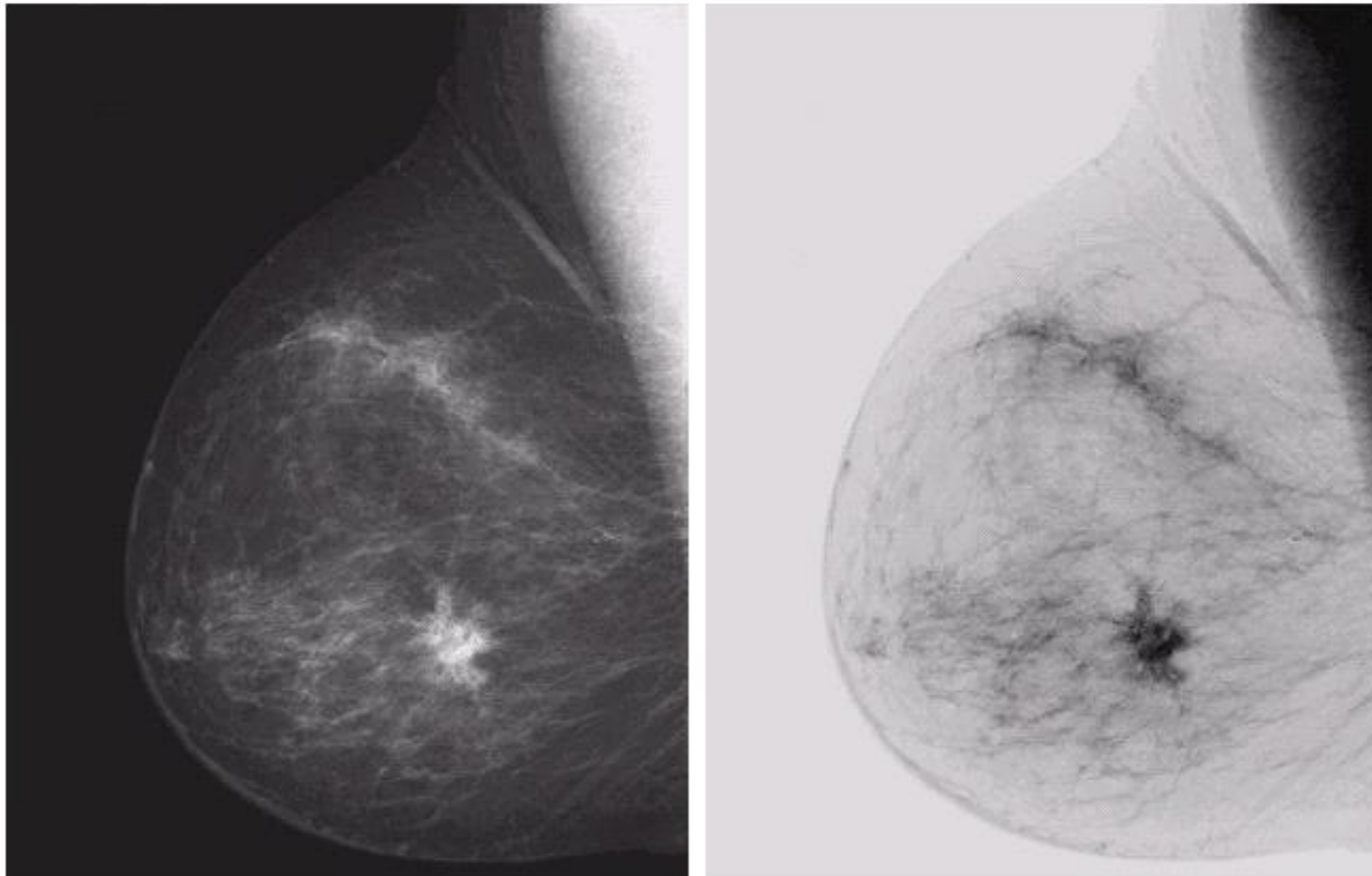
- The negative of an image with intensity  $r \in [0, L - 1]$  is obtained by using the transformation function  $s = T(r) = L - 1 - r$ .
- The above function reverses the order of gray shades from black to white so that the intensity of the output image decreases as the intensity of the input increases.
- These images are used mainly in medical imaging science.





## Point processing: Image negatives cont.

Observe that the suspicious region is highlighted better in the negative image.



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.)

## Point processing: Log transformations

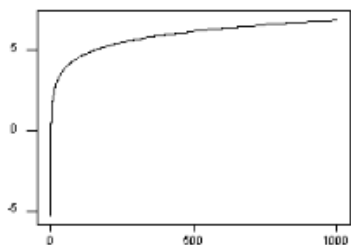
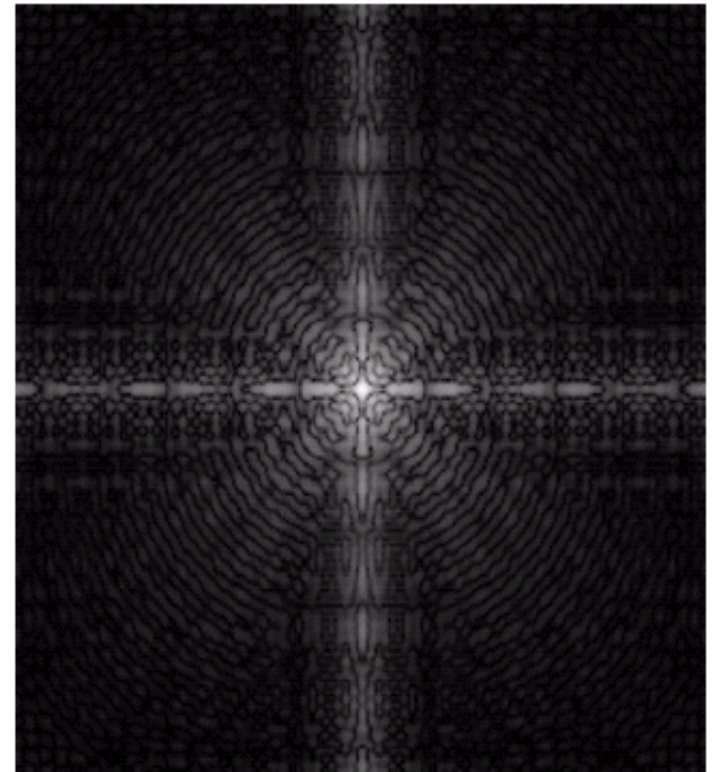
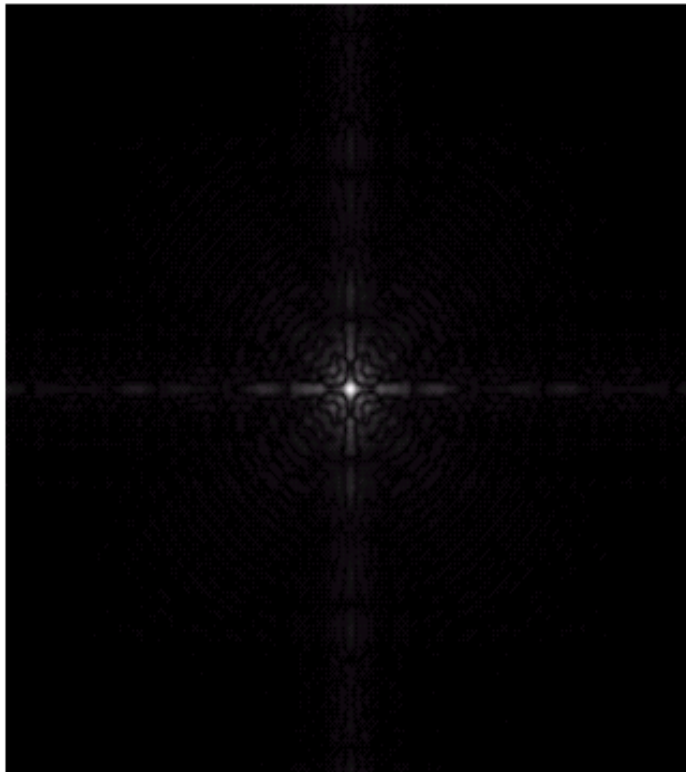
- The log-transformations are a family of transforms of the form:
$$s = c \log(1 + r), c: \text{constant.}$$
- They are used to enhance the range of small intensities which is compressed and therefore, not visible, in images with large range of intensities.

a b

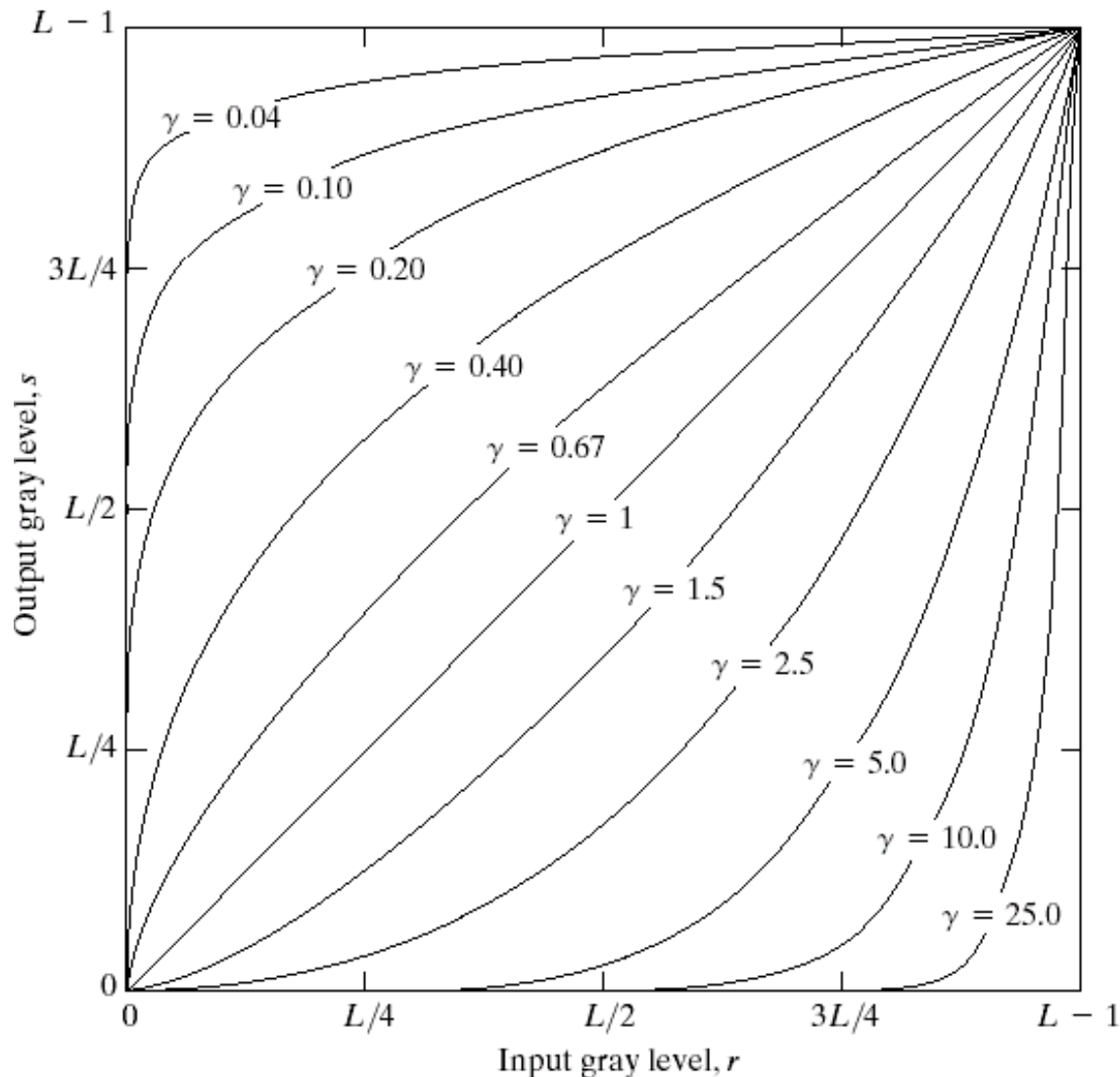
**FIGURE 3.5**

(a) Fourier spectrum.

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



## Point processing: Power law transformations



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

The power law transformations is a family of transforms of the form  $s = cr^\gamma$  with  $c, \gamma$ : constants.

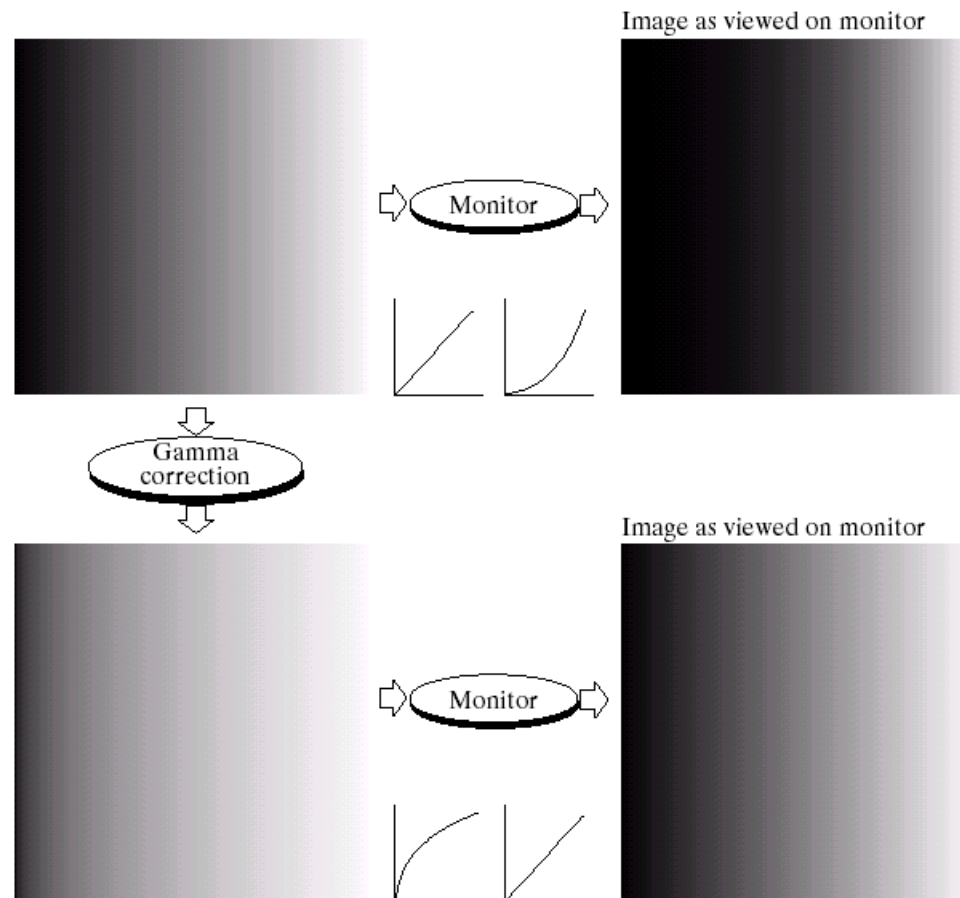
This technique is often called Gamma Correction (used in monitor displays).

## Point processing: Power law transformations cont.

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.



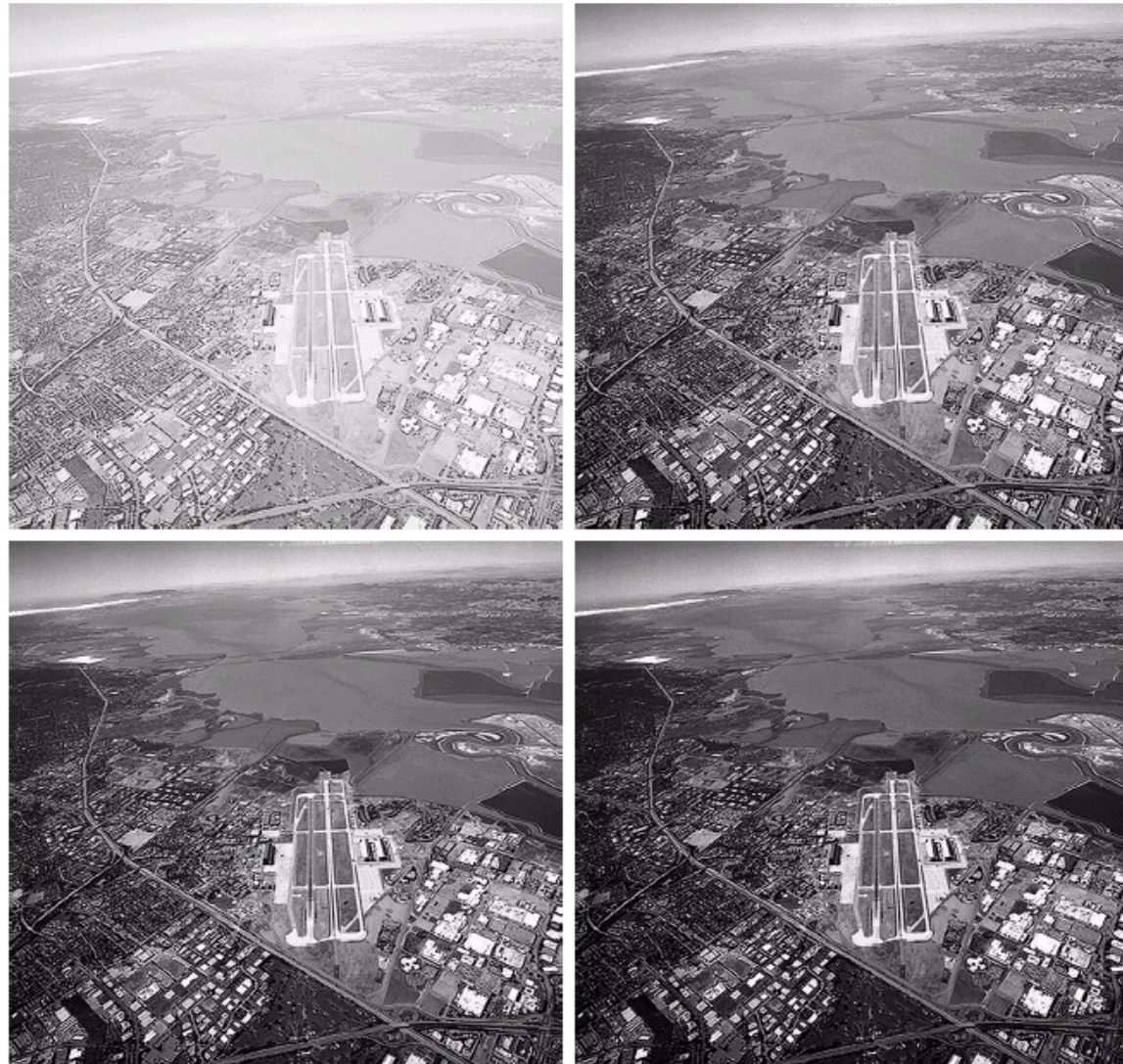


## Point processing: Power law transformations cont.

a	b
c	d

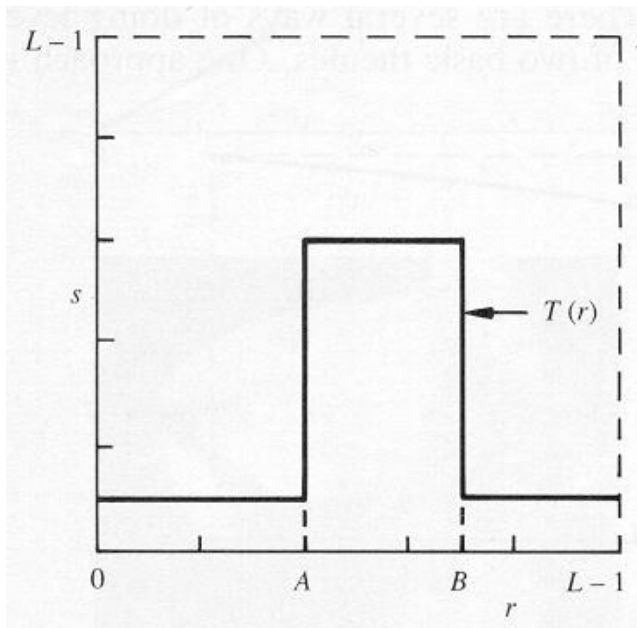
**FIGURE 3.9**

(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.)

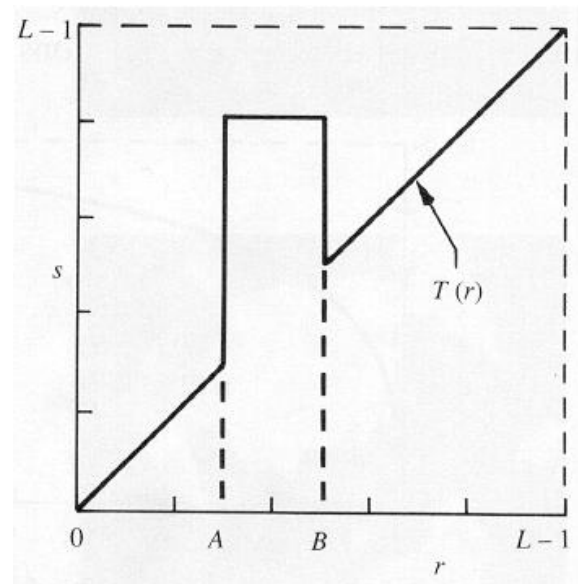


## Point Processing: Gray-level slicing

The goal is to highlight a specific range of gray levels in an image (e.g. to enhance certain features).

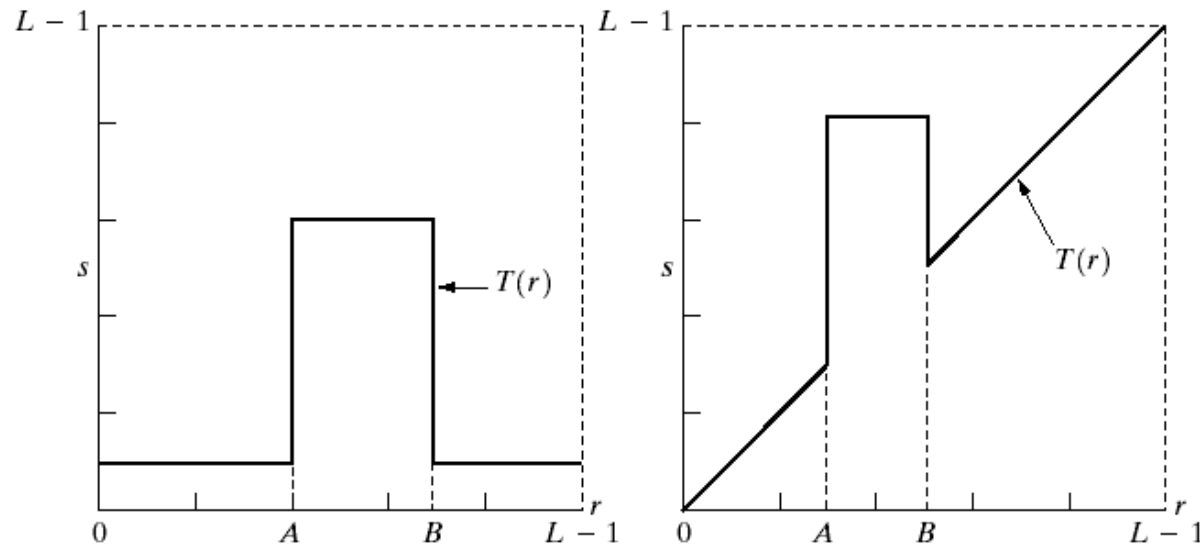


One way is to display a high value for all gray levels in the range of interest and a low value for all other gray levels (binary image).



The second approach is to brighten the desired range of gray levels but preserve (not change) the background and gray-level tonalities in the image.

## Point Processing: Gray-level slicing cont.



a	b
c	d

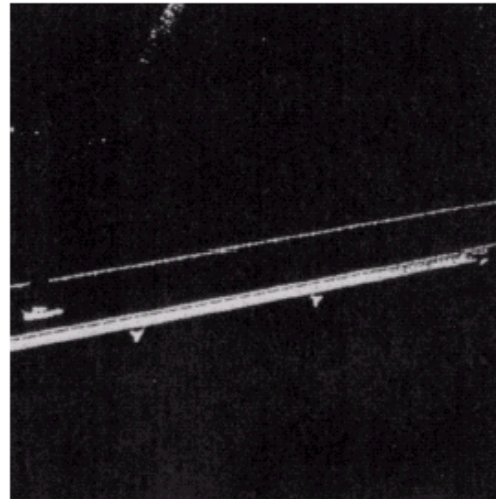
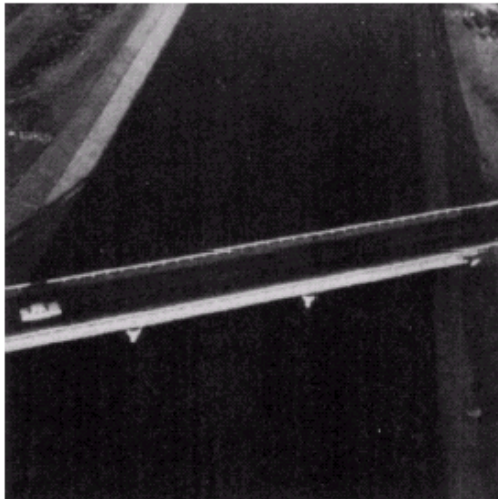
**FIGURE 3.11**

(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).



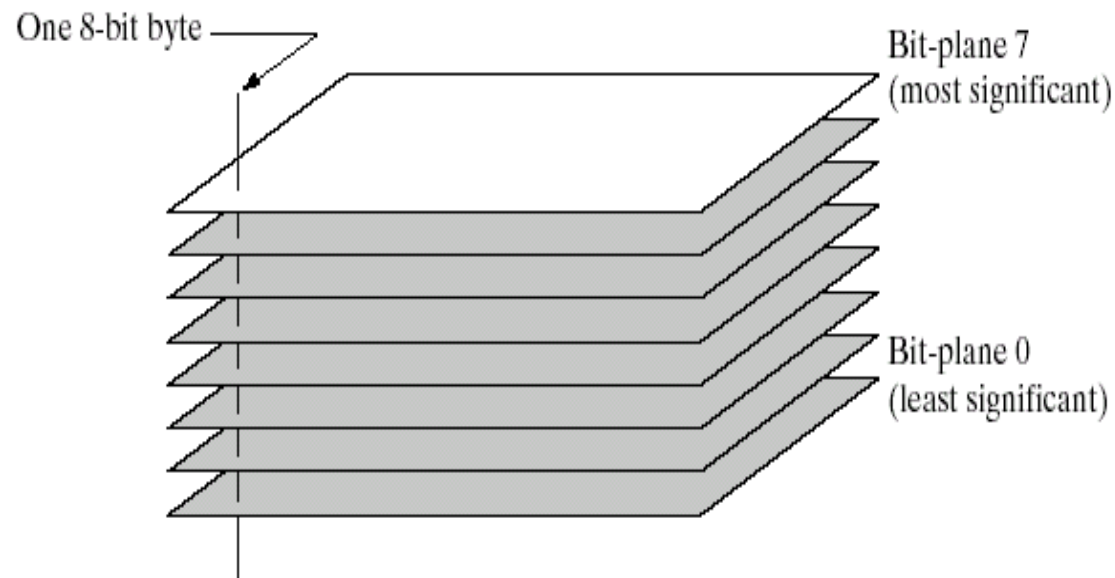
## Point processing: Bit-plane slicing

The goal is to highlight the contribution made to the image's appearance by specific bits.

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

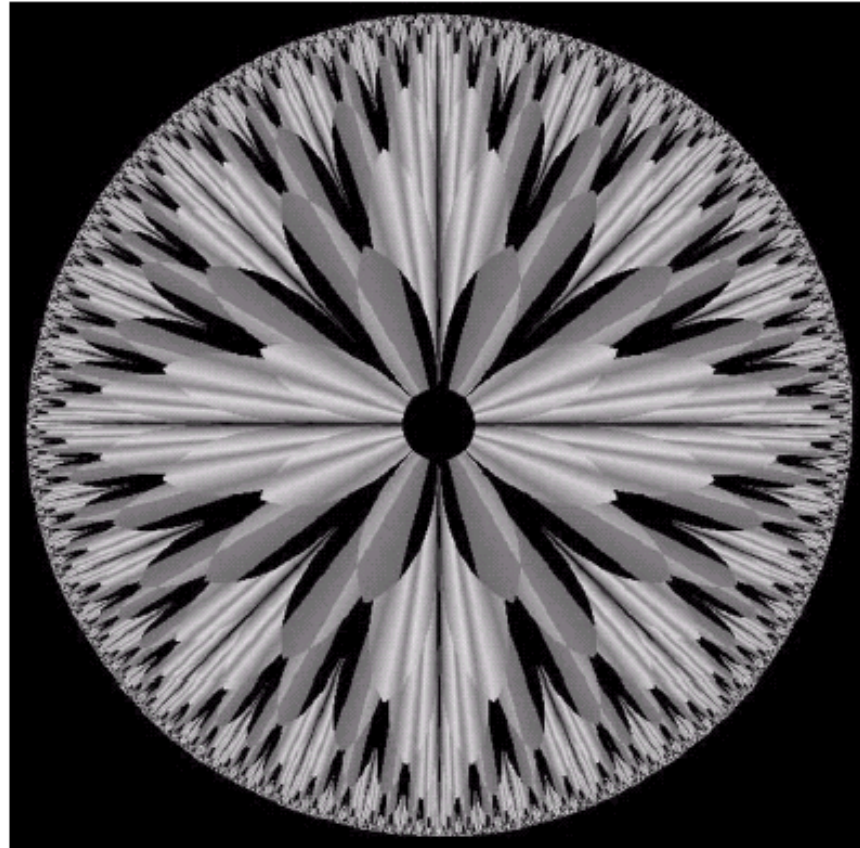


## Point processing: Bit-plane slicing cont.



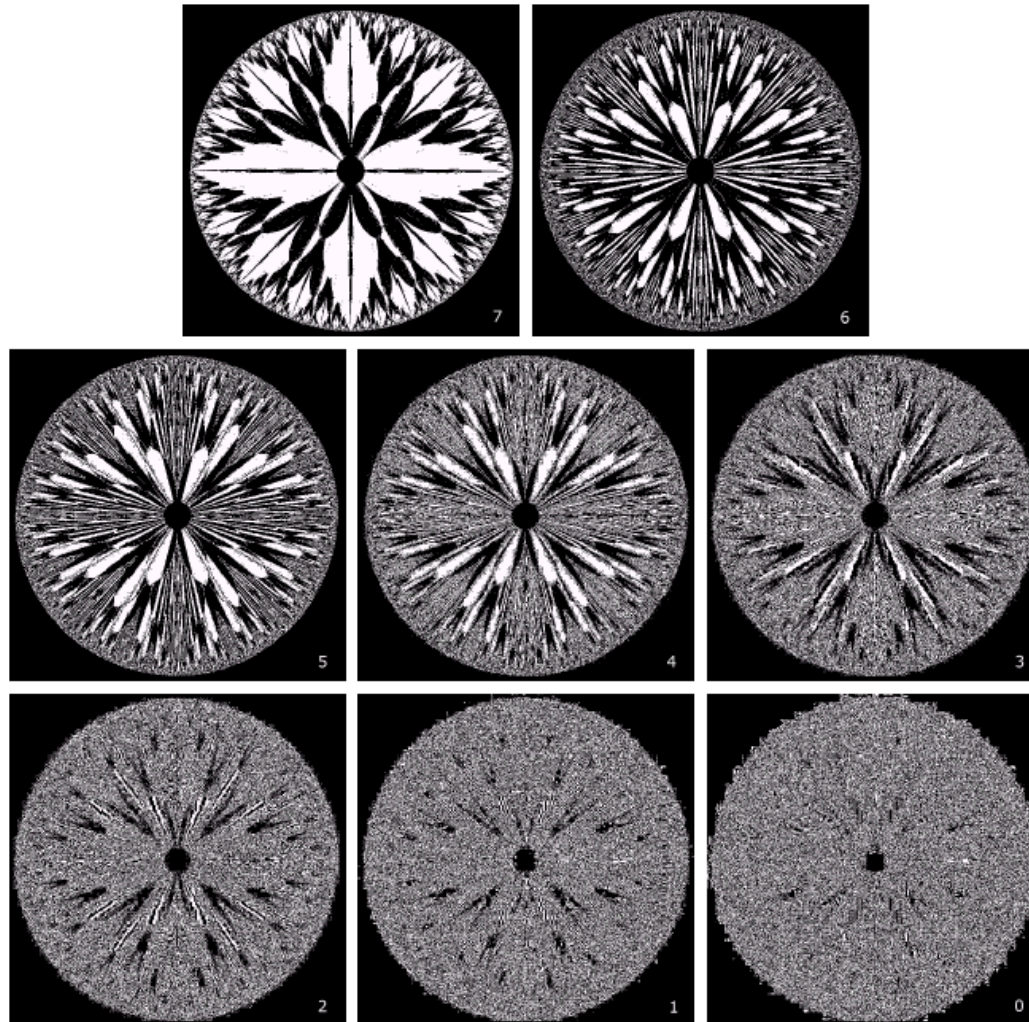
**FIGURE 3.12**  
Bit-plane  
representation of  
an 8-bit image.

## Point processing: Bit-plane slicing cont.



**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.)

## Point processing: Bit-plane slicing cont.



**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.

## Image Enhancement in the Spatial Domain: Summary of intensity transformations

**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

