Lecture 5 – Intensity Transformation

This lecture will cover:

- Spatial domain（空间域）
- Intensity Transformation （灰度变换）

Image Domain

➢ Spatial Domain (空间域)

- Refer to Image plane
- Direct manipulation of pixels
- Computation efficient

➢ Transform Domain (变换域) / Frequency Domain(频率域)

Transform and inverse transform image, and implement by

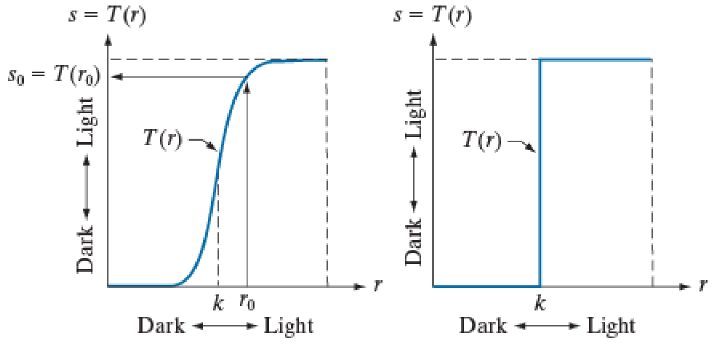
- applying small spatial mask（空间掩模）
- using approximations based on mathematical or statistical criteria

Spatial Domain

The processing in the spatial domain:

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

- **Intensity Transformation（灰度变换）**
  - Operate on single pixels of an image – point processing
  - Contrast manipulation and image thresholding（对比度和阈值处理）
- **Spatial Filtering（空间滤波器）**
  - Operate on a neighborhood of pixels of an image – neighborhood processing
  - Deal with performing operations, for example sharpening and smoothing（锐化和平滑）



a b

FIGURE 3.2 Intensity transformation functions. (a) Contrast-stretching function. (b) Thresholding function.

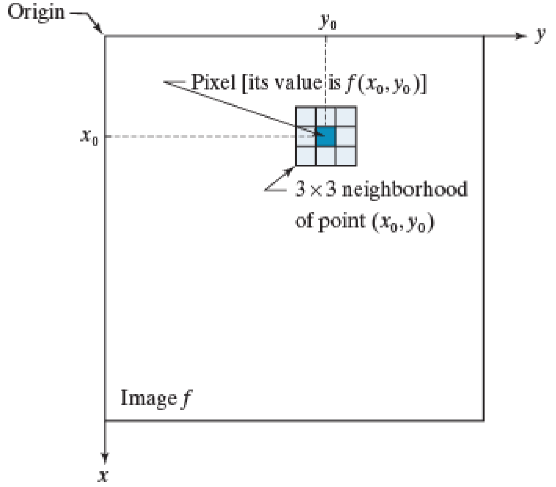


FIGURE 3.1 A 3×3 neighborhood about a point (x_0, y_0) in an image. The neighborhood is moved from pixel to pixel in the image to generate an output image. Recall from Chapter 2 that the value of a pixel at location (x_0, y_0) is $f(x_0, y_0)$, the value of the image at that location.

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Image Enhancement (图像增强)

Goal - More suitable for specific application

- ➢ Problem oriented
- ➢ Specific
- ➢ Subjective
  - For visual interpretation : viewer is the judge
  - For machine perception : easy to quantify

Intensity Transformation

- **Simplest image processing techniques:** intensity mapping by pixel

$$s = T(r)$$

- **Types of Intensity Transformation**
  - Linear transformation
    - ✓ Image Negatives（图像反转）
    - ✓ Piecewise-Linear Transformation（分段线性变换）
  - Log Transformation（对数变换）
  - Power-law (gamma) Transformation（幂律/伽马变换）
  - Histogram（直方图处理）

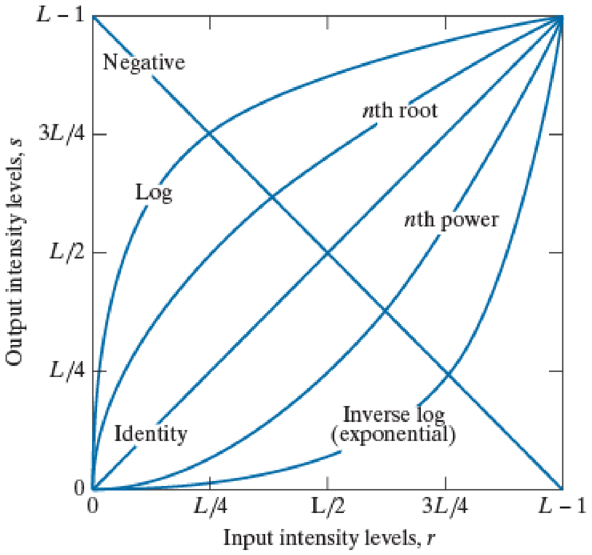


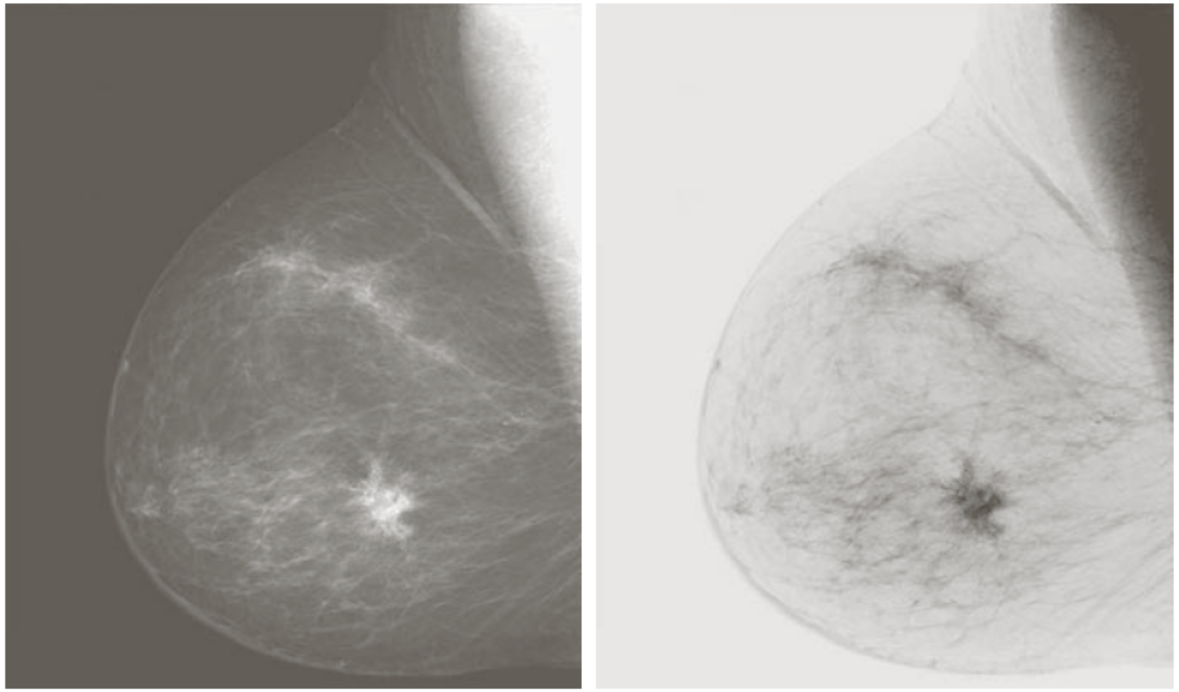
FIGURE 3.3 Some basic intensity transformation functions. Each curve was scaled independently so that all curves would fit in the same graph. Our interest here is on the shapes of the curves, not on their relative values.

Image Negatives

$$s = L - 1 - r$$

a b

FIGURE 3.4
(a) A digital mammogram. (b) Negative image obtained using Eq. (3-3). (Image (a) Courtesy of General Electric Medical Systems.)



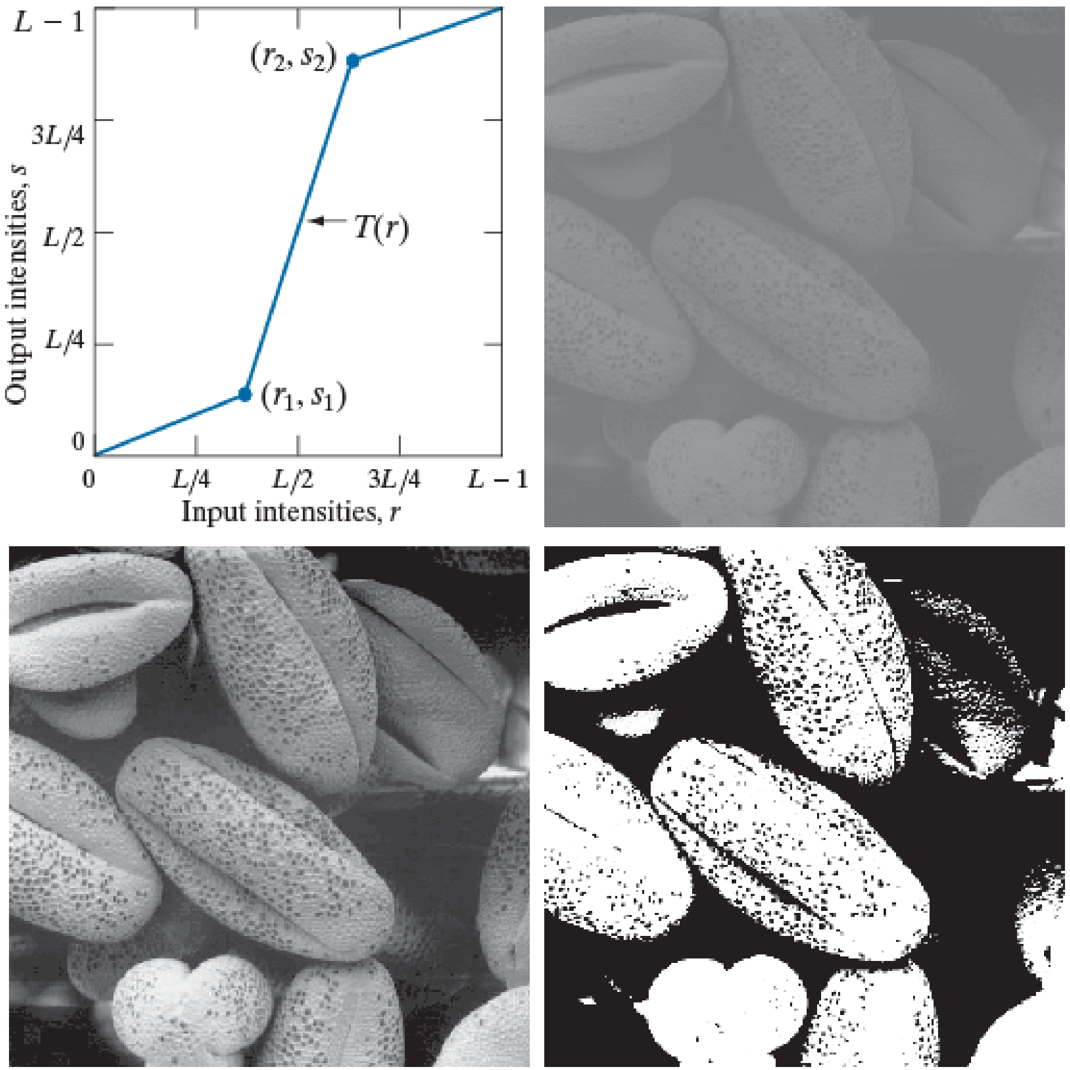
Piecewise-Linear Transformation

- **Arbitrarily complex**
- **User defined**
- **Commonly used methods**
  - Contrast Stretching（对比度拉伸）
  - Intensity-level slicing（灰度级分层）
  - Bit-plane slicing （比特平面分层）

Contrast Stretching

a b
c d

FIGURE 3.10 Contrast stretching. (a) Piecewise linear transformation function. (b) A low-contrast electron microscope image of pollen, magnified 700 times. (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.)

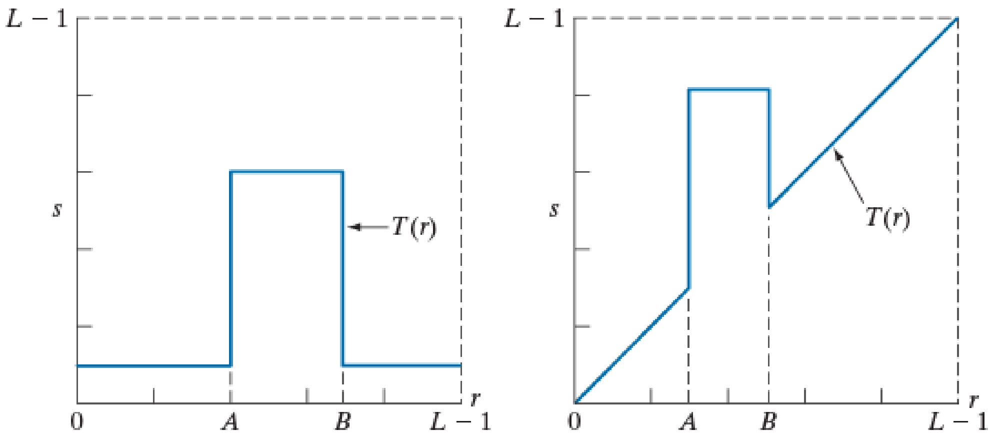


$r_1 = r_2$
$s_1 = 0$
$s_2 = L\text{-}1$

Intensity-level slicing

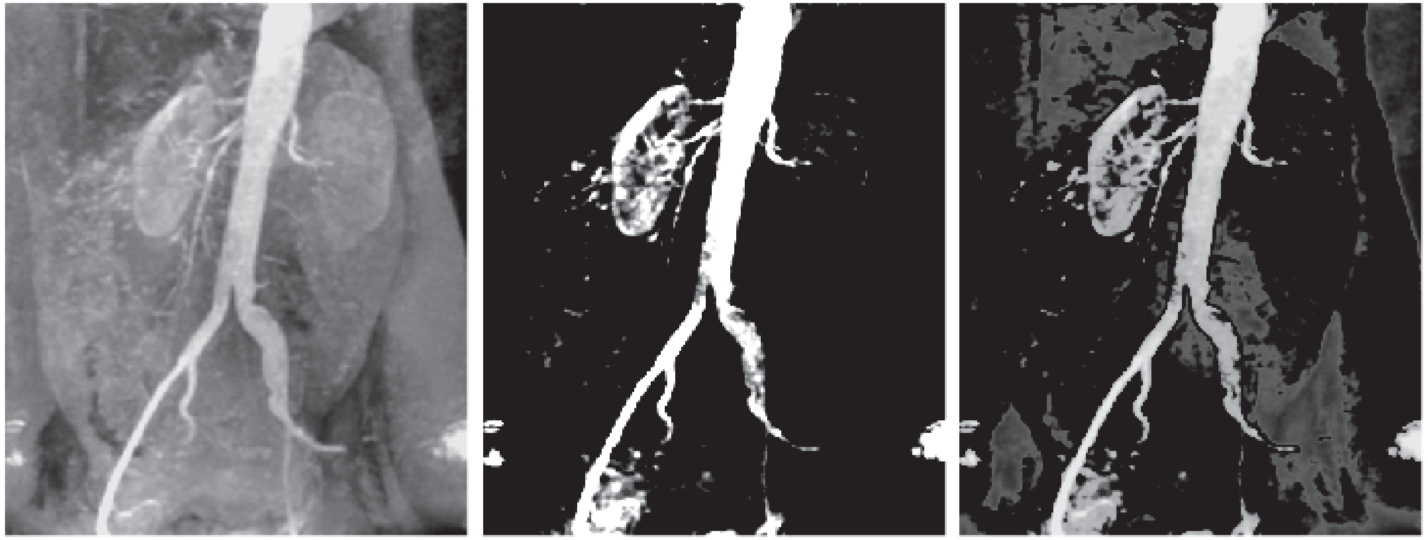
a b

FIGURE 3.11
(a) This transformation function highlights range $[A, B]$ and reduces all other intensities to a lower level.
(b) This function highlights range $[A, B]$ and leaves other intensities unchanged.



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 range set near black, so that the 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

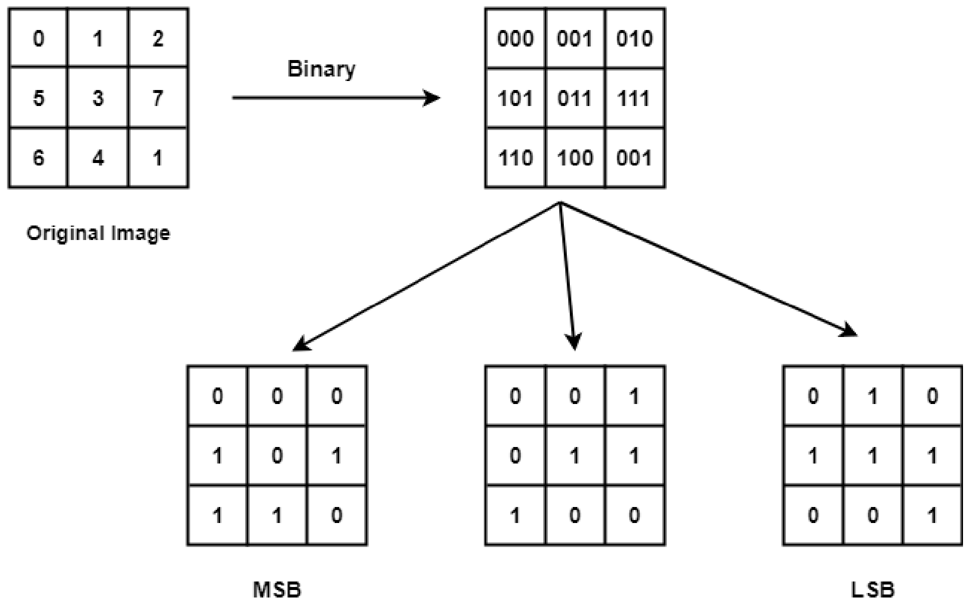


Fig. Bit-planes of an 8 gray-level (3-bit) image.

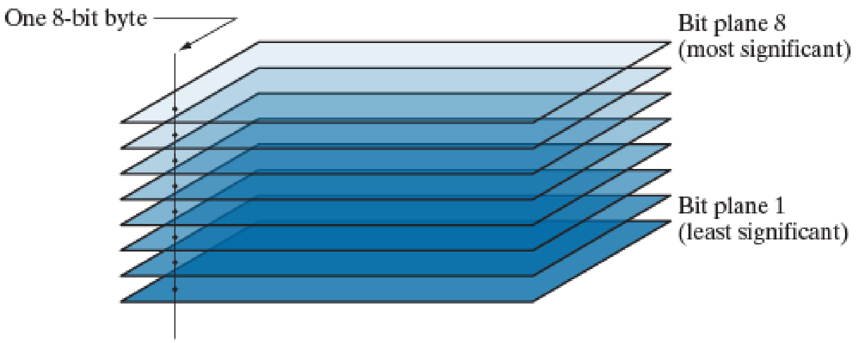


FIGURE 3.13 Bit-planes of an 8-bit image.

Bit-plane slicing

a b c
d e f
g h i

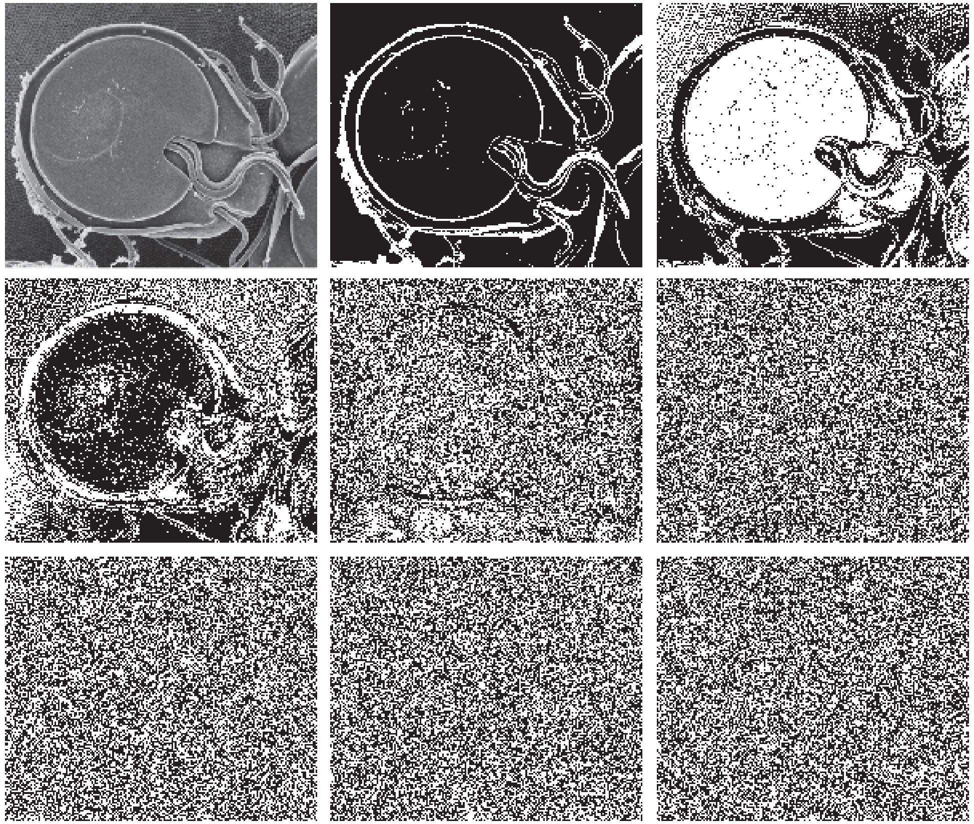


FIGURE 3.14 (a) An 8-bit gray-scale image of size 837 × 988 pixels. (b) through (i) Bit planes 8 through 1, respectively, where plane 1 contains the least significant bit. Each bit plane is a binary image. Figure (a) is an SEM image of a trophozoite that causes a disease called *giardiasis*. (Courtesy of Dr. Stan Erlandsen, U.S. Center for Disease Control and Prevention.)

a b c

FIGURE 3.15 Image reconstructed from bit planes: (a) 8 and 7; (b) 8, 7, and 6; (c) 8, 7, 6, and 5.

- Higher order bit planes contains a great deal of the visually significant data
- Decomposition of an image

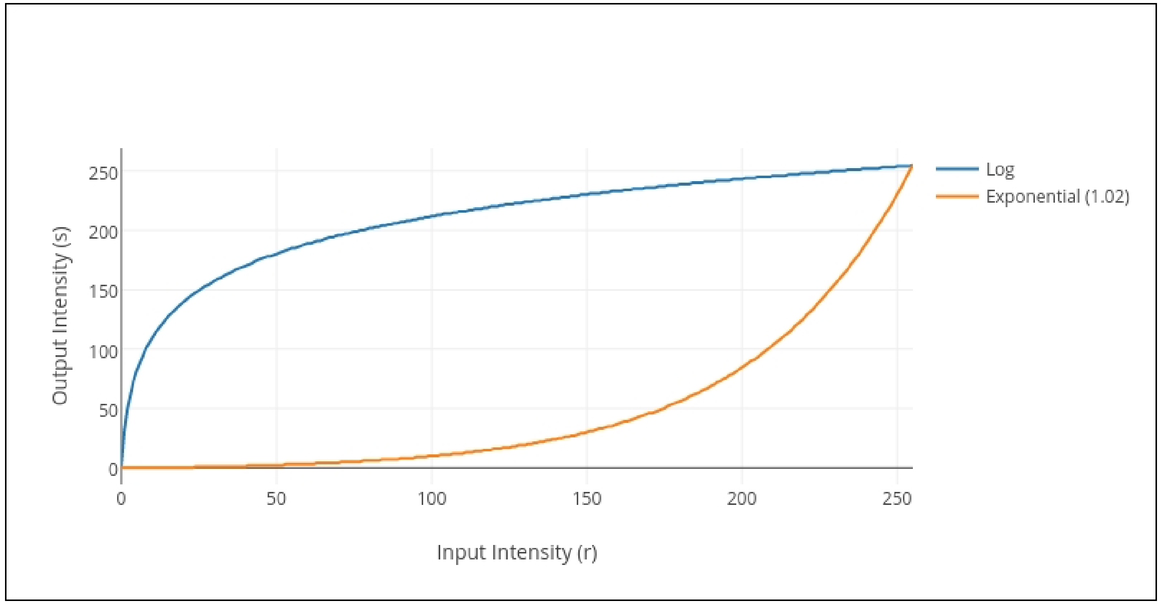
Log Transformation

- **Log Transformation (对数变换)**

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

- **Inverse Log Transformation (反对数变换)**

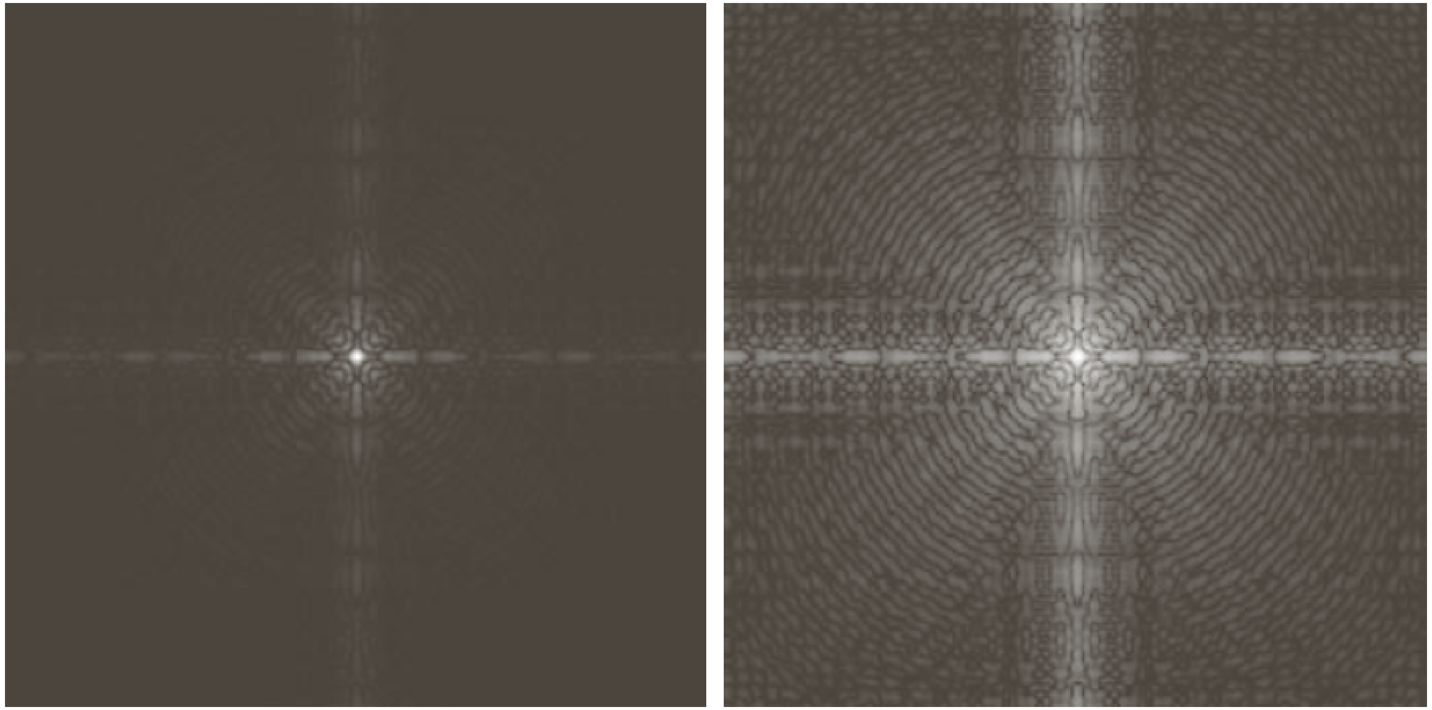
$$s = c \cdot (b^r - 1)$$



Fourier Spectrum

a b

FIGURE 3.5
(a) Fourier spectrum displayed as a grayscale image. (b) Result of applying the log transformation in Eq. (3-4) with $c = 1$. Both images are scaled to the range [0, 255].



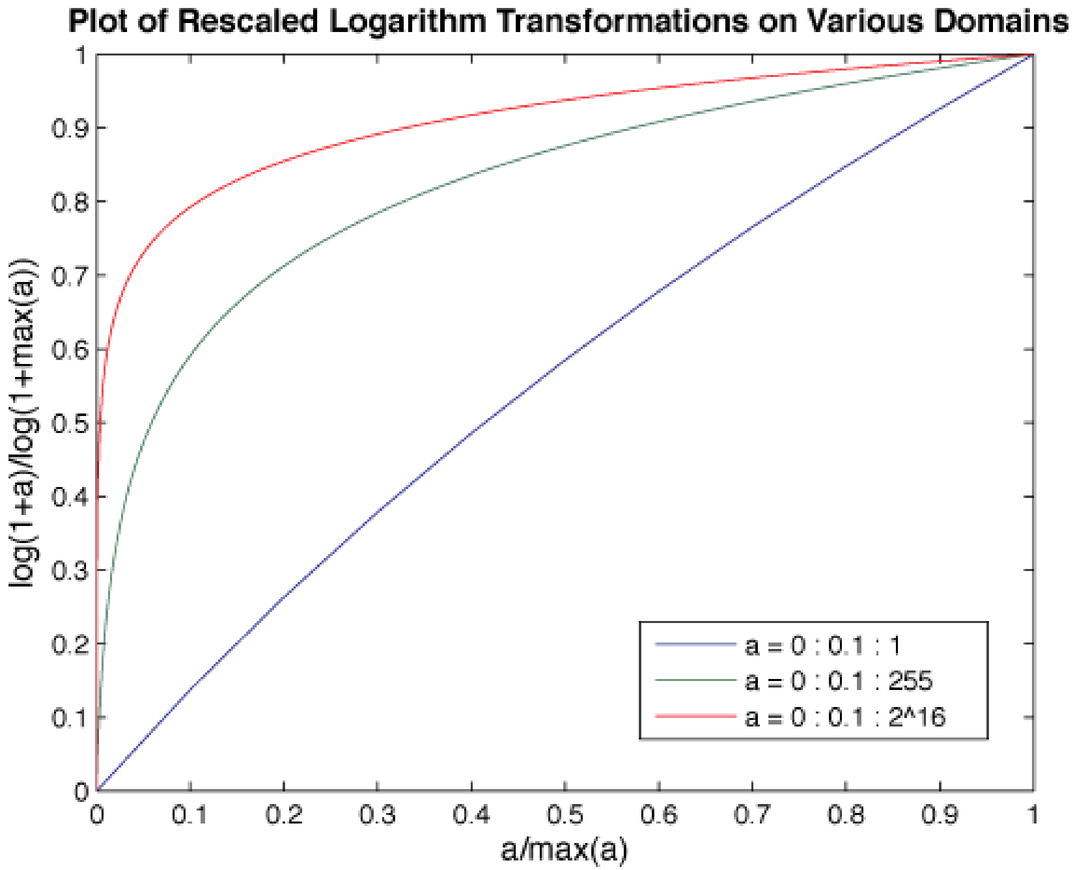
Gray Level Range

Original Picture

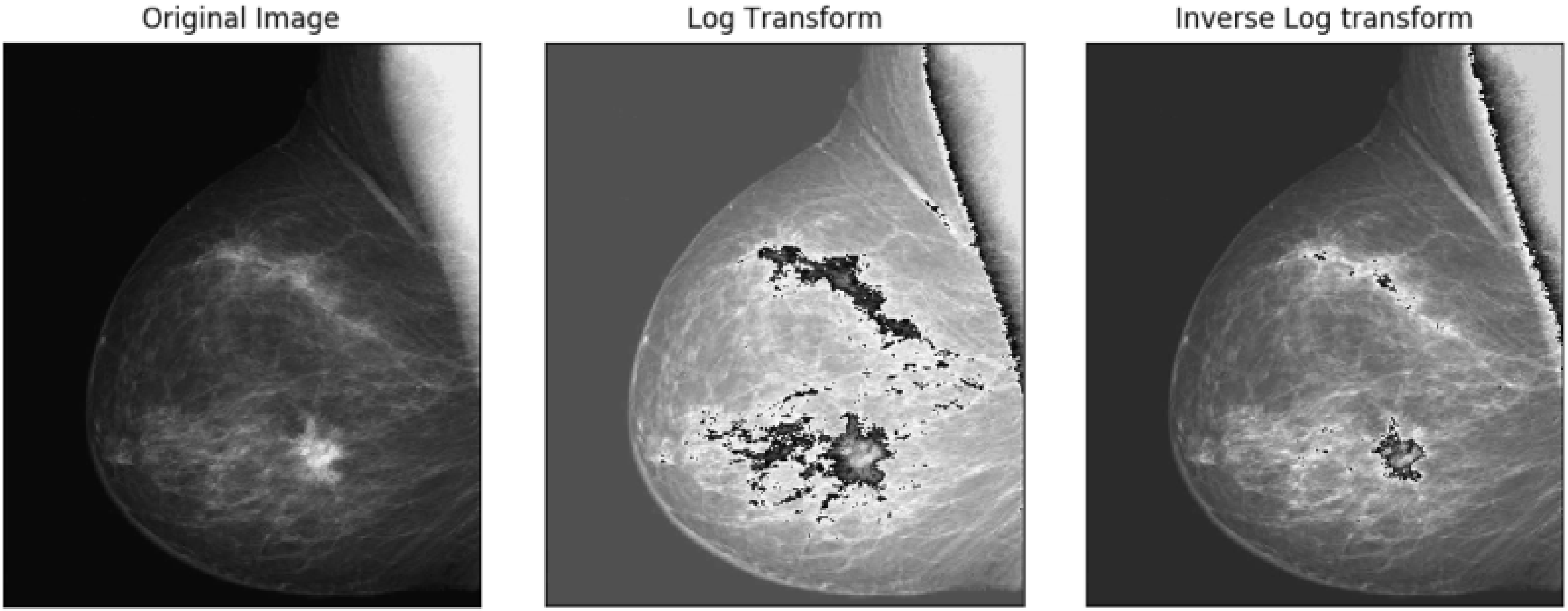
log on domain [0, 1]

log on domain [0, 255]

log on domain [0, 65535]



Log Transformation



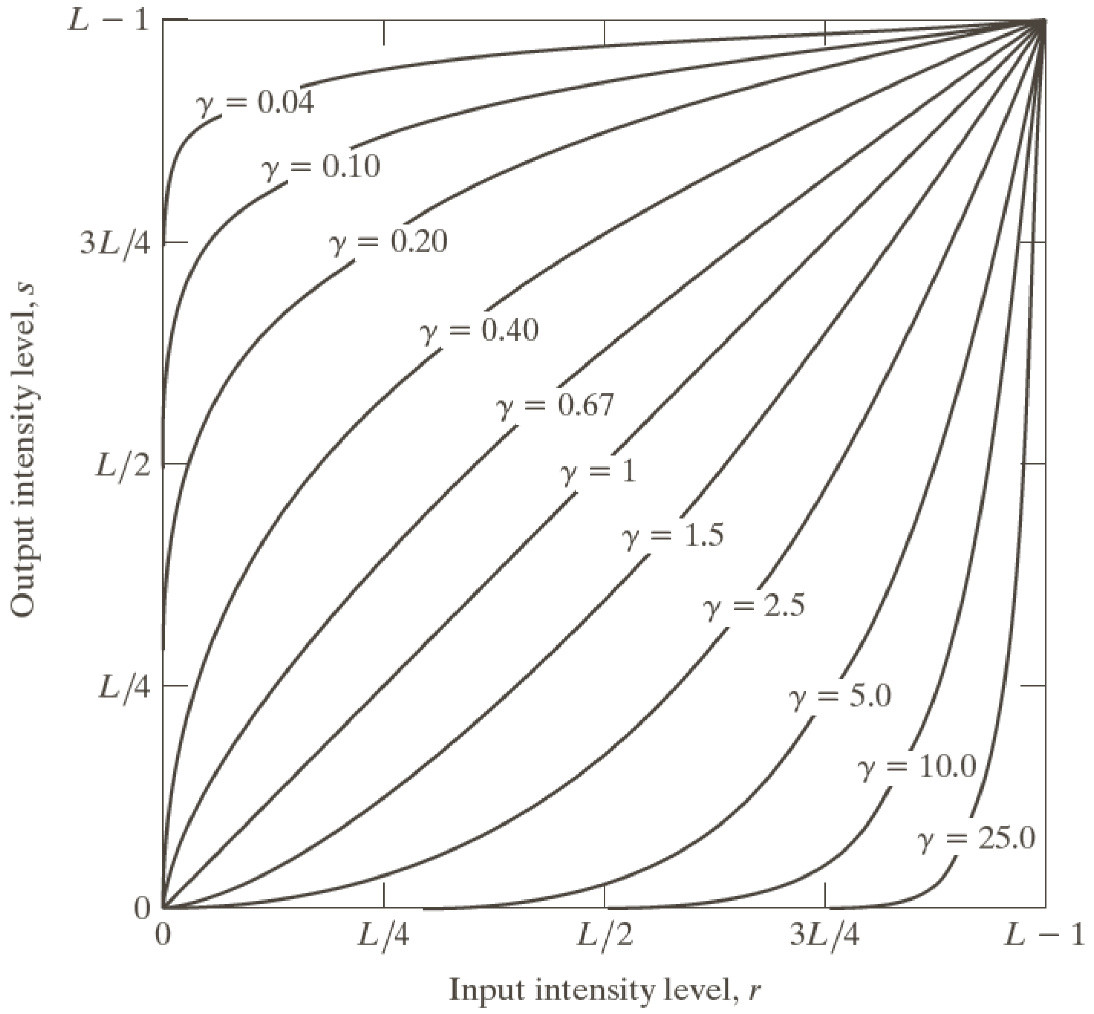
Gamma Transformation

- **Gamma Transformation （伽马变换）**

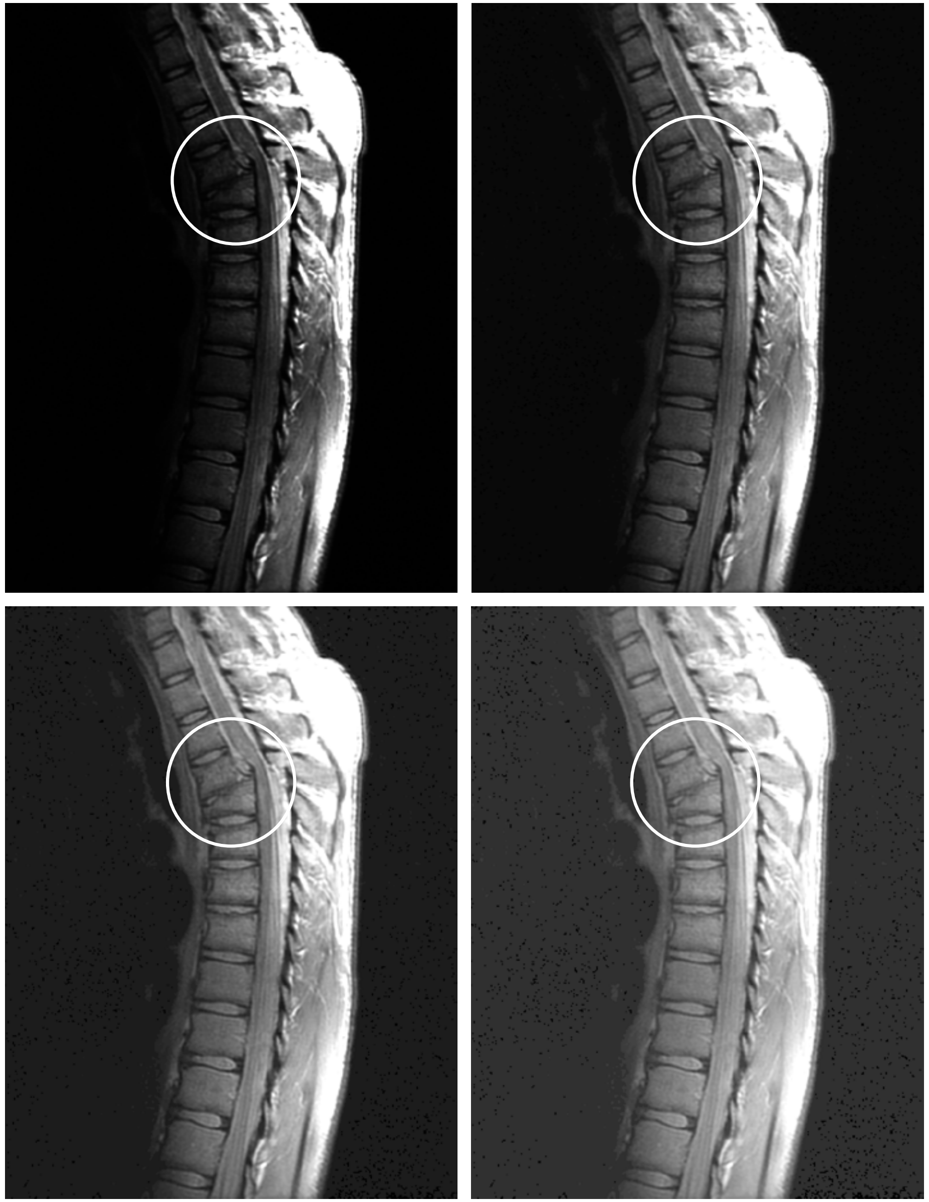
$$s = c \cdot r^{\gamma}$$

or

$$s = c \cdot (r + \varepsilon)^{\gamma}$$



Gamma Transformation



a b
c d

FIGURE 3.8
(a) Magnetic resonance image (MRI) of a fractured human spine (the region of the fracture is enclosed by the circle). (b)–(d) Results of applying the transformation in Eq. (3-5) with $c = 1$ and $\gamma = 0.6, 0.4$, and 0.3, respectively. (Original image courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Gamma Transformation

a b
c d

FIGURE 3.9
(a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3-5) with $\gamma = 3.0, 4.0$, and 5.0, respectively. ($c = 1$ in all cases.) (Original image courtesy of NASA.)

Gamma Correction （伽马校正）

a b
c d

FIGURE 3.7
(a) Image of a human retina. (b) Image as as it appears on a monitor with a gamma setting of 2.5 (note the darkness). (c) Gamma-corrected image. (d) Corrected image, as it appears on the same monitor (compare with the original image). (Image (a) courtesy of the National Eye Institute, NIH)