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Digital Image Processing

Image Enhancement

Review of Spatial Domain Methods

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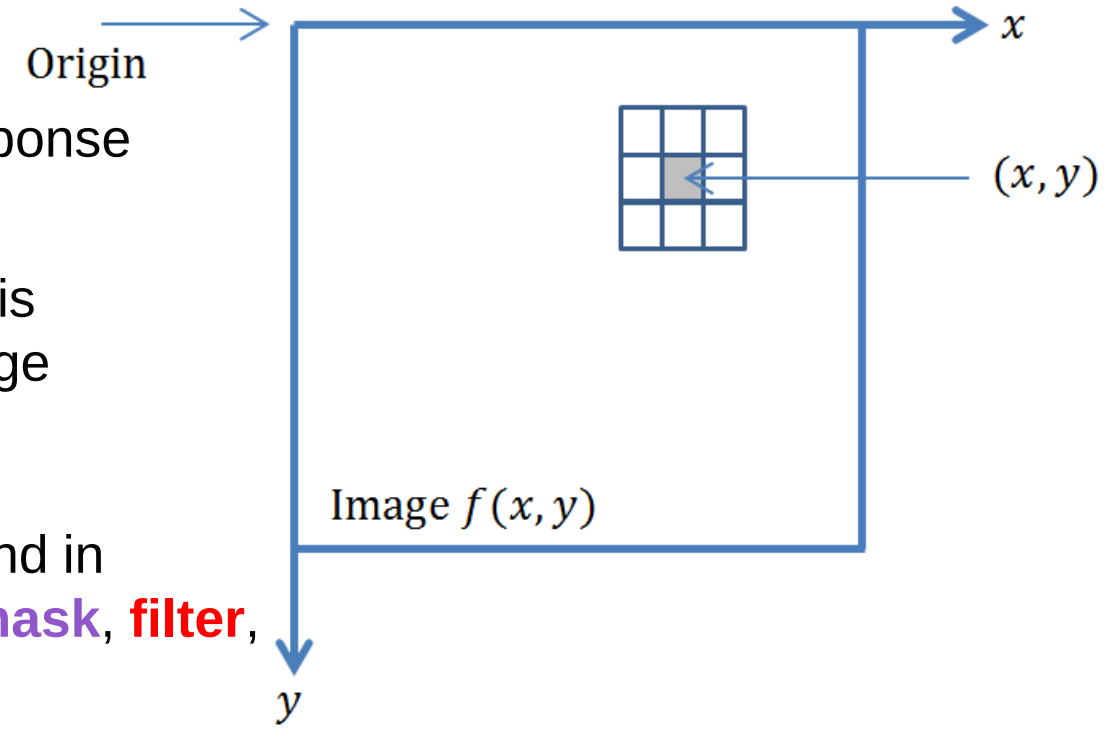
Image Enhancement

- 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

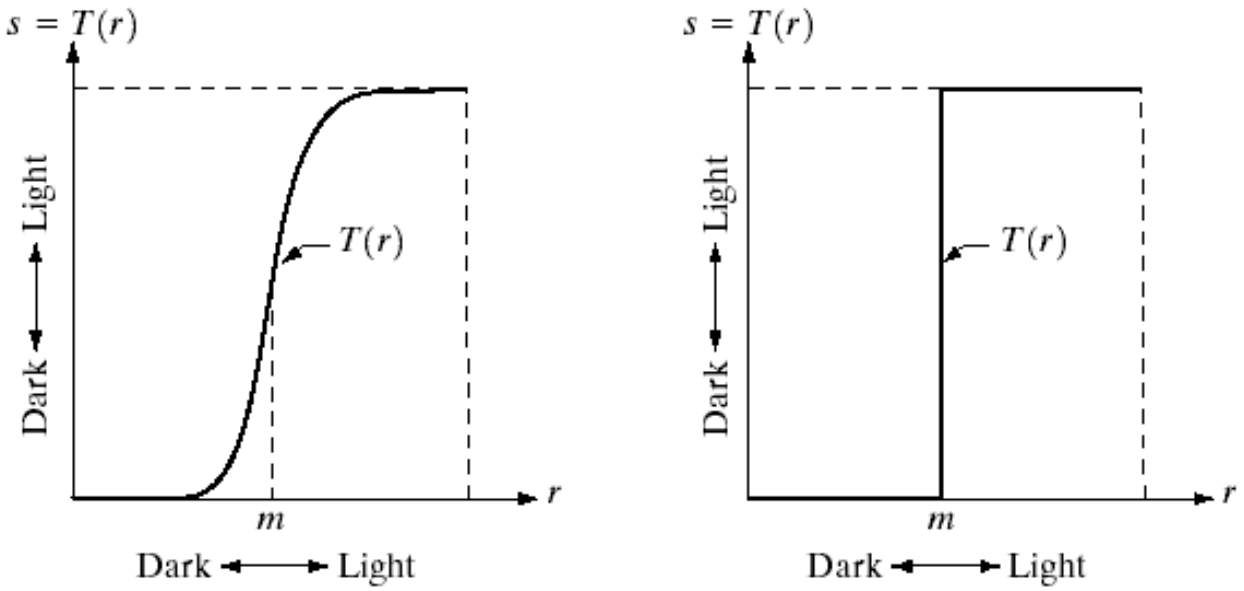
- When the previously mentioned neighborhood is of size 1×1, $g(x, y)$ depends only on the value of $f(x, y)$ at (x, y)
- A very important family of transformations of that type are the so called gray level or intensity transformations of the form:

$$s = T(r)$$

  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.

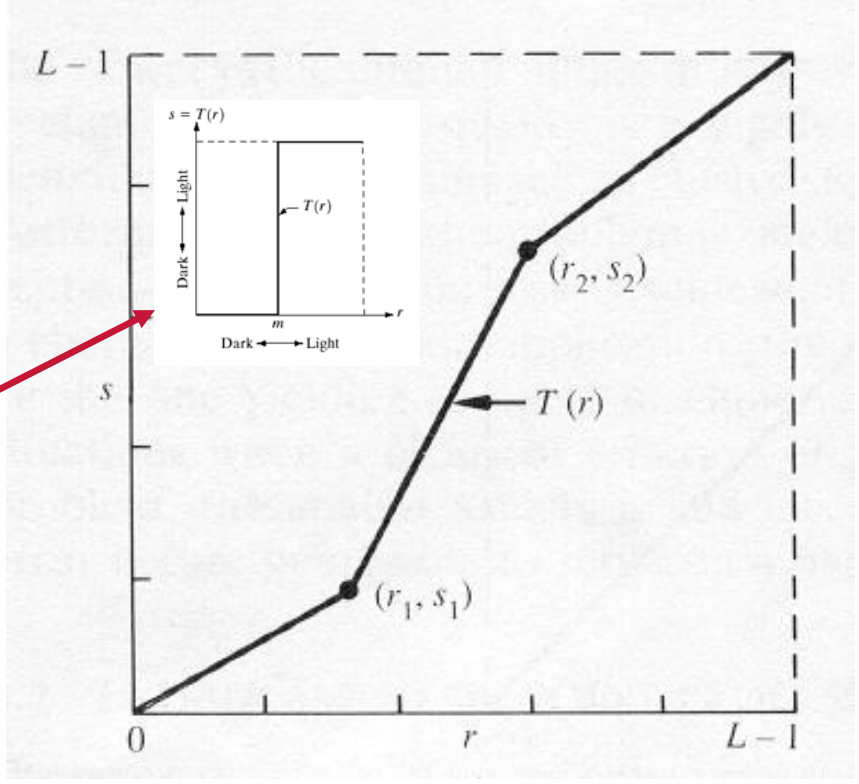


a b

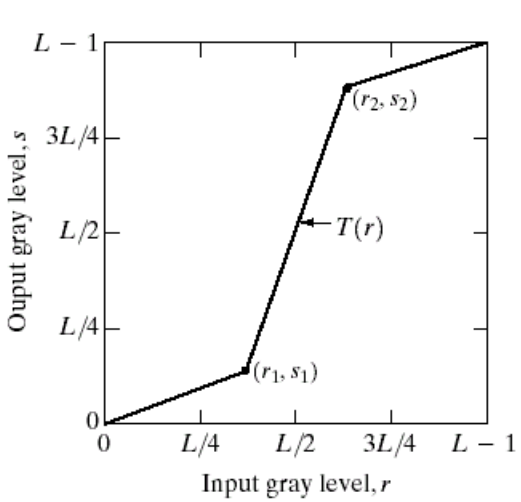
FIGURE 3.2 Gray-level transformation functions for contrast enhancement.

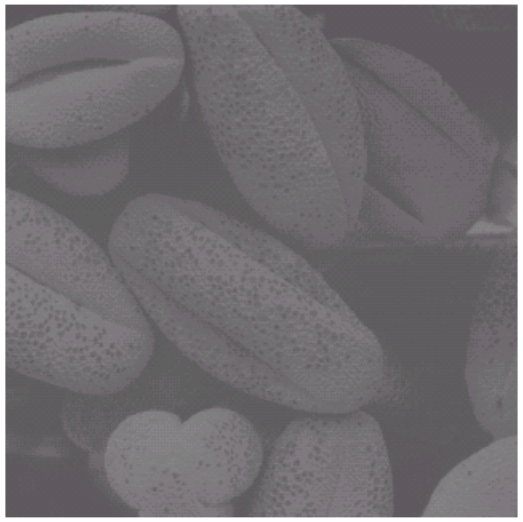
Point Processing: Contrast manipulation cont.

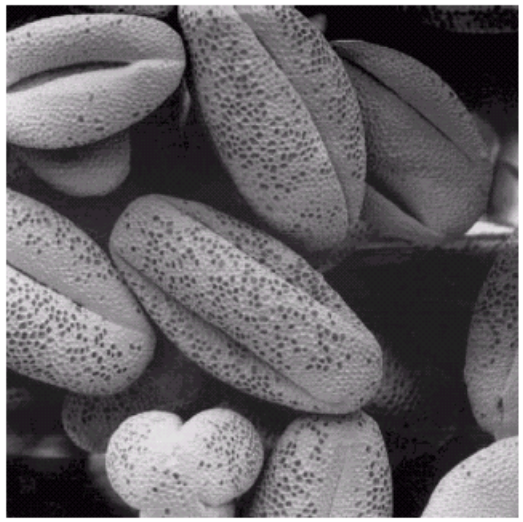
- Another type of transformation is a piecewise linear functions shown below.
- Depending on the slope of each straight line, the original local range of intensities is decreased (slope <1) or increased (slope >1).
- The locations of $(r_1,\ s_1)$ and $(r_2,\ s_2)$ control the shape of the transformation 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.





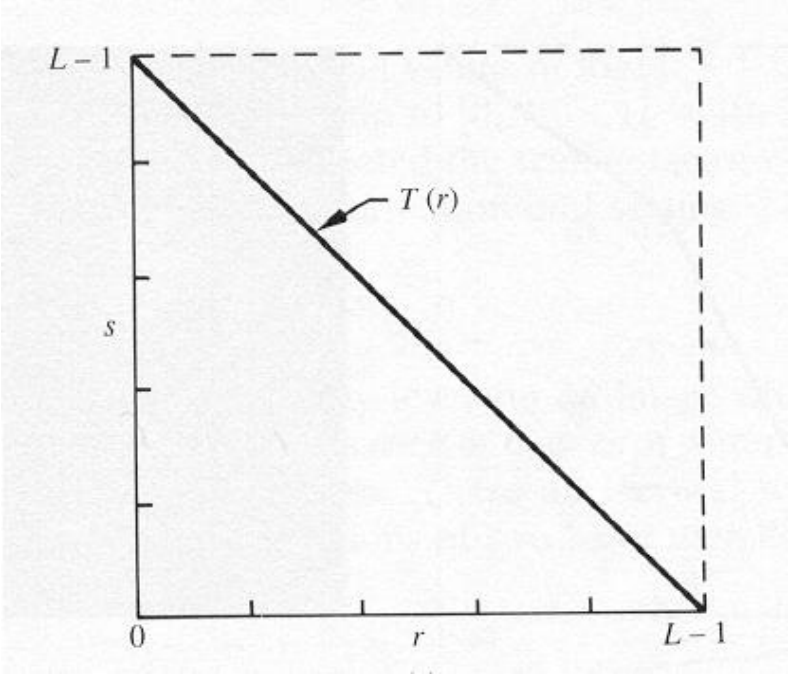


a b
c d

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.)

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Point processing: Log transformations

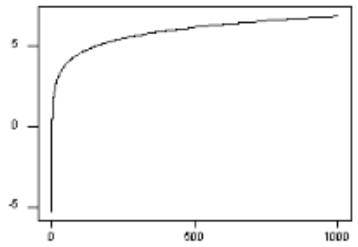
- The log-transformations are a family of transforms of the form:

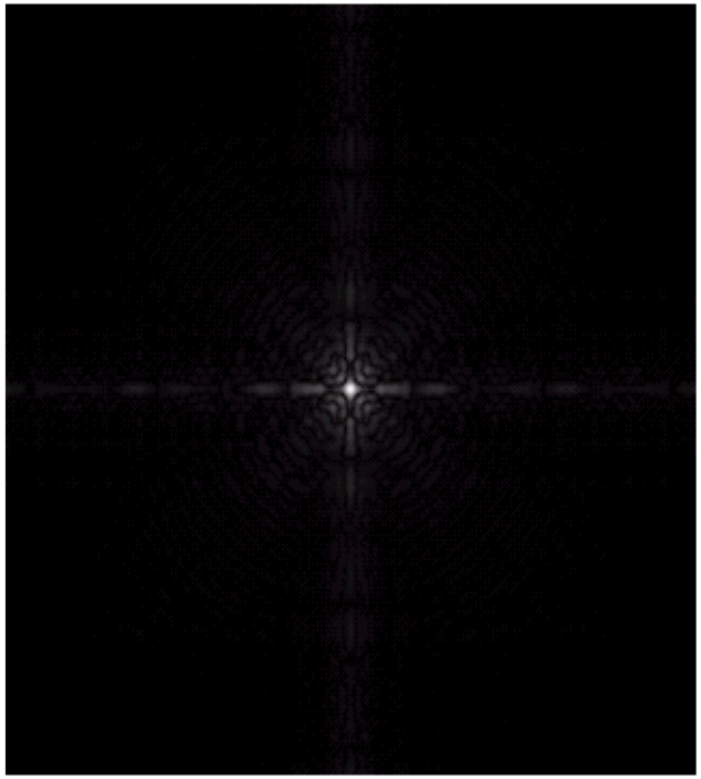
$$s = c\log(1 + r), c: \text{ constant.}$$

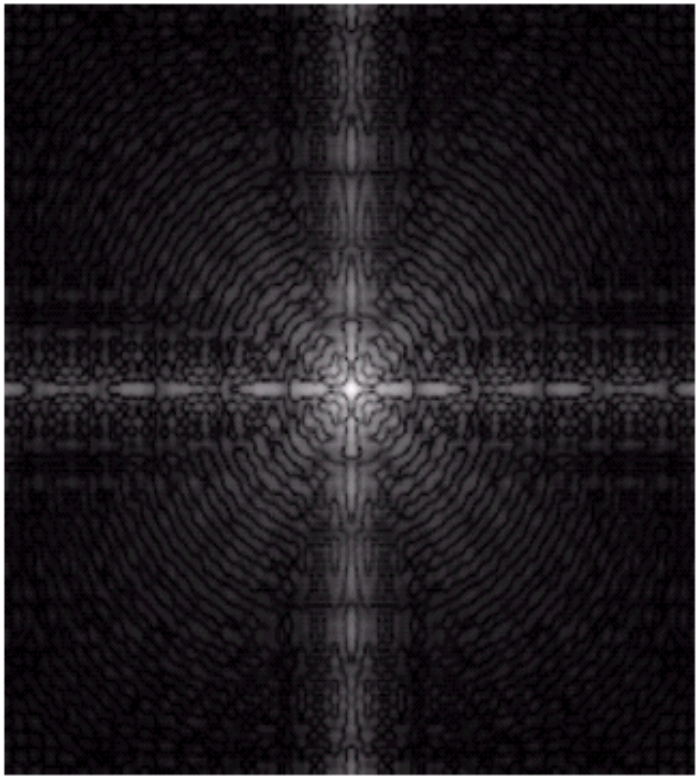
- They are used to enhance the range of small intensities which is compressed and therefore, not visible, in images with large range of intensities.

a b

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







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Point processing: Power law transformations

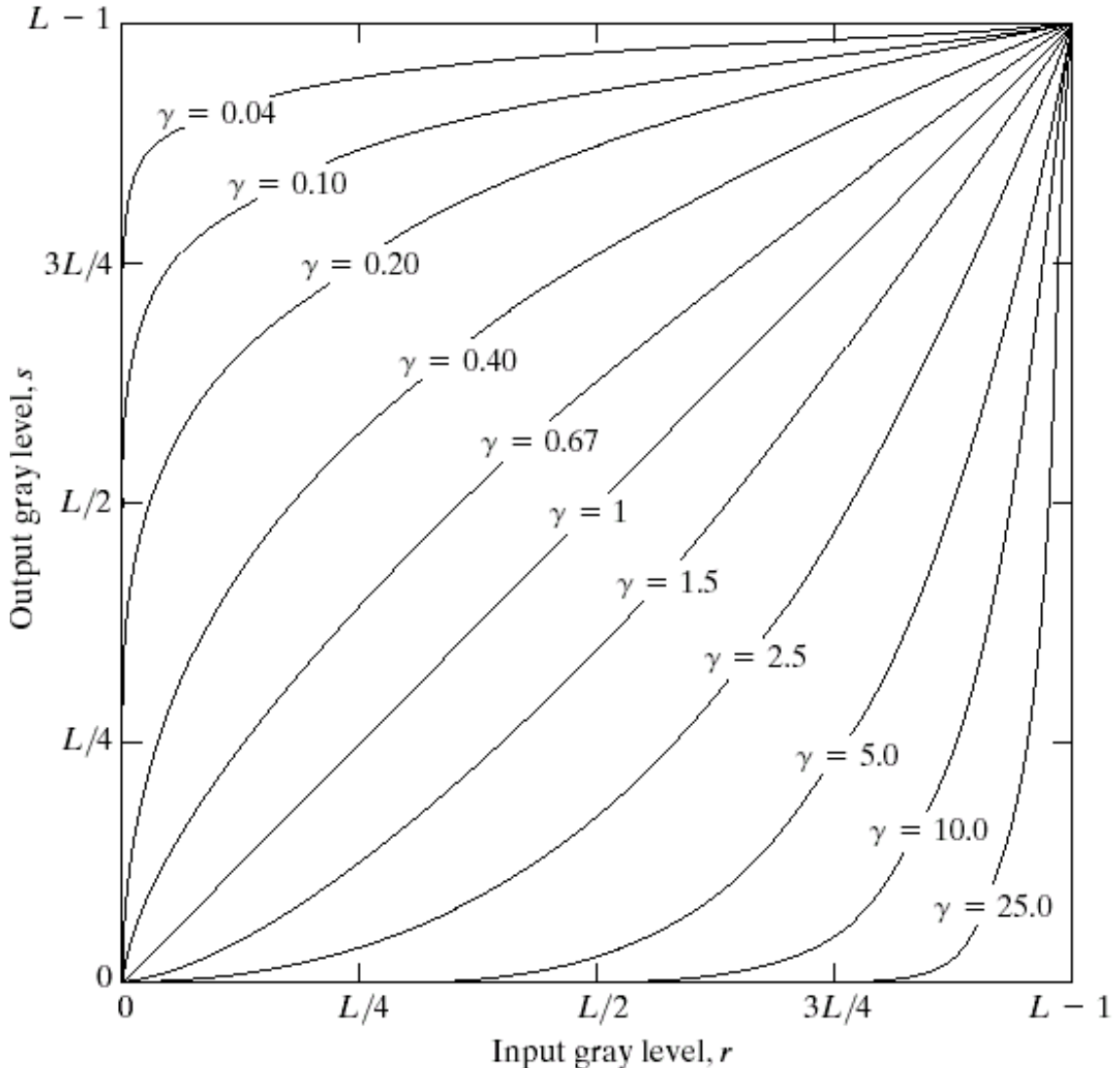


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

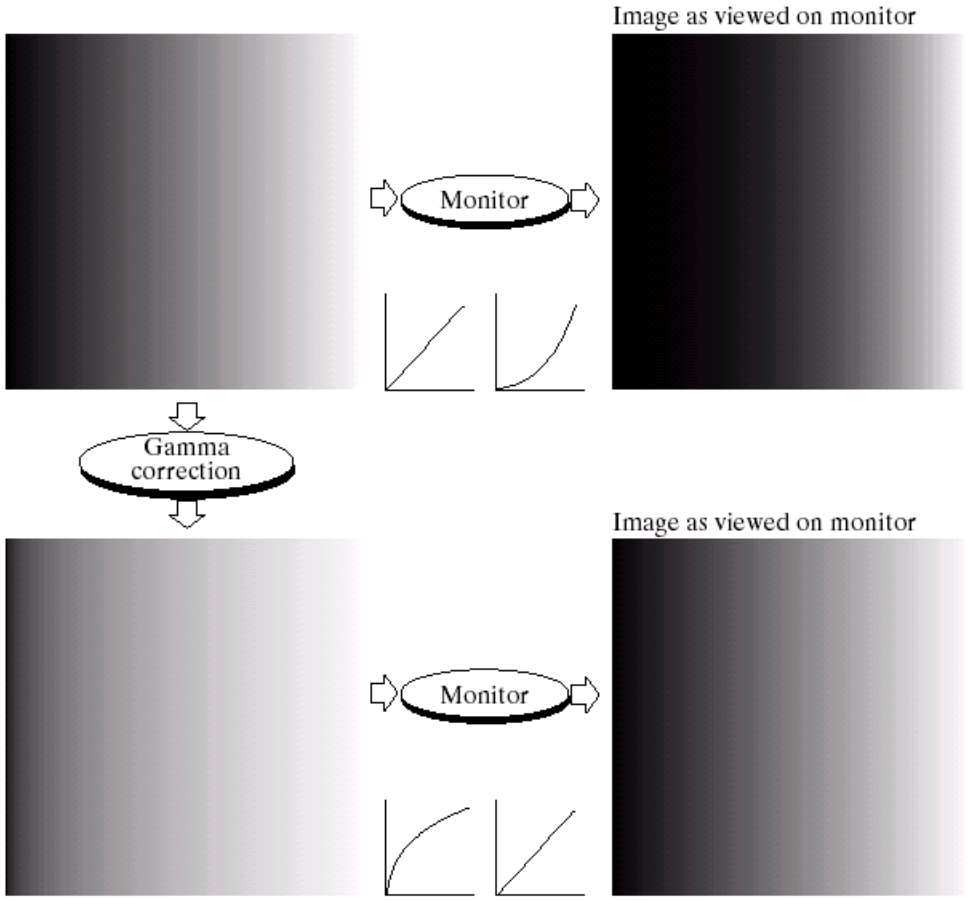
The power law transformations is a family of transforms of the form $s = cr^{\gamma}$ with c, γ: constants.

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.



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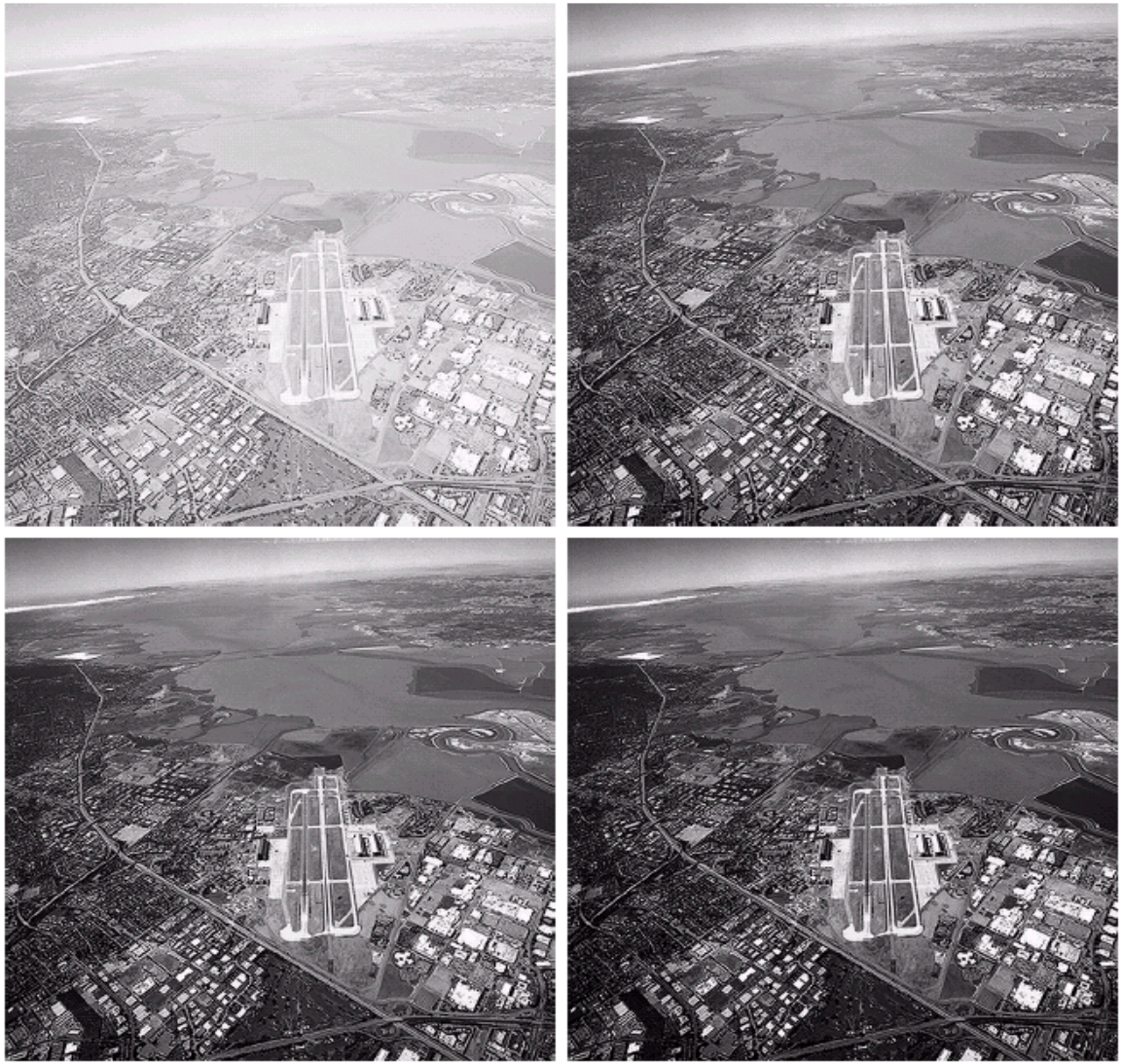
Point processing: Power law transformations cont.

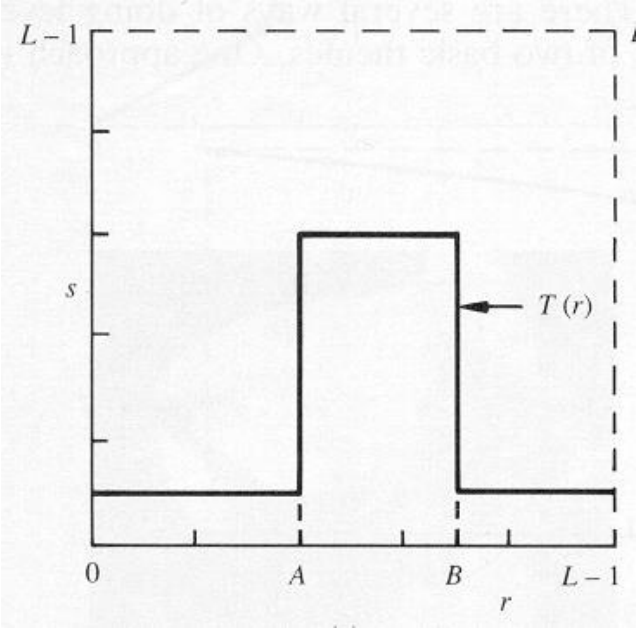
a b
c d

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.)



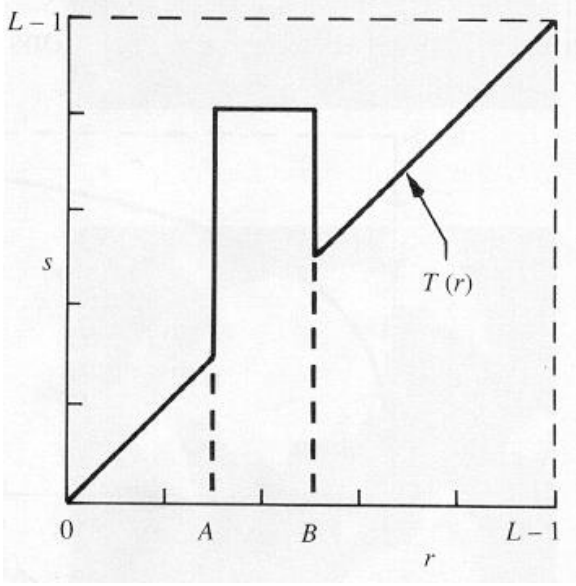
Point Processing: Gray-level slicing

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

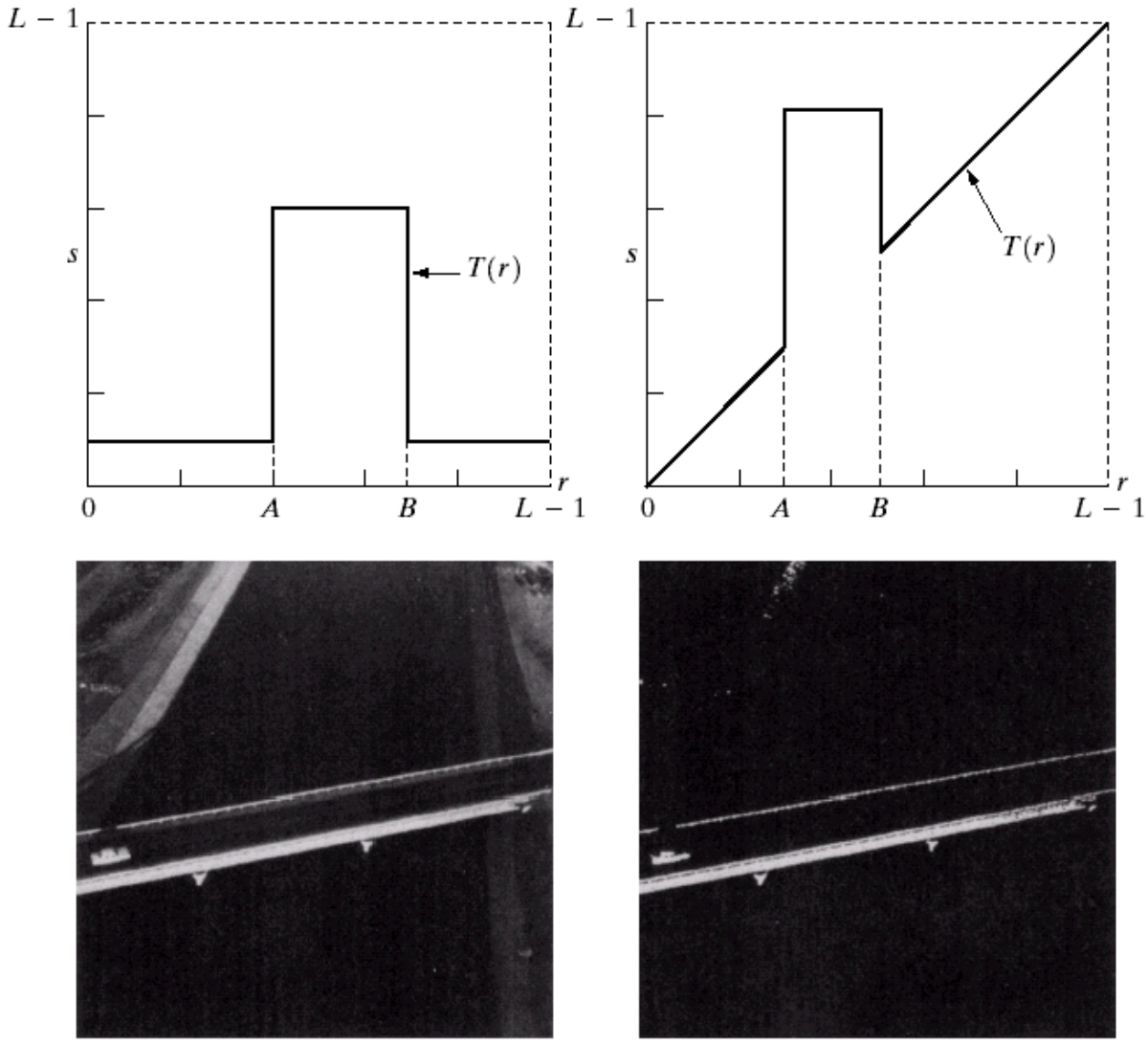


One way is to display a high value for all gray levels in the range of interest and a low value for all other gray levels (binary image).

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.

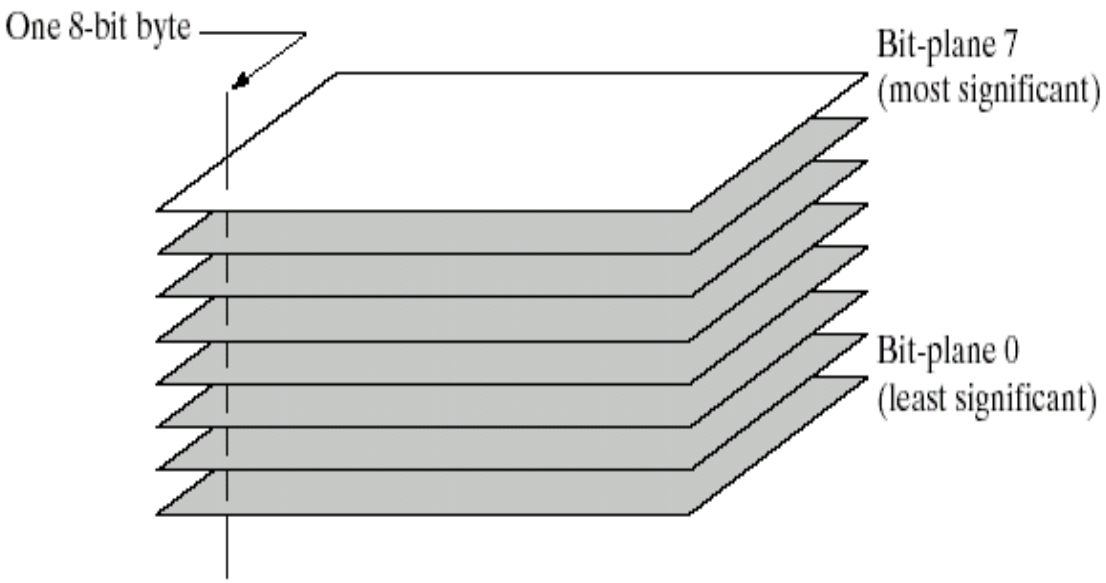


FIGURE 3.12
Bit-plane representation of an 8-bit image.

Point processing: Bit-plane slicing cont.

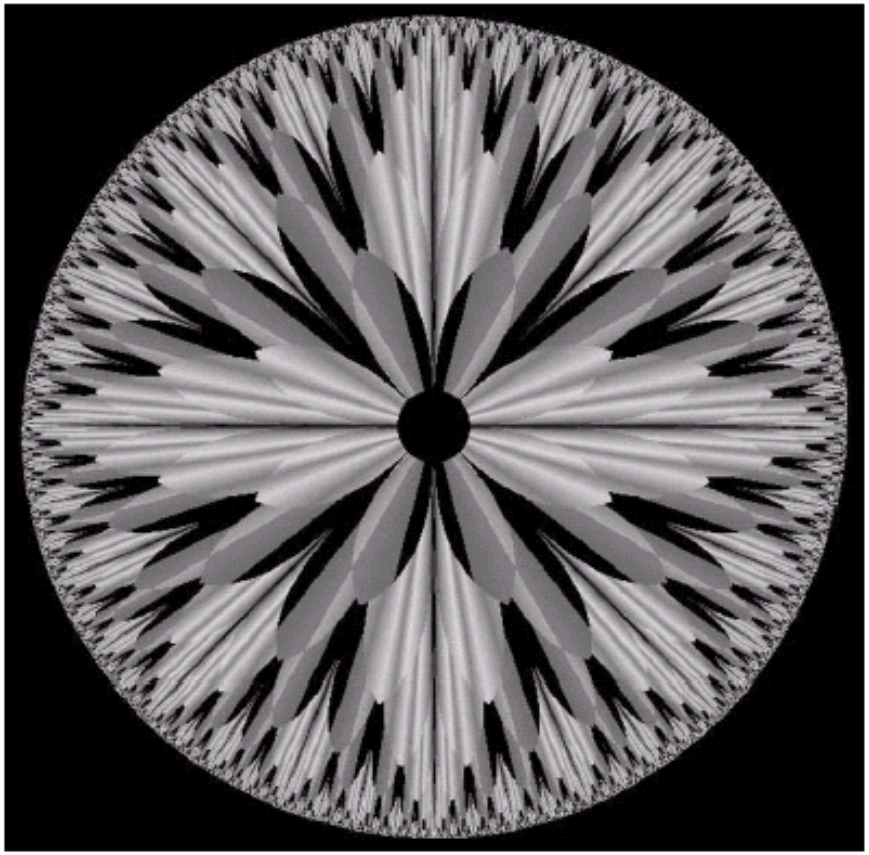


FIGURE 3.13 An 8-bit fractal image. (A fractal is an image generated from mathematical expressions). (Courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA.)

Point processing: Bit-plane slicing cont.

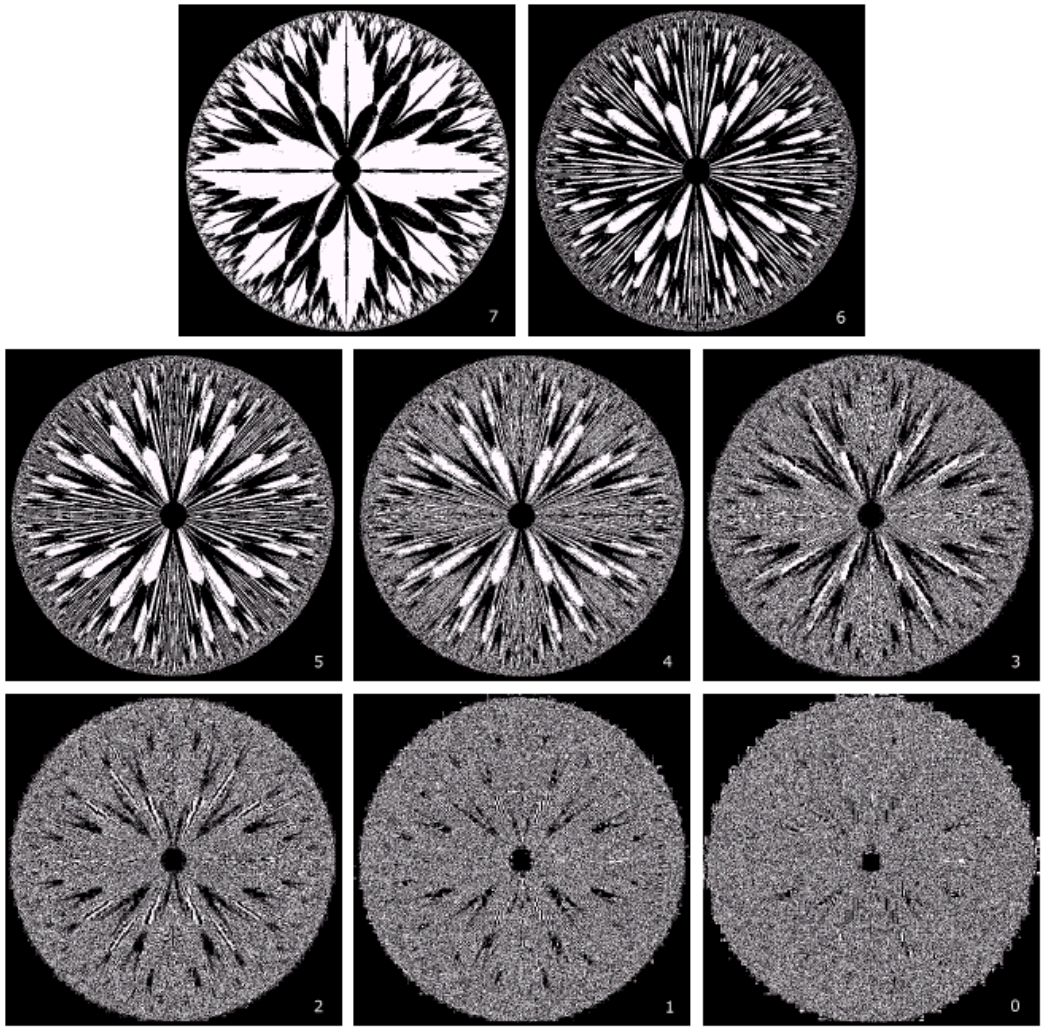


FIGURE 3.14 The eight bit planes of the image in Fig. 3.13. The number at the bottom, right of each image identifies the bit plane.

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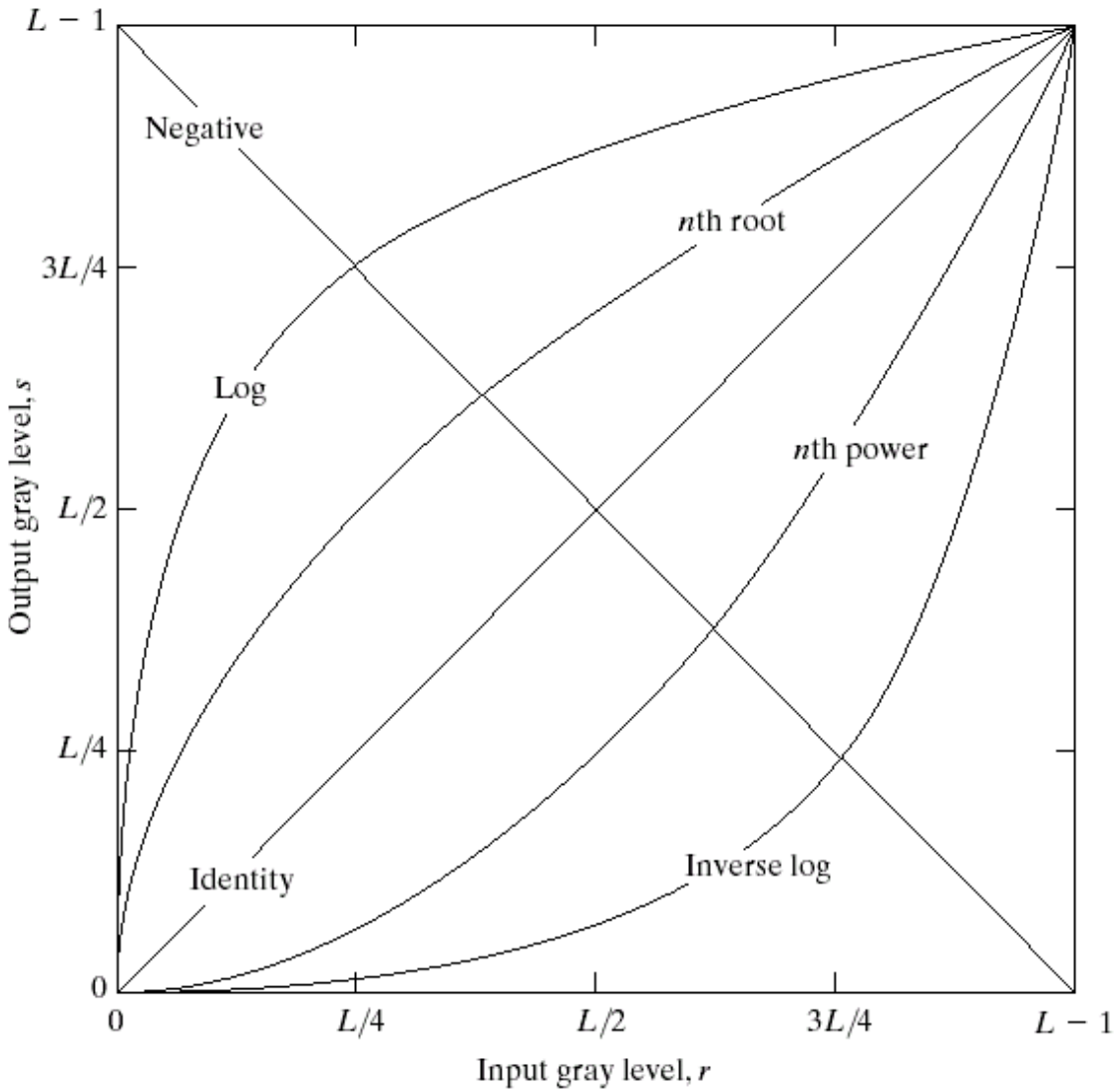
Image Enhancement in the Spatial Domain: Summary of intensity transformations

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



Linear: Negative, Identity

Logarithmic: Log, Inverse Log

Power-Law: nth power, nth root