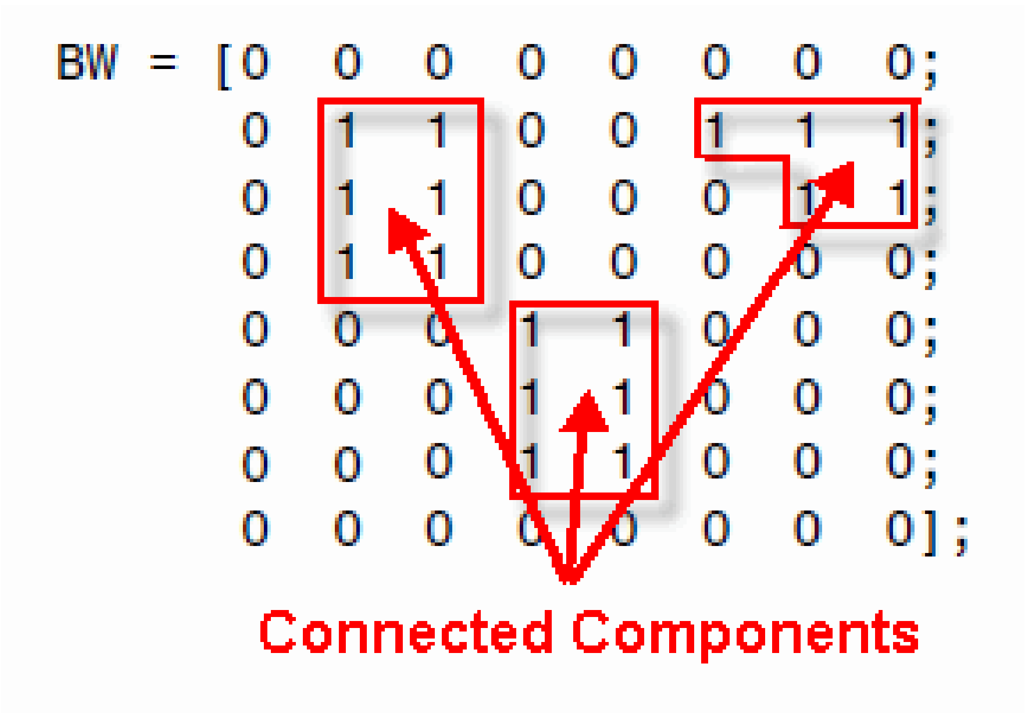
Digital Image Processing

Connected component



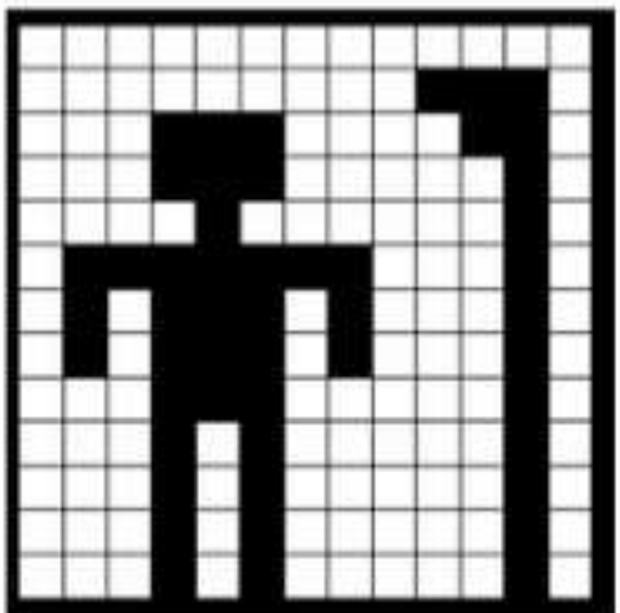
Connected component labeling

- the process of identifying the connected components in an image and assigning each one a unique label, like this:

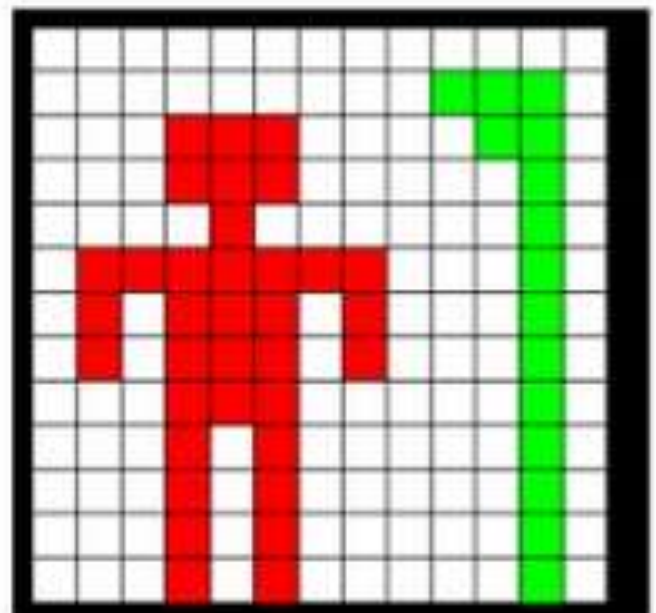
```
BW = [0   0   0   0   0   0   0   0   0;
      0   1   1   0   0   0   3   3   3;
      0   1   1   0   0   0   0   3   3;
      0   1   1   0   0   0   0   0   0;
      0   0   0   0   2   2   0   0   0;
      0   0   0   0   2   2   0   0   0;
      0   0   0   0   2   2   0   0   0;
      0   0   0   0   0   0   0   0   0];
```

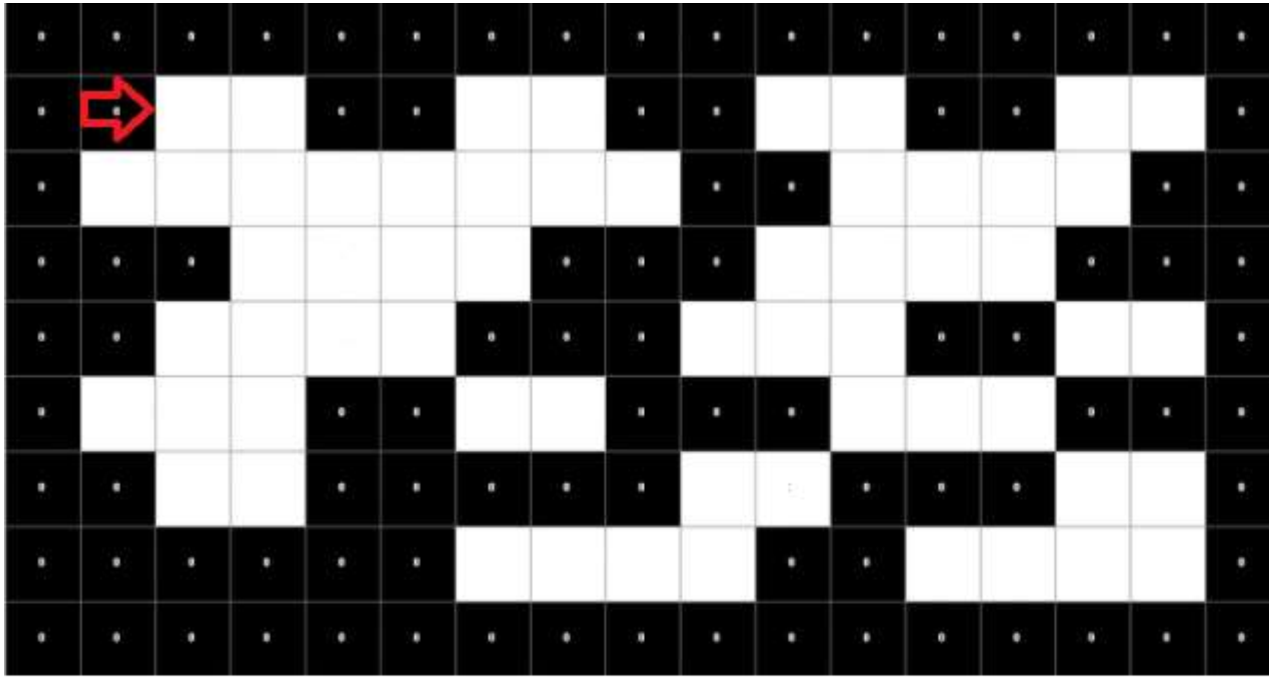
Labeled Connected Components

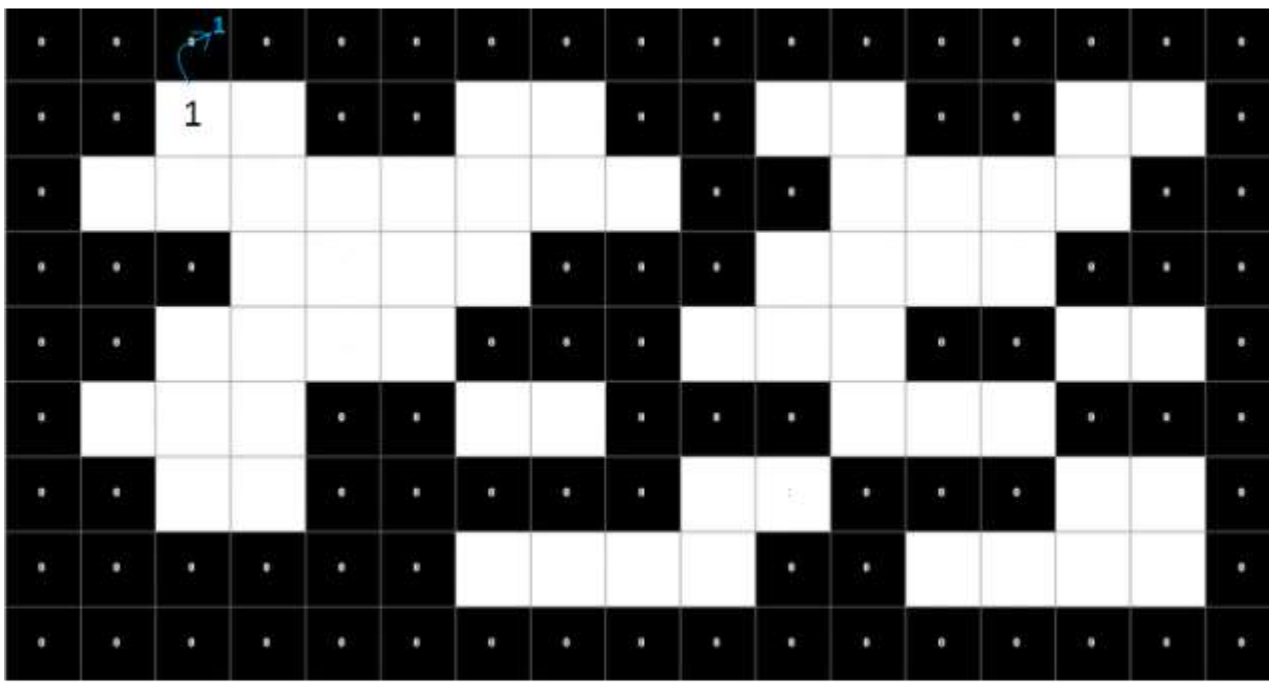
Original Image

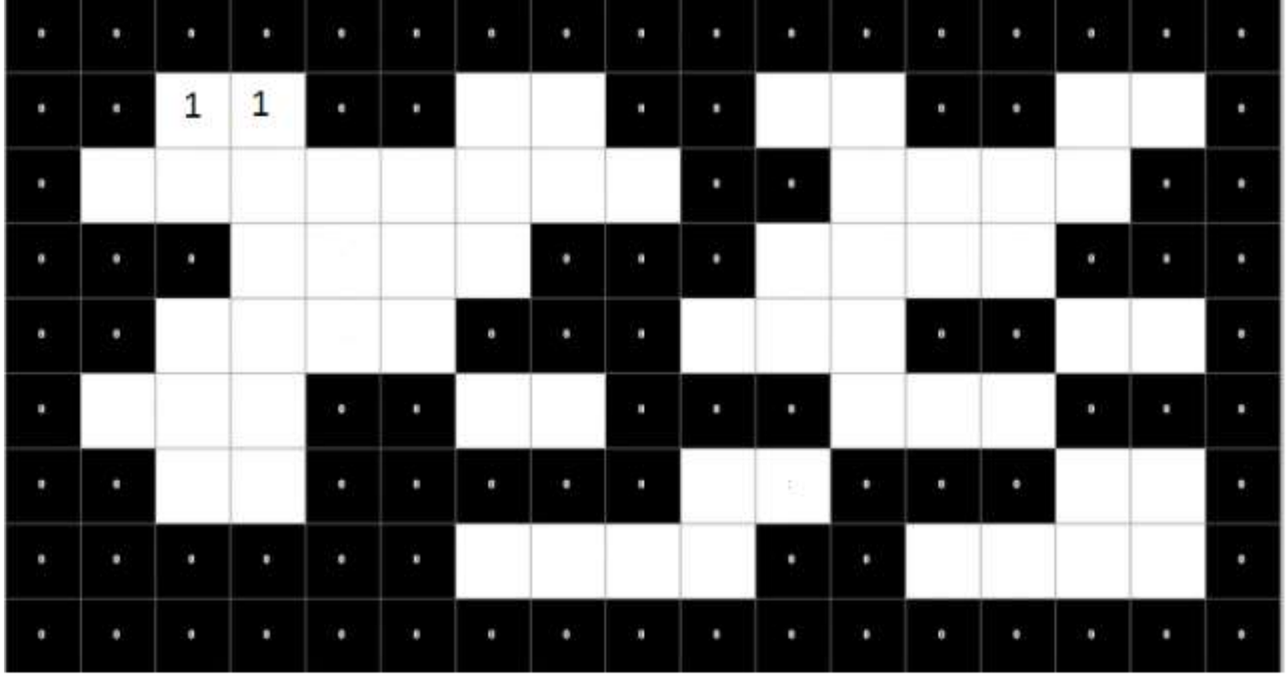


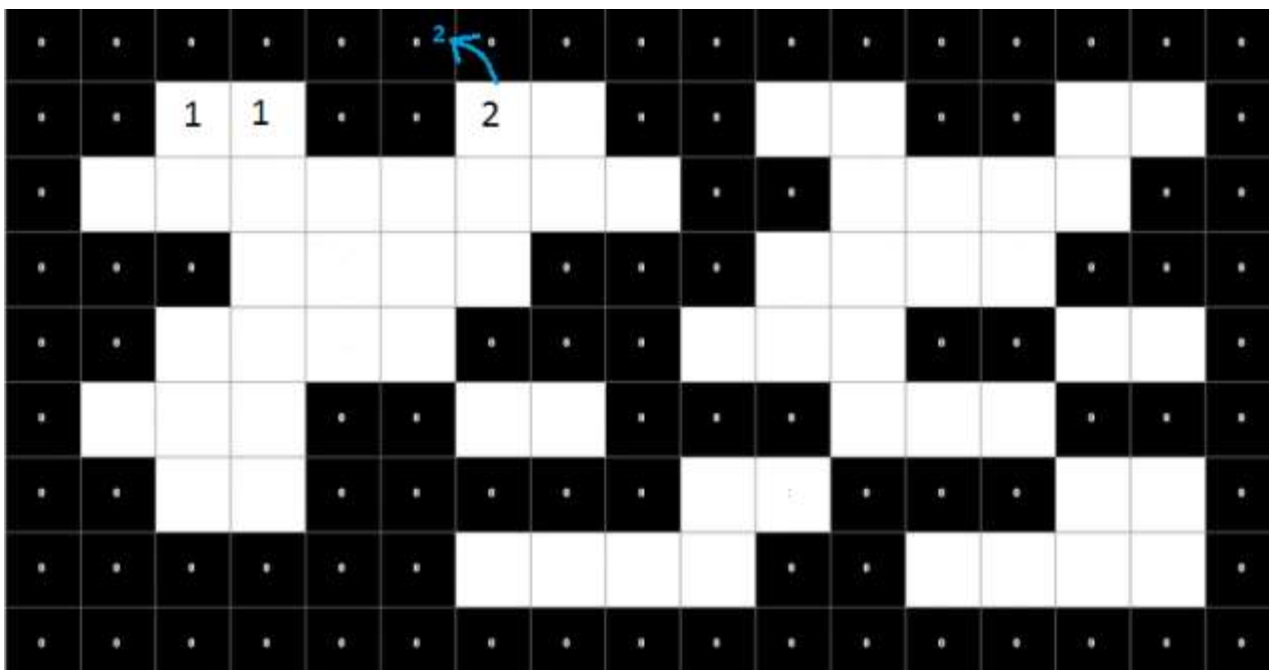
Labeled Objects

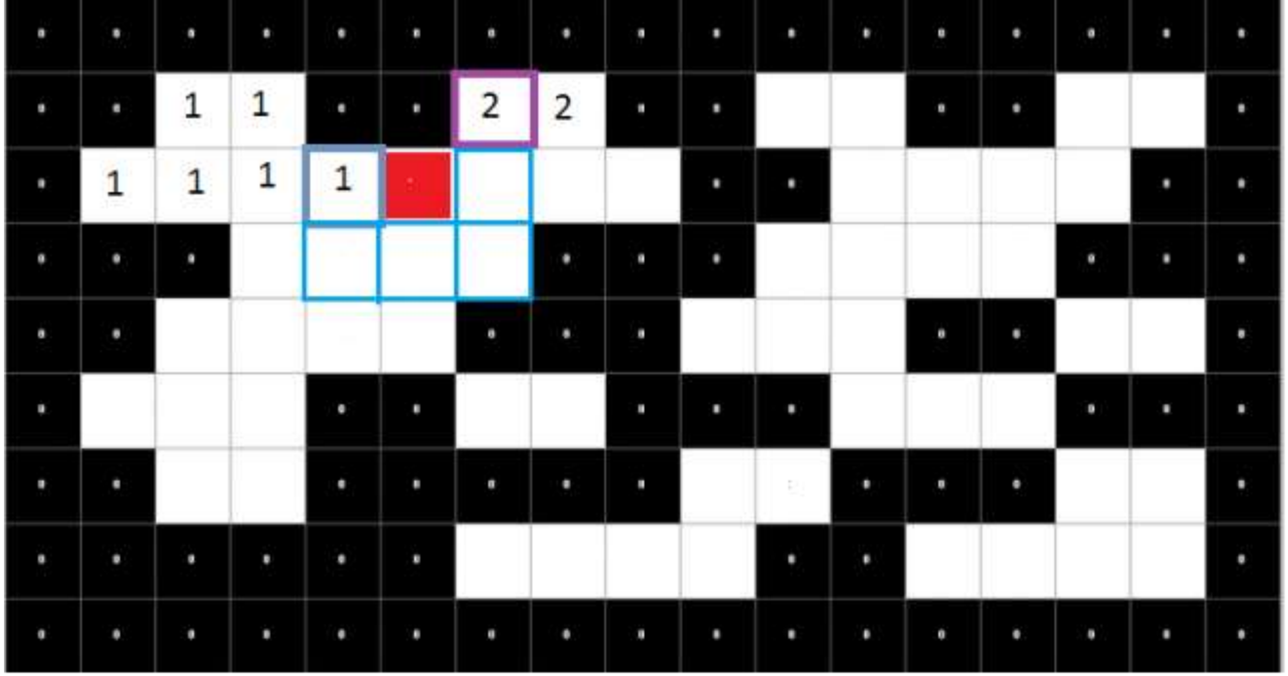


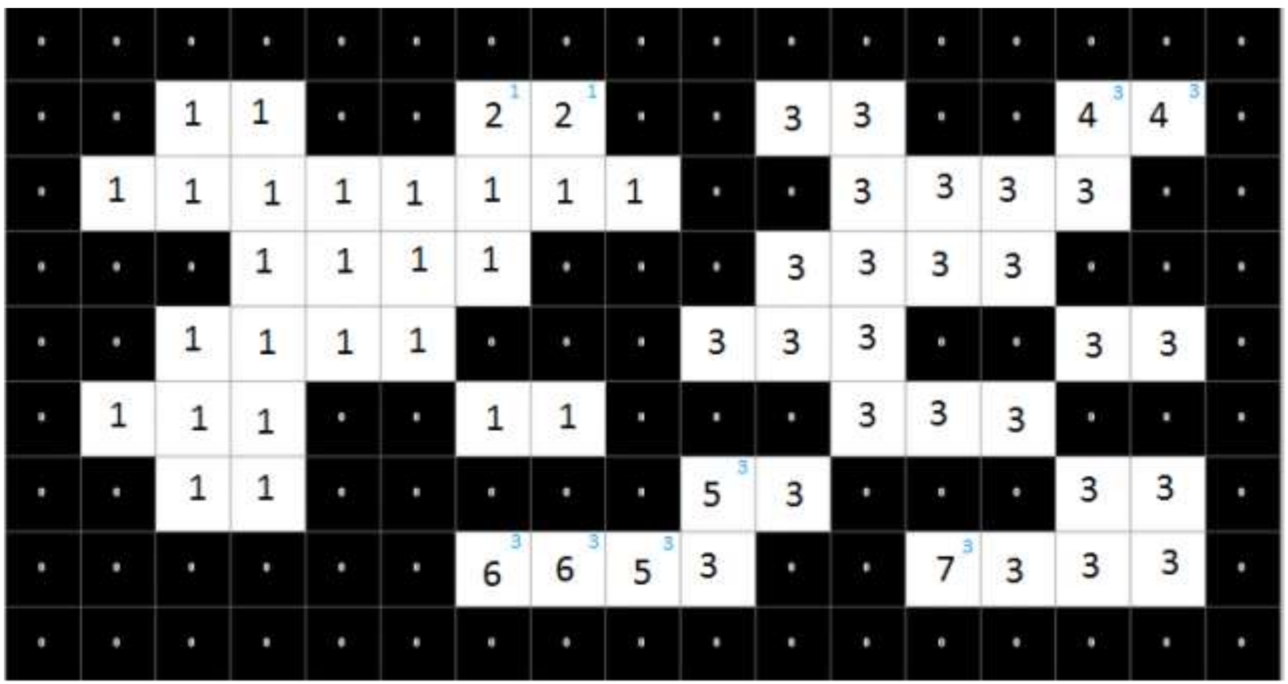



1
1


1 1


2
1 1 2





Intensity Transformation

Contents

- Spatial domain vs. Transform domain
- Enhancement
- Intensity transformation functions
  - Linear
  - Logarithmic
  - Power law
- Piecewise-Linear Transformation function
  - Contrast stretching
  - Intensity-level slicing
  - Bit-plane slicing

Spatial Domain vs. Transform Domain

- Spatial domain

  image plane itself, directly process the intensity values of the image plane

- Transform domain

  process the transform coefficients, not directly process the intensity values of the image plane

Enhancement

- To manipulate an image so that the result is more suitable than the original for a specific application
  - Problem oriented

Spatial Domain Process

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

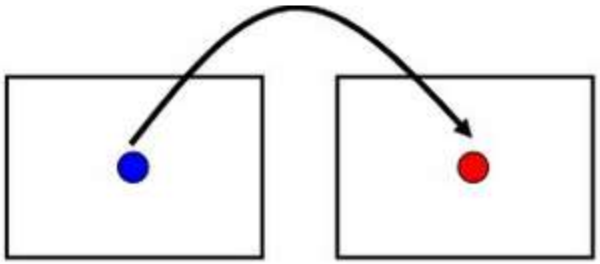
$f(x,y)$: input image

$g(x,y)$: output image

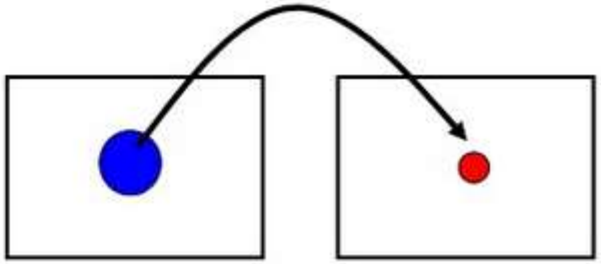
T : an operator on f defined over a neighborhood of point (x,y)

Spatial Operations

- Point/Pixel operations
  - Output value at specific coordinates (x,y) is dependent only on the input value at (x,y)



- Local/neighborhood operations
  - The output value at (x,y) is dependent on the input values in the neighborhood of (x,y)

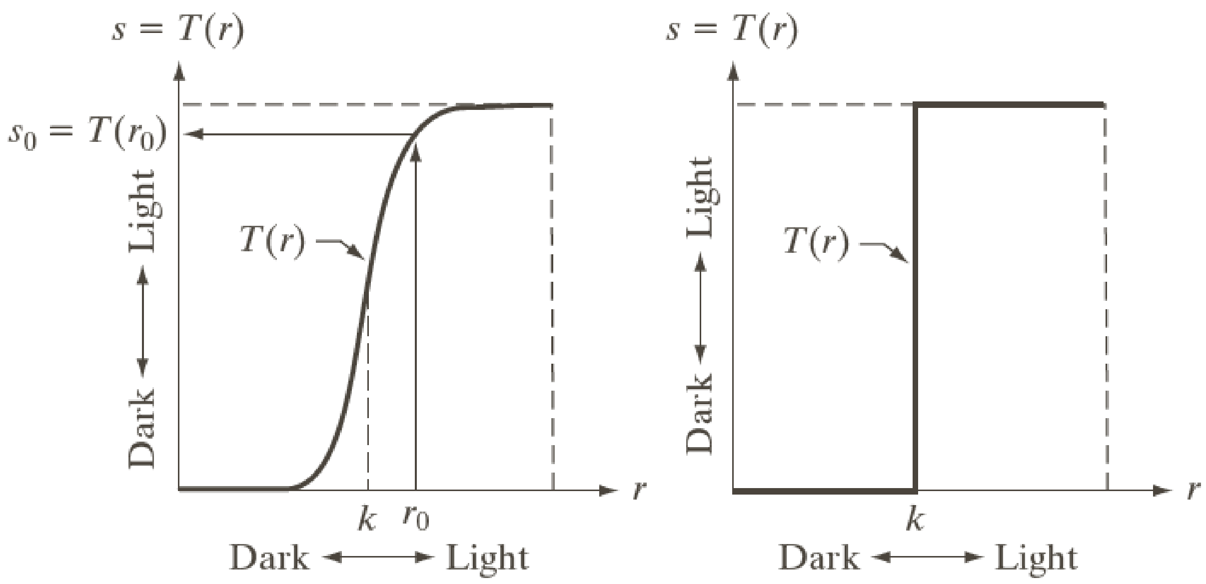


- Geometric spatial transformations
  - Affine transformation
  - Image Registration

Point/Pixel operations

Intensity transformation function

$$s = T(r)$$



a b

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

Local/neighborhood operation

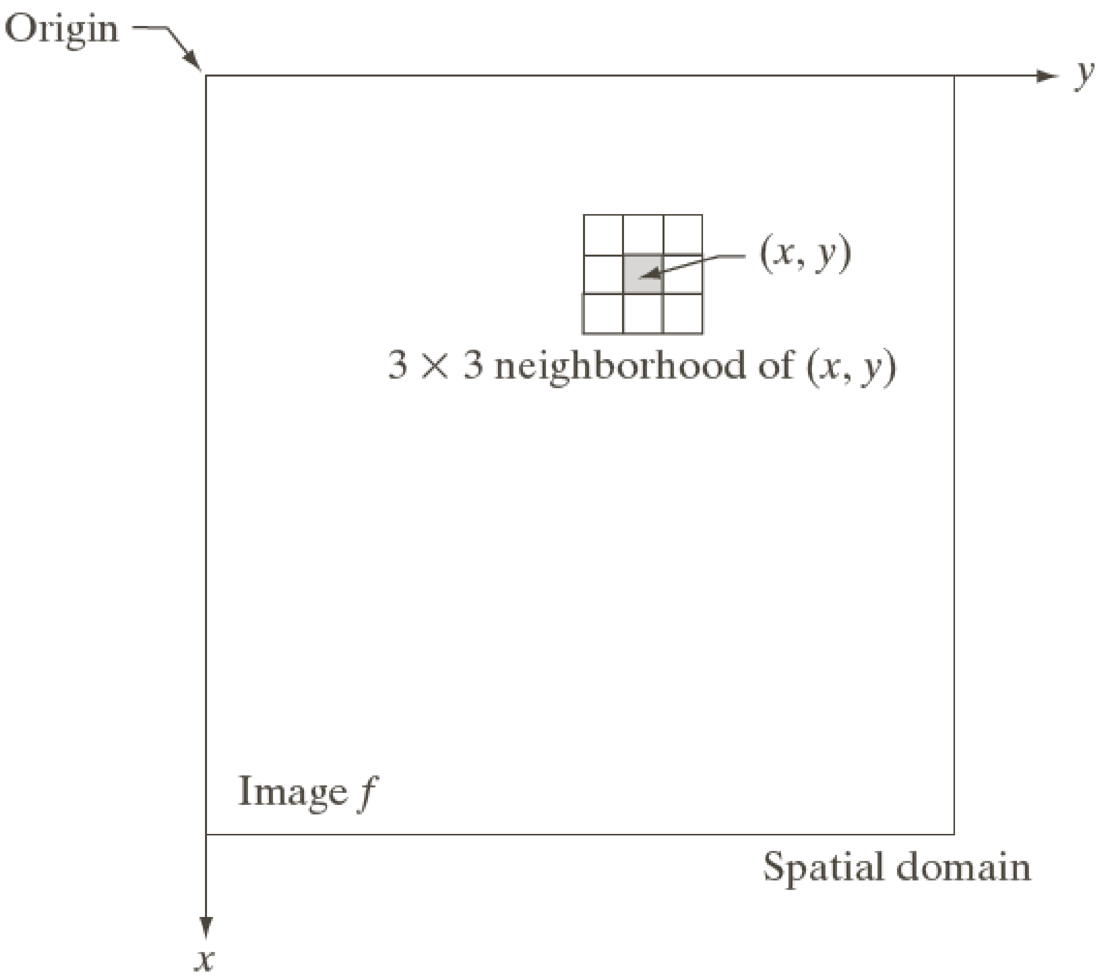
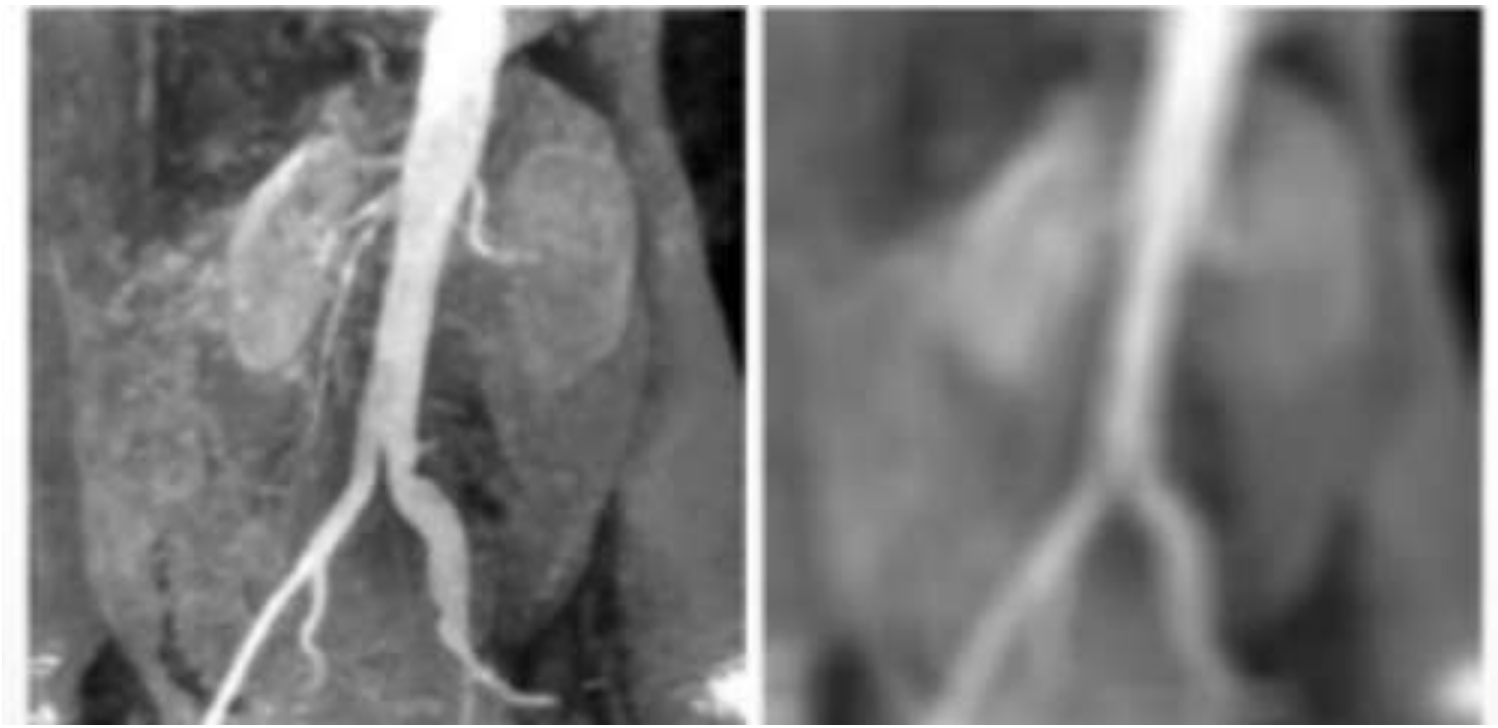


FIGURE 3.1 A 3 × 3 neighborhood about a point (x, y) in an image in the spatial domain. The neighborhood is moved from pixel to pixel in the image to generate an output image.

Local/neighborhood operation



Geometric/Spatial transformation

•

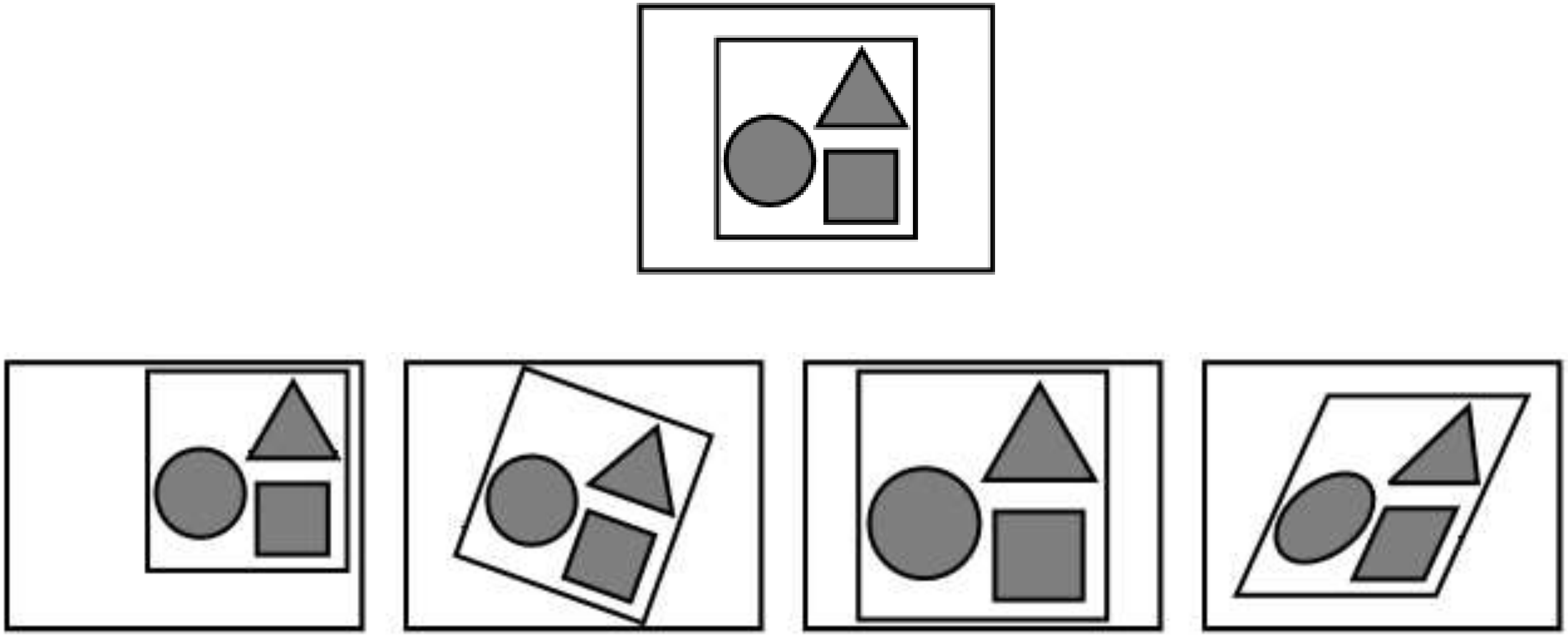


TABLE 2.2
Affine transformations based on Eq. (2.6-23).

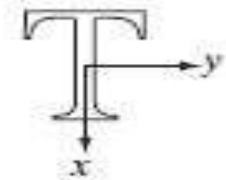
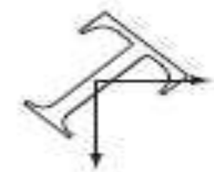
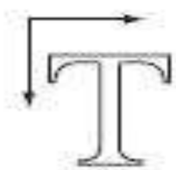
Transformation Name	Affine Matrix, T	Coordinate Equations	Example
Identity	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = w$	
Scaling	$\begin{bmatrix} c_x & 0 & 0 \\ 0 & c_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = c_x v$ $y = c_y w$	
Rotation	$\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v\cos\theta - w\sin\theta$ $y = v\cos\theta + w\sin\theta$	
Translation	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix}$	$x = v + t_x$ $y = w + t_y$	
Shear (vertical)	$\begin{bmatrix} 1 & 0 & 0 \\ s_v & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v + s_v w$ $y = w$	
Shear (horizontal)	$\begin{bmatrix} 1 & s_h & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = s_h v + w$	

Image Registration

- One of the most important applications of geometric transformations is image registration
- Goal: Image registration seeks to align images taken in different times, or taken from different
- How: estimate a transformation that aligns the two or more images.
- Image registration has applications especially in
  - Medicine
  - Remote sensing
  - Entertainment

Image Registration

- Background—Example, Panorama Stitching

image 1

image 2

Two images, sharing some objects

Image Registration

Transform image 1 into the same coordinate system of image 2

Image Registration

Finally, stitch the transformed image 1 with image 2 to get the panorama

Intensity transformation functions

- Linear
  - Negative
  - Identity
- Logarithmic
  - Log transform
  - Inverse Log transform
- Power law
  - nth power
  - nth root

Some Basic Intensity Transformation Functions

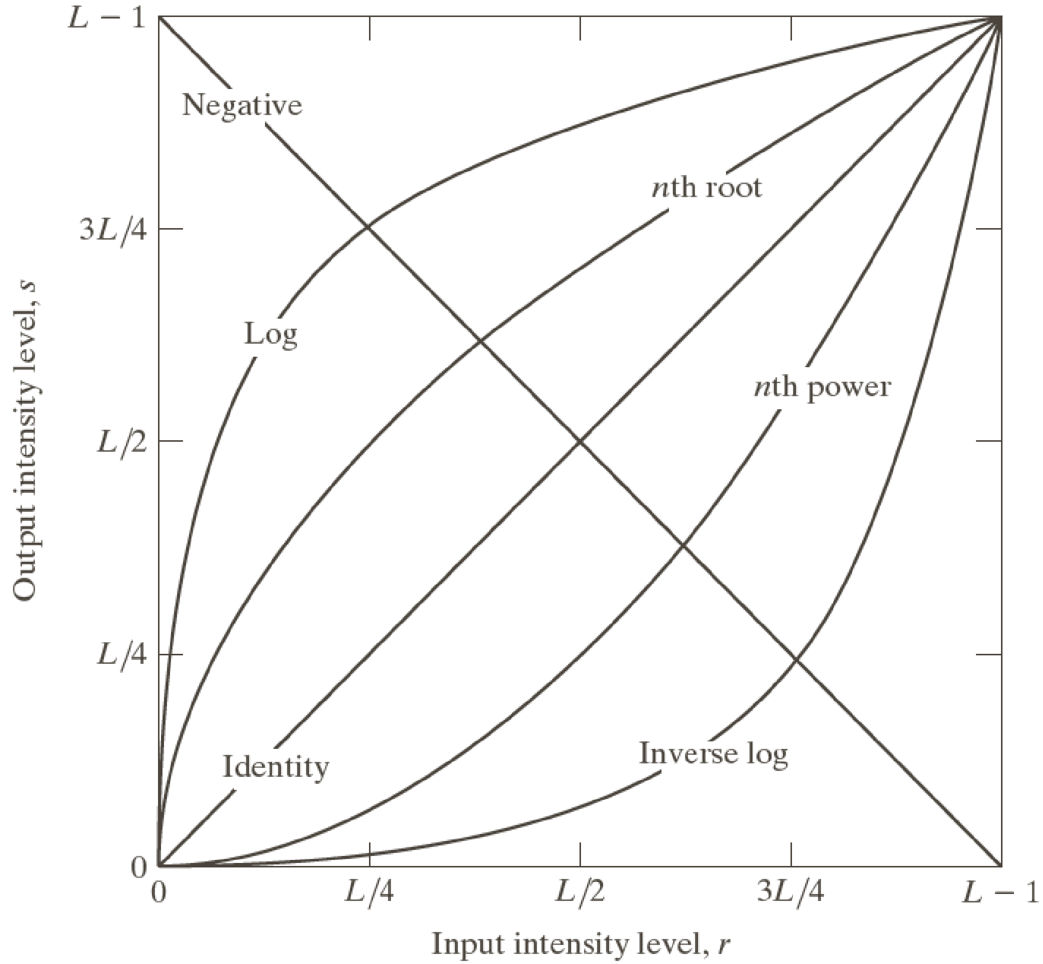


FIGURE 3.3 Some basic intensity transformation functions. All curves were scaled to fit in the range shown.

Image Negatives

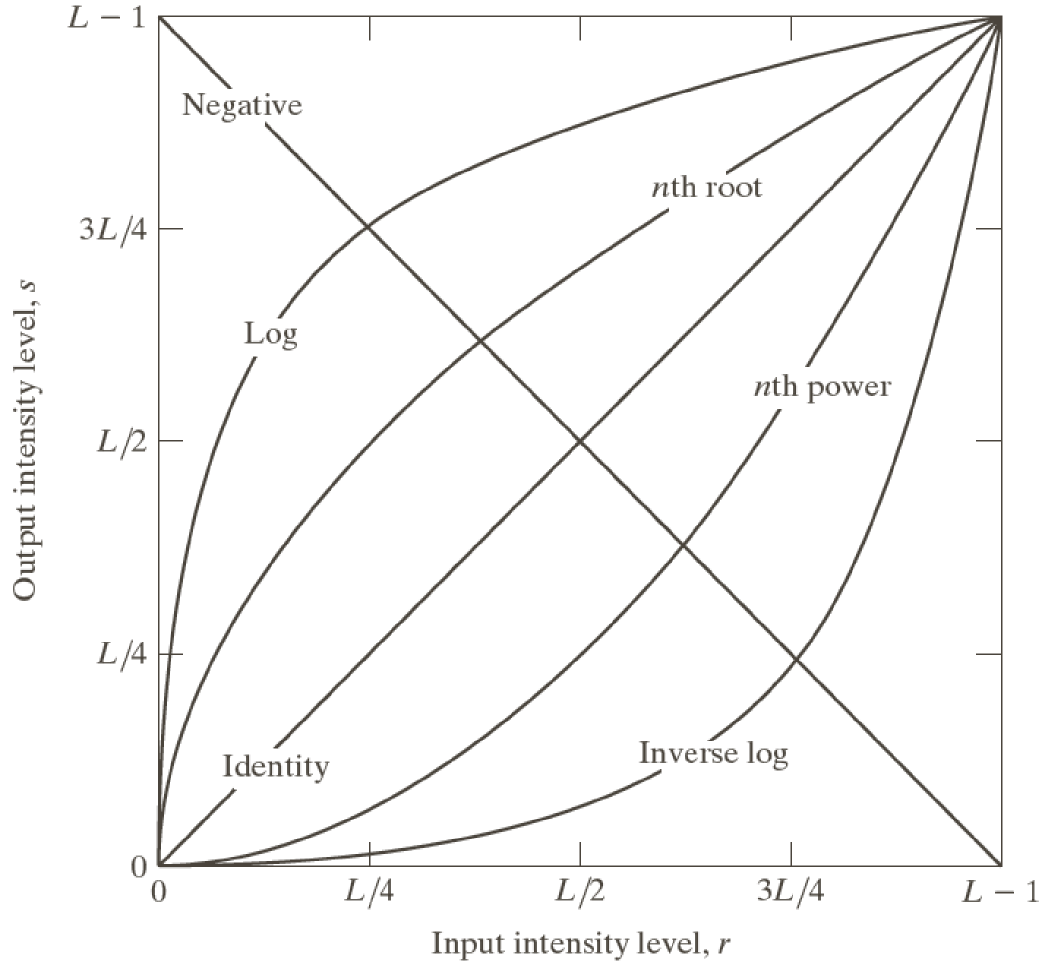


Image negatives

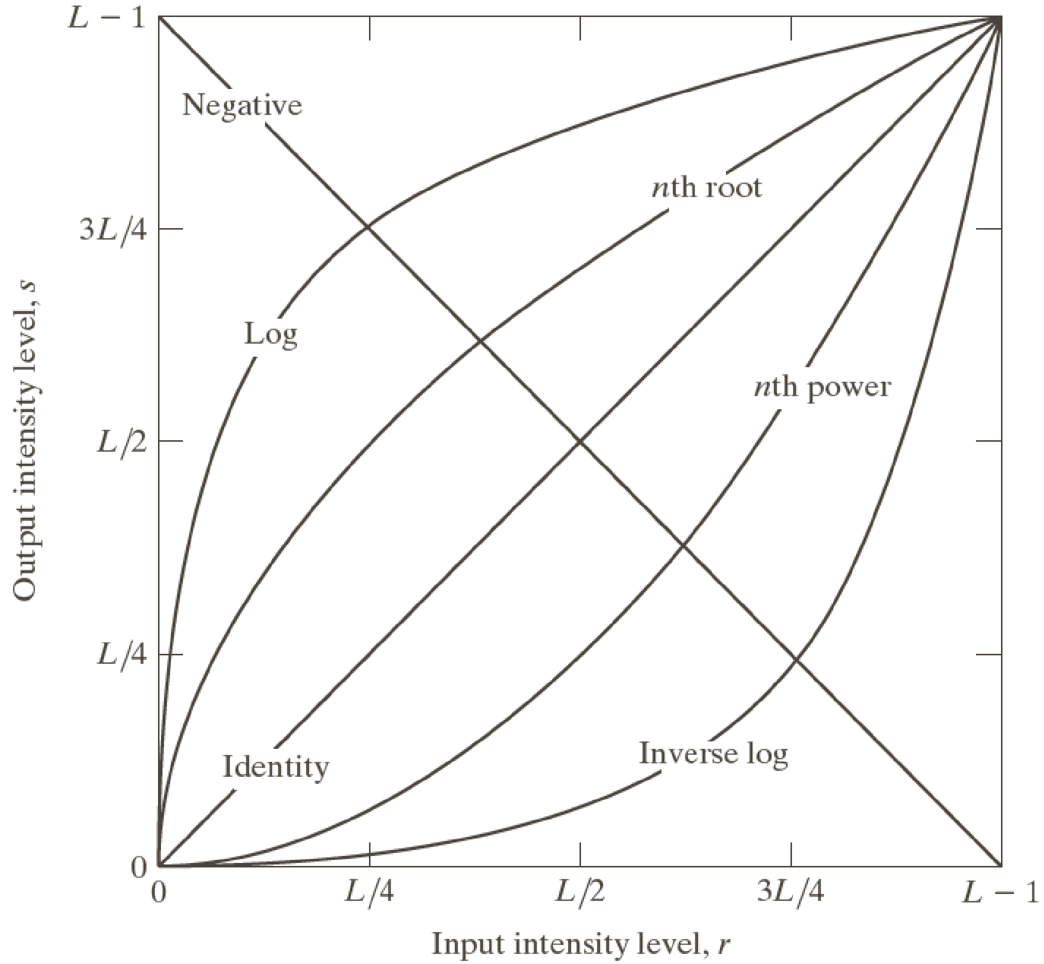
$$s = L - 1 - r$$

Example: Image Negatives

Original Image

Image negative

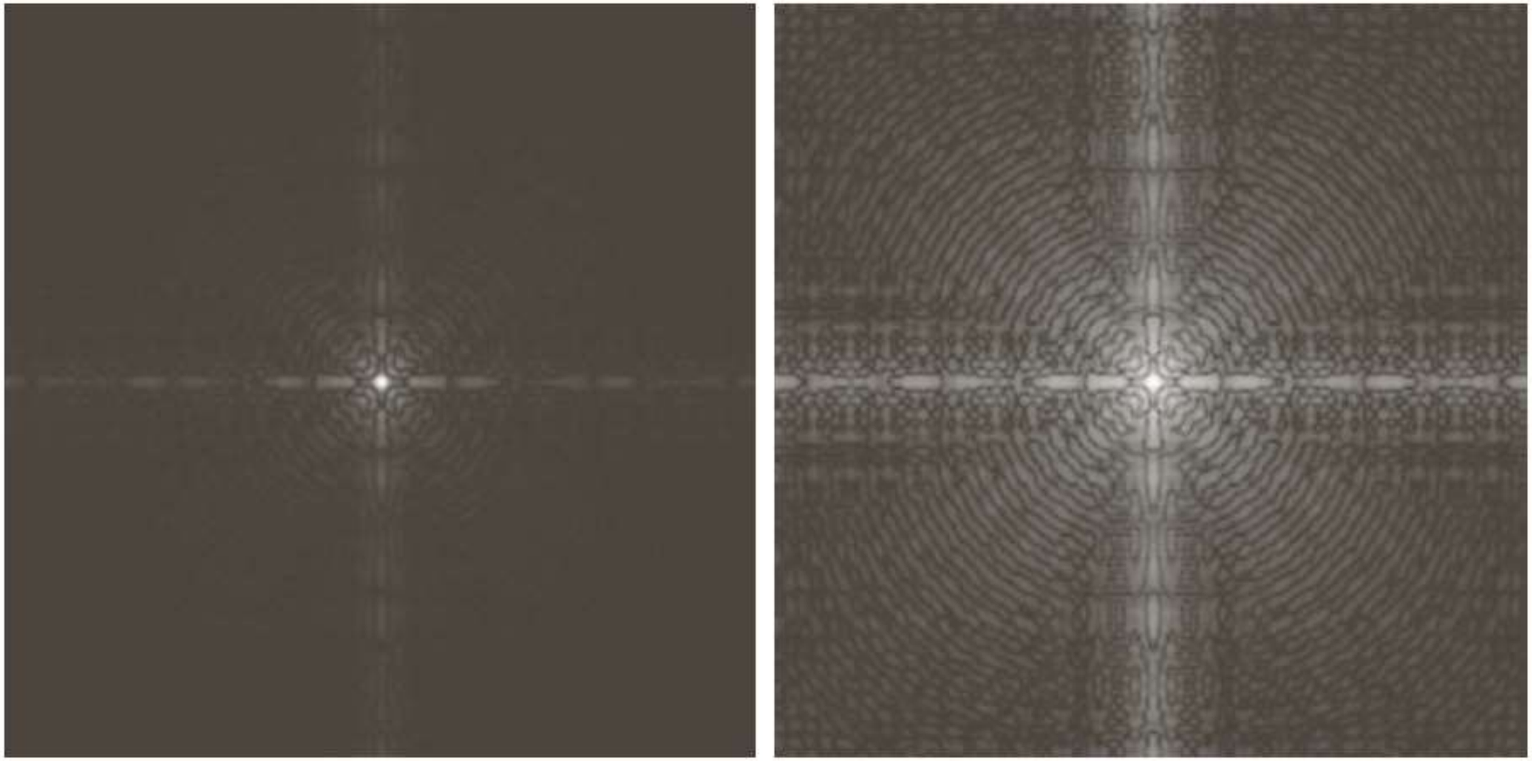
Log Transformations



Log Transformations

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

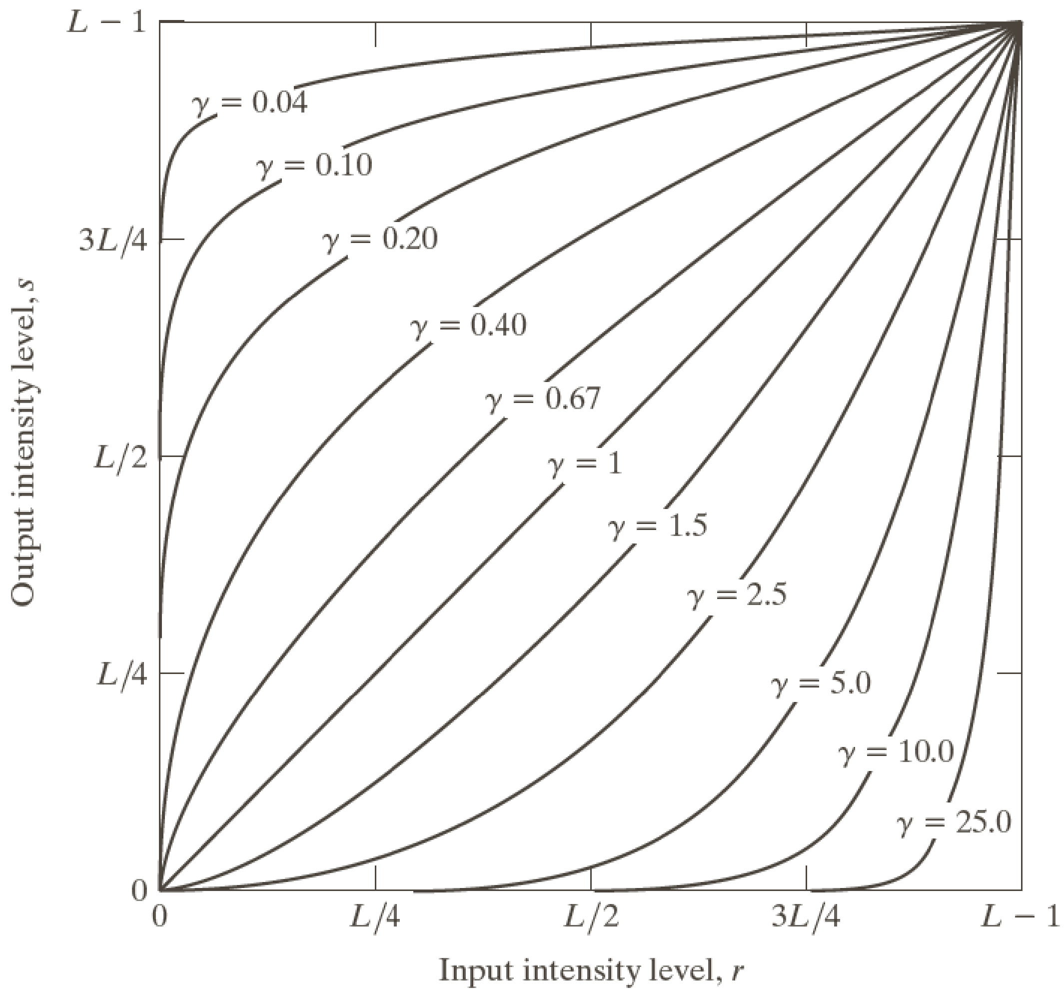
Example: Log Transformations



a b

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

Power-Law (Gamma) Transformations



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

FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases). All curves were scaled to fit in the range shown.

Example: Gamma Transformations

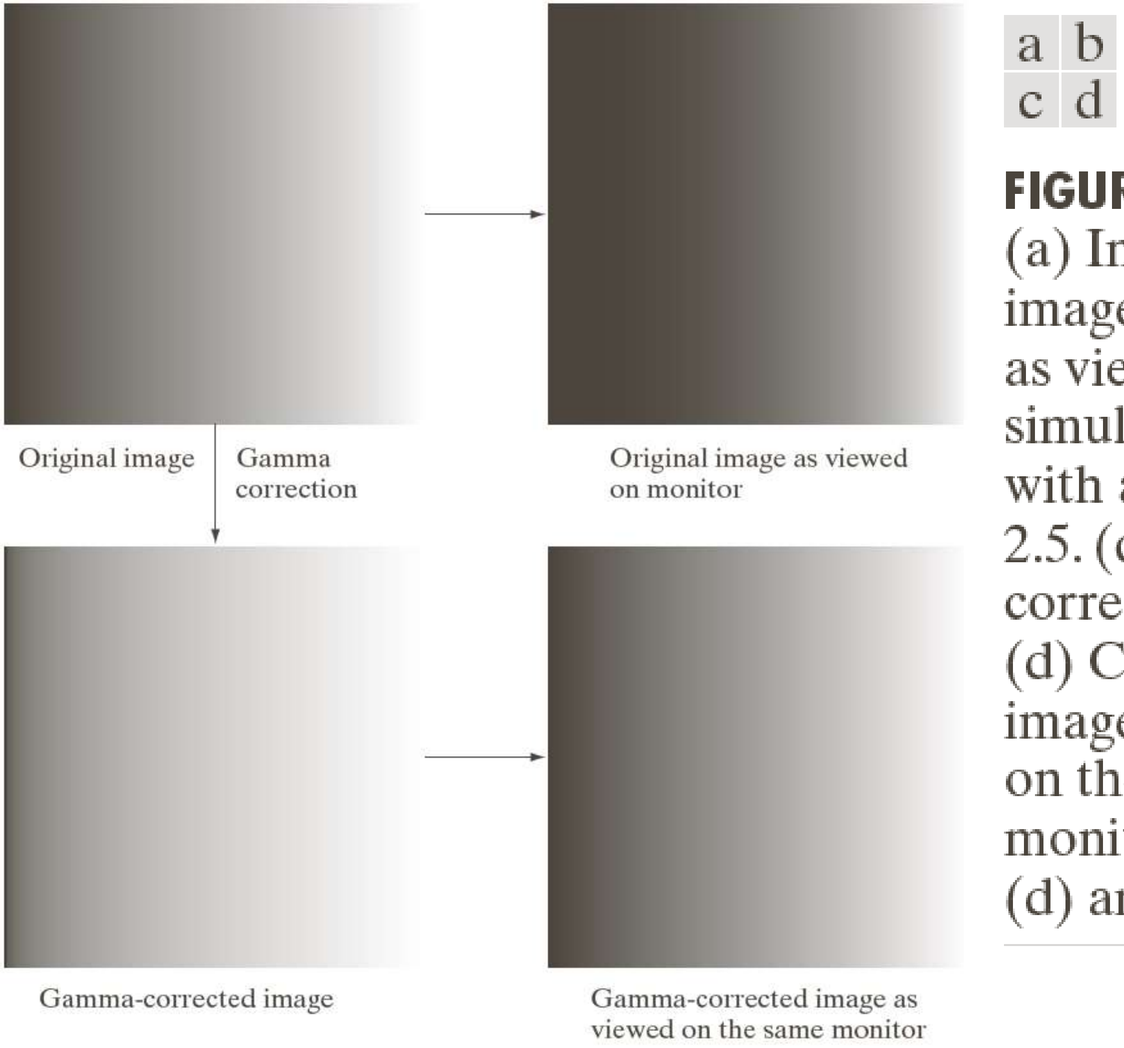
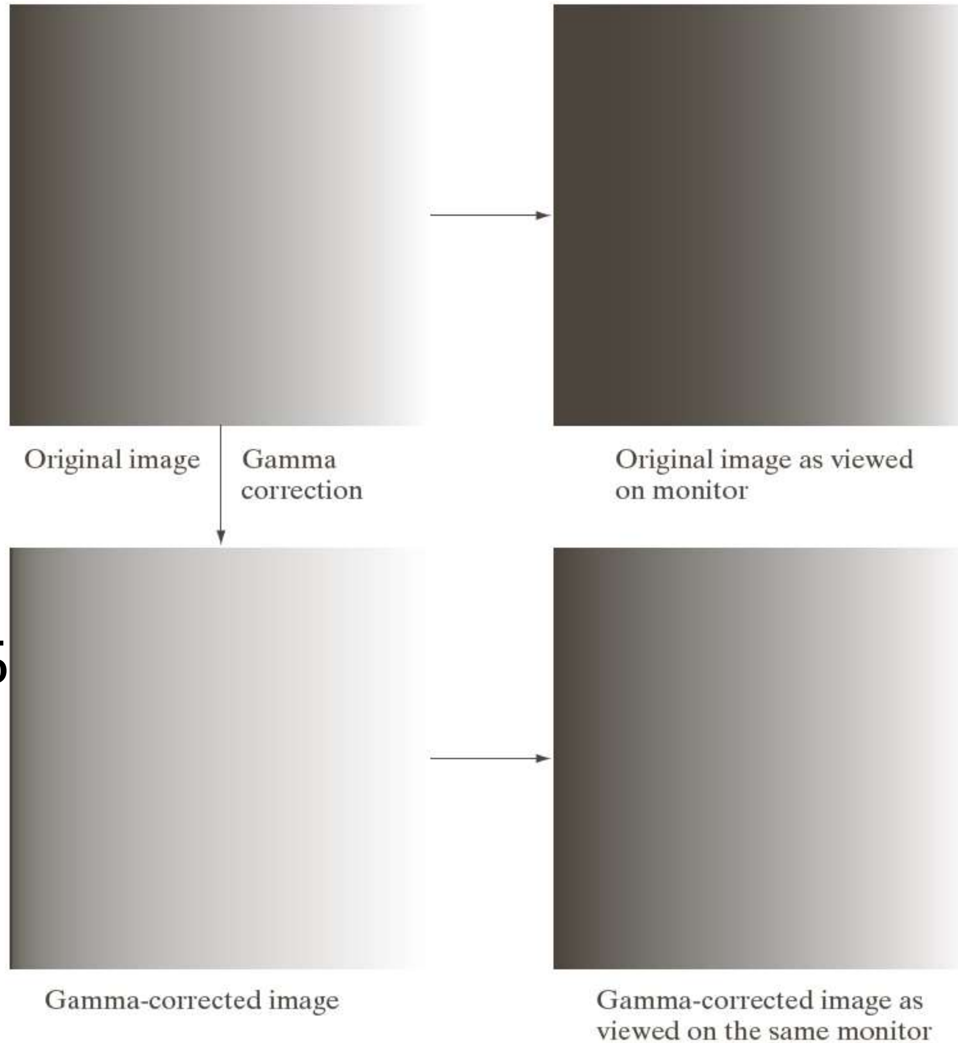


FIGURE 3.7 (a) Intensity ramp image. (b) Image as viewed on a simulated monitor with a gamma of 2.5. (c) Gamma-corrected image. (d) Corrected image as viewed on the same monitor. Compare (d) and (a).

Example: Gamma Transformations



$$s = r^{1/2.5}$$

Example: Gamma Transformations

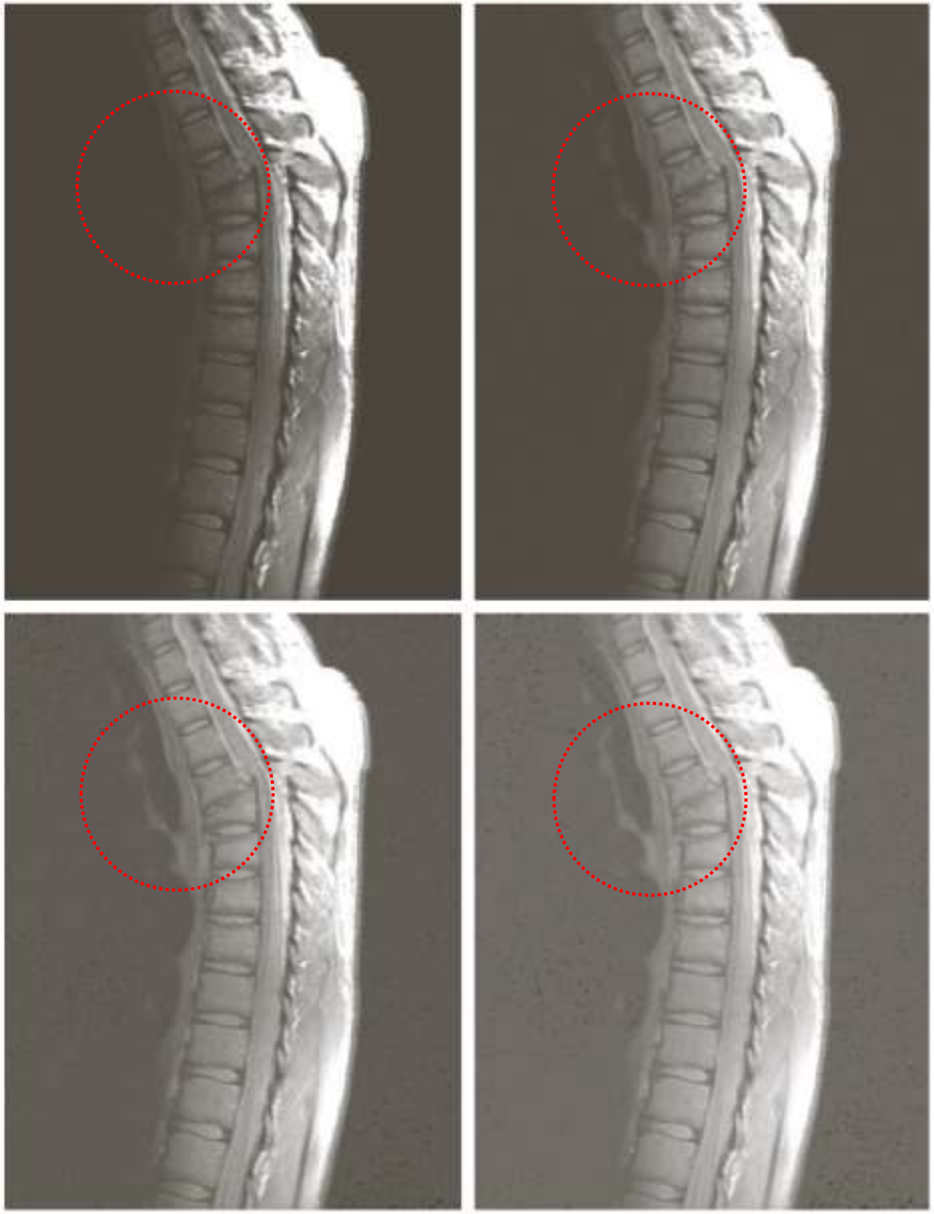


FIGURE 3.8 (a) Magnetic resonance image (MRI) of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4,$ and 0.3, respectively. (Original image courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Example: Gamma Transformations

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 Transformations

- Contrast Stretching
  - Expands the range of intensity levels in an image so that it spans the full intensity range of the recording medium or display device.

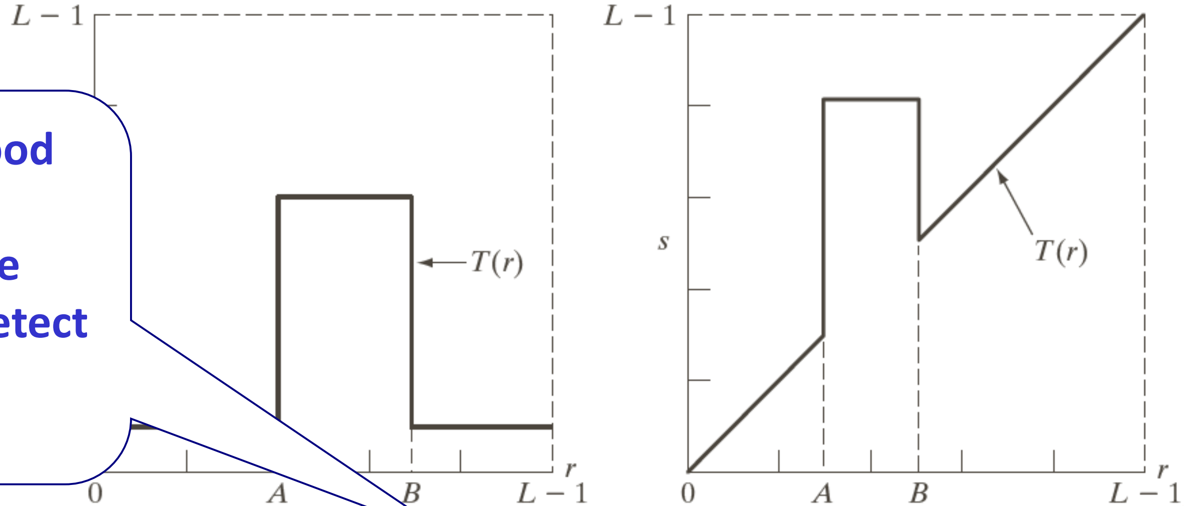
- Intensity-level Slicing
  - Highlighting a specific range of intensities in an image often is of interest.

a	b
c	d

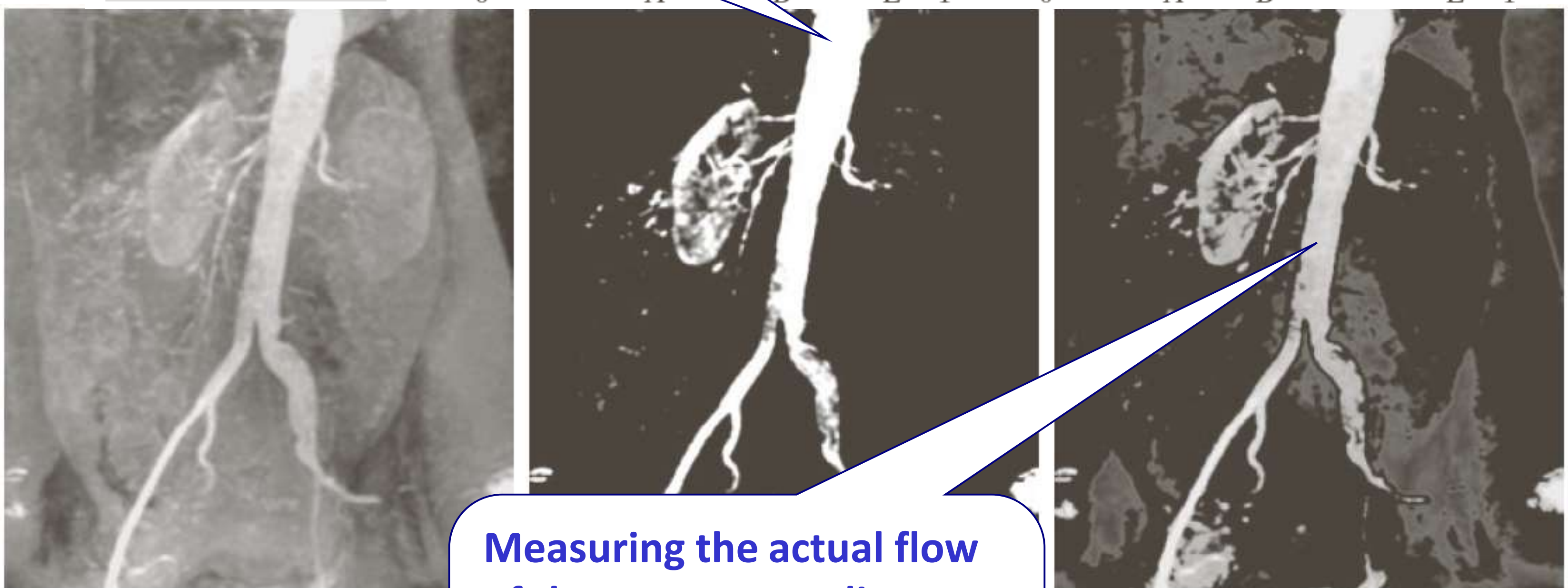
FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

a b

FIGURE 3.11 (a) This



Highlight the major blood vessels and study the shape of the flow of the contrast medium (to detect blockages, etc.)



Measuring the actual flow of the contrast medium as a function of time in a series of images

a b c

FIGURE 3.12 (a) Aortic angiog… mation of the type illustrated in Fig. 3.11(a), with the range of inte… end of the gray scale. (c) Result of using the transformation in Fig… ack, so that 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

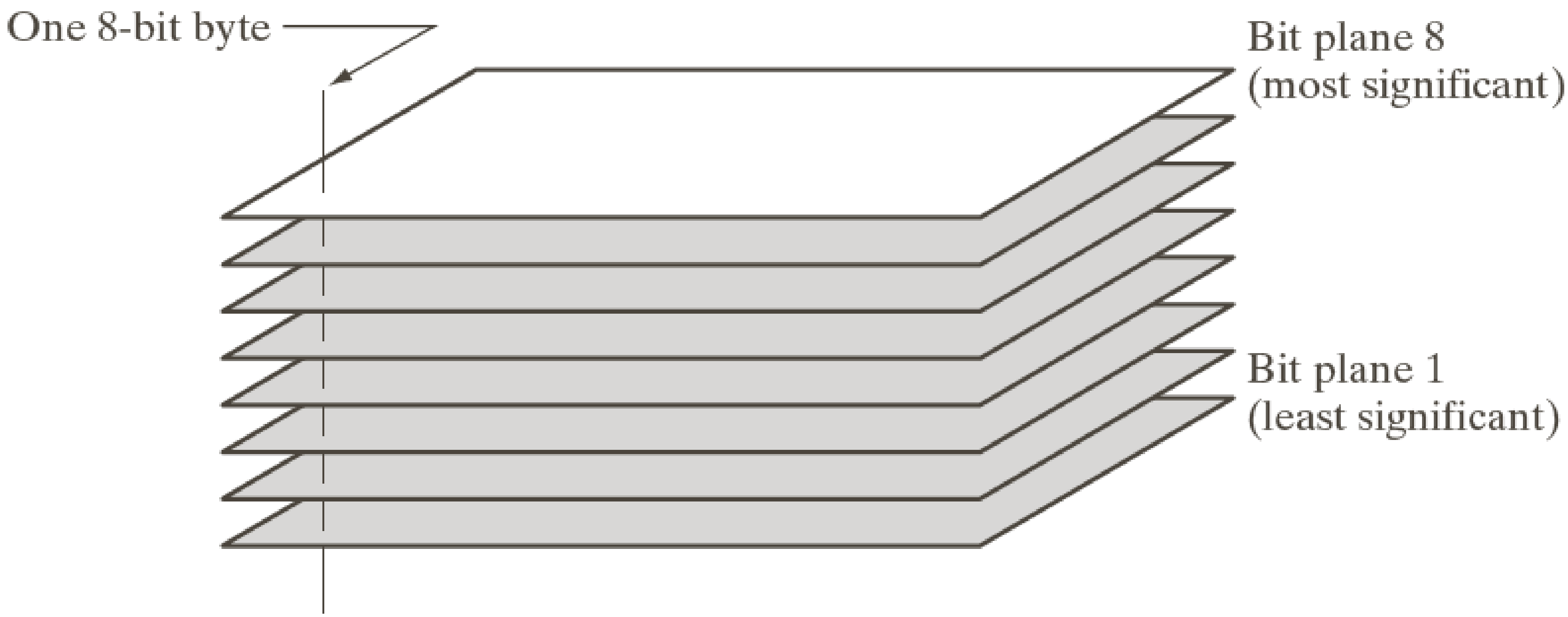


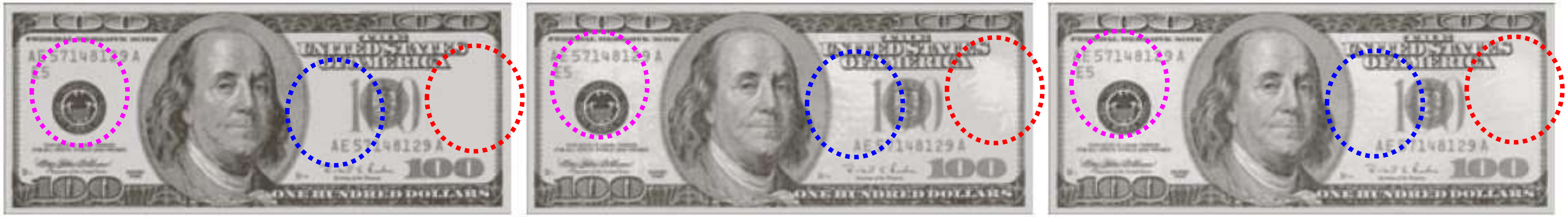
FIGURE 3.13
Bit-plane representation of an 8-bit image.

Bit-plane Slicing

a b c
d e f
g h i

FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

Bit-plane Slicing



a b c

FIGURE 3.15 Images reconstructed using (a) bit planes 8 and 7; (b) bit planes 8, 7, and 6; and (c) bit planes 8, 7, 6, and 5. Compare (c) with Fig. 3.14(a).