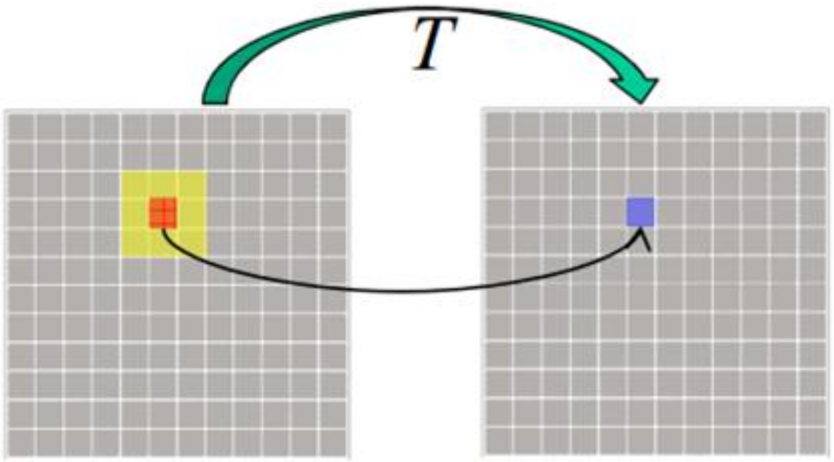
Intensity Transformations

Chapter 3

Intensity Transformations

- Spatial domain refers to the image plane itself.
- Two principal categories :
  1. **Intensity transformations:** operates on single pixels of an image, for the purpose of contrast manipulation and image thresholding.
  2. Spatial filtering: deals with performing operations, such as, image sharpening, by working in the neighborhood of every pixel in image.

Intensity Transformation and Spatial Filtering



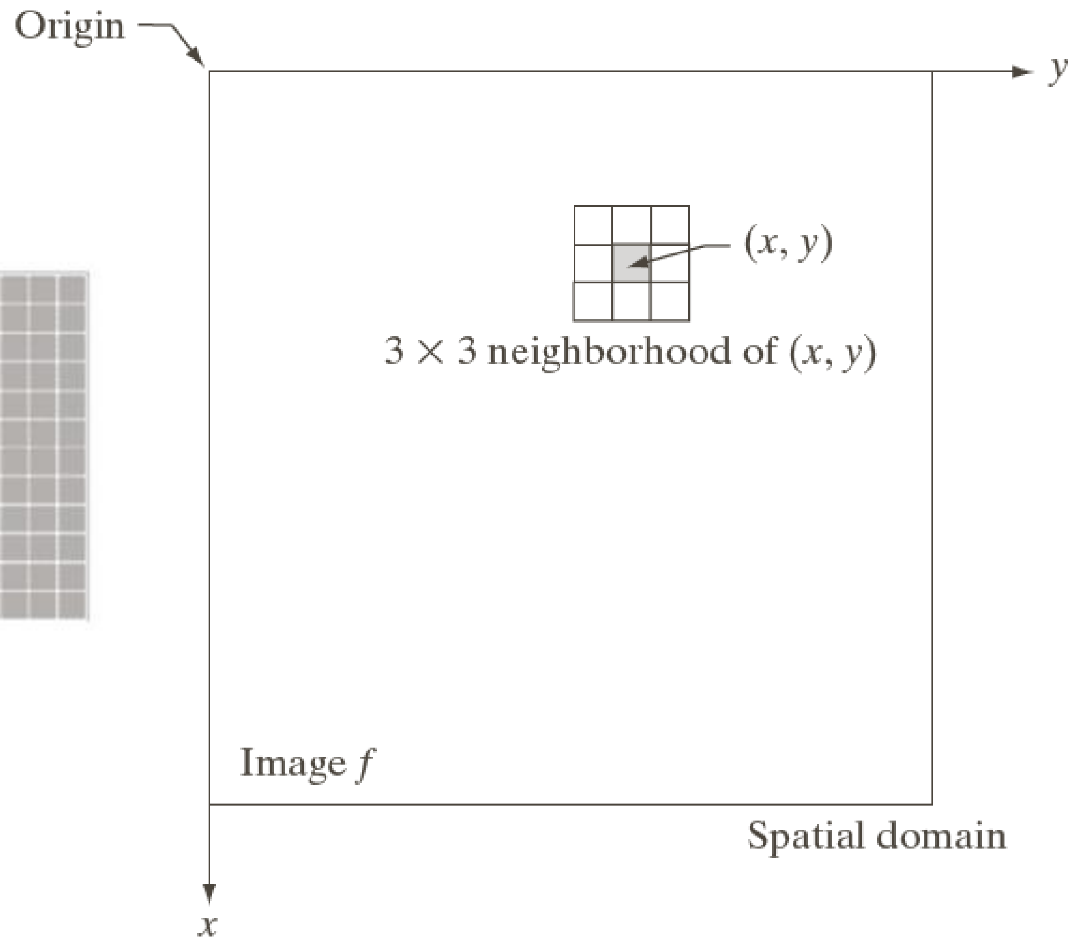


FIGURE 3.1 A 3 × 3 neighborhood about a point (x, y) in an image in the spatial domain. The neighborhood is moved from pixel to pixel in the image to generate an output image.

- The spatial domain can be denoted by the expression:

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

- Where $f(x,y)$ is the input image, $g(x,y)$ is the output image, and T is an operator on f defined over a neighborhood of point (x,y)

Image Enhancement

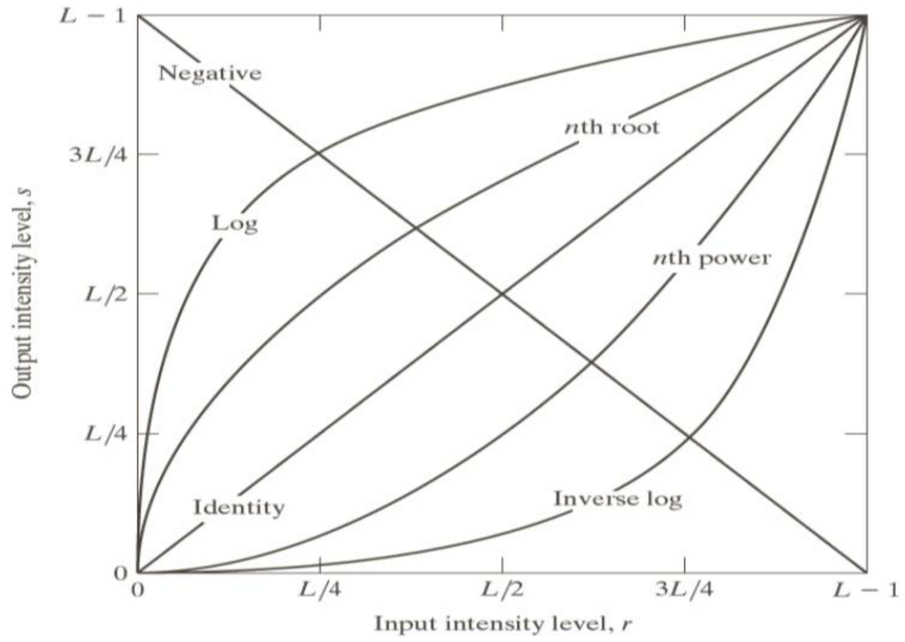
Image enhancement is the process of manipulating an image so that the result is more suitable than the original for a specific application

The reasons for doing this include:

- Highlighting interesting detail in images
- Removing noise from images
- Making images more visually appealing

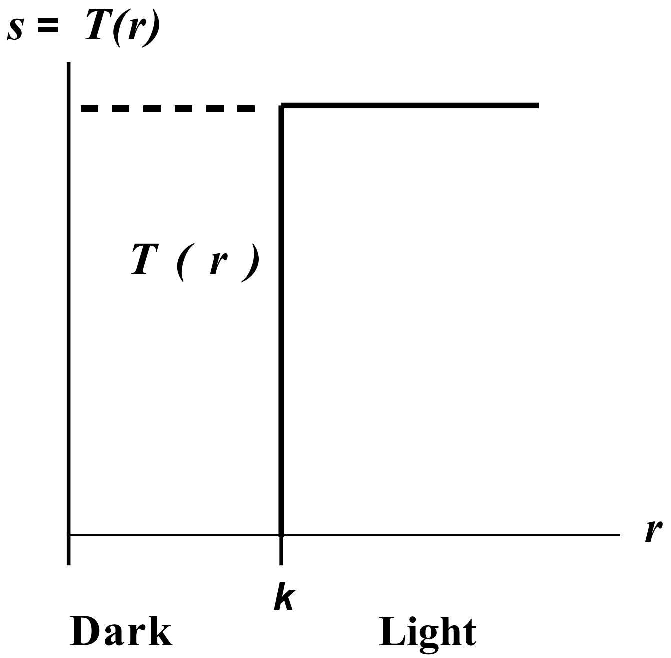
Basic Intensity Transformation Functions:

- Image Negatives
- Log Transformations
- Power-Law (Gamma) Transformations
- Piecewise-Linear Transformation Functions
  - Contrast Stretching
  - Intensity-level slicing
  - Bit-Plane slicing
- **Histogram Processing**
  - Histogram Specification
  - Histogram Matching



Thresholding

•Thresholding transformations are particularly useful for segmentation in which we want to isolate an object of interest from a background



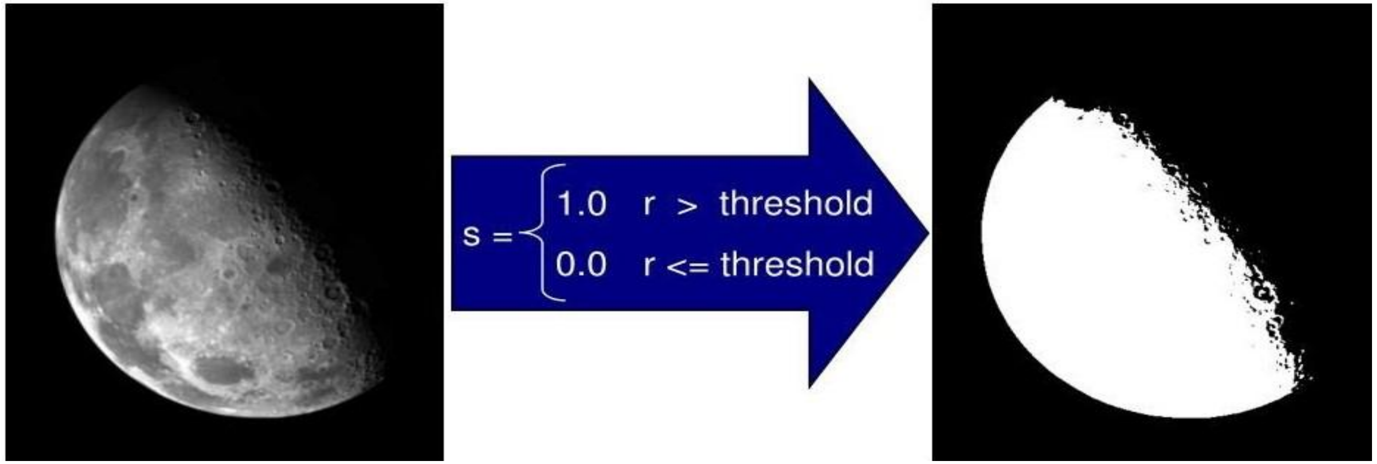
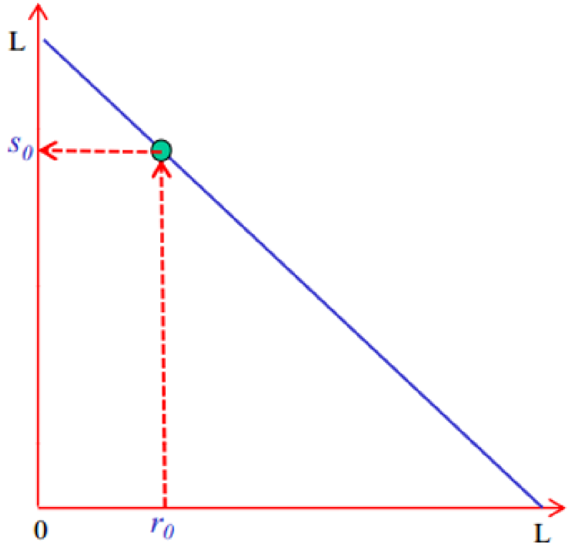


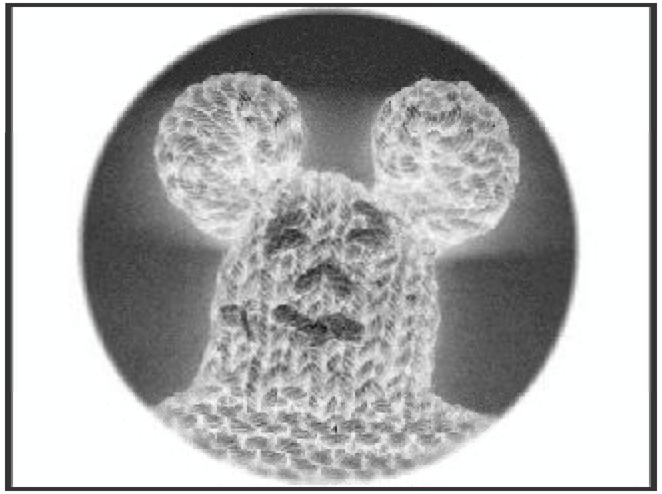
Image Negatives

- The negative of an image with intensity levels in the range [0,L-1] is obtained by using the negative transformation shown below, which is given by the expression:

$$s = L-1-r$$

- Revising the intensity levels of an image in this manner produces the equivalent of a photographic negative.





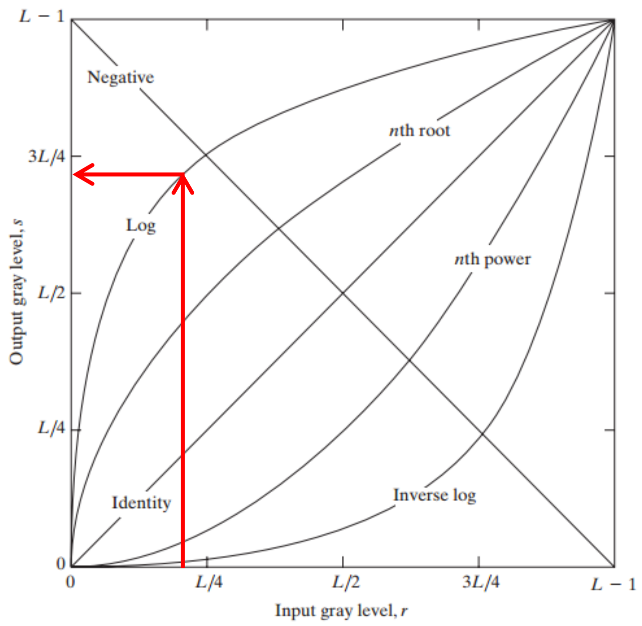
Log Transformation

- The general form of the log transformation is:

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

Where c is a constant, and it is assumed that r >=0. c is given by 255/(log (1 + L)), where L is the maximum pixel value in the image.

The shape of the log curve shows that this transformation maps a narrow range of low intensity values in the input into a wider range of output levels. The opposite is true of higher values of input levels.



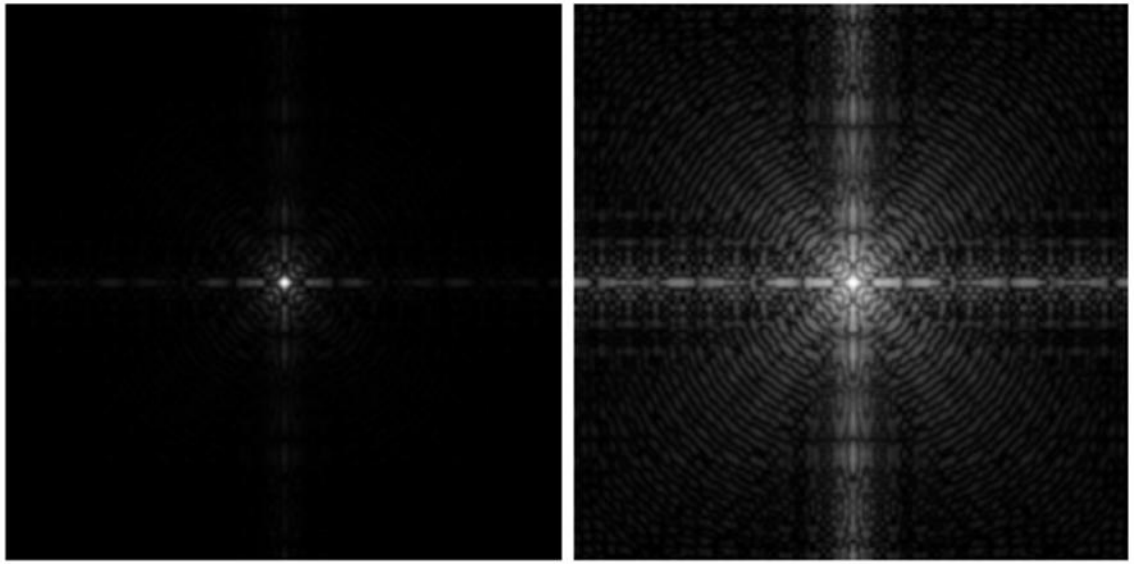
Log Transformation

- The value of ‘c’ is chosen such that we get the maximum output value corresponding to the bit size used.

- So, the formula for calculating ‘c’ is as follows:

$$c = \frac{\text{max\_output\_pixel\_value} = 255}{\log\,(1 + \text{max\_input\_pixel\_value}) = 8}$$

Log Transformation



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 (Gamma) Transformations

- Power-law transformations have the basic form:

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

where c and ϒ are positive constants

- As in the case of the log transformation, power-law curves with fractional values of ϒ map a narrow range of dark input values into a wider range of output values with the opposite being true for higher values of input levels.

Power-law (Gamma) Transformations

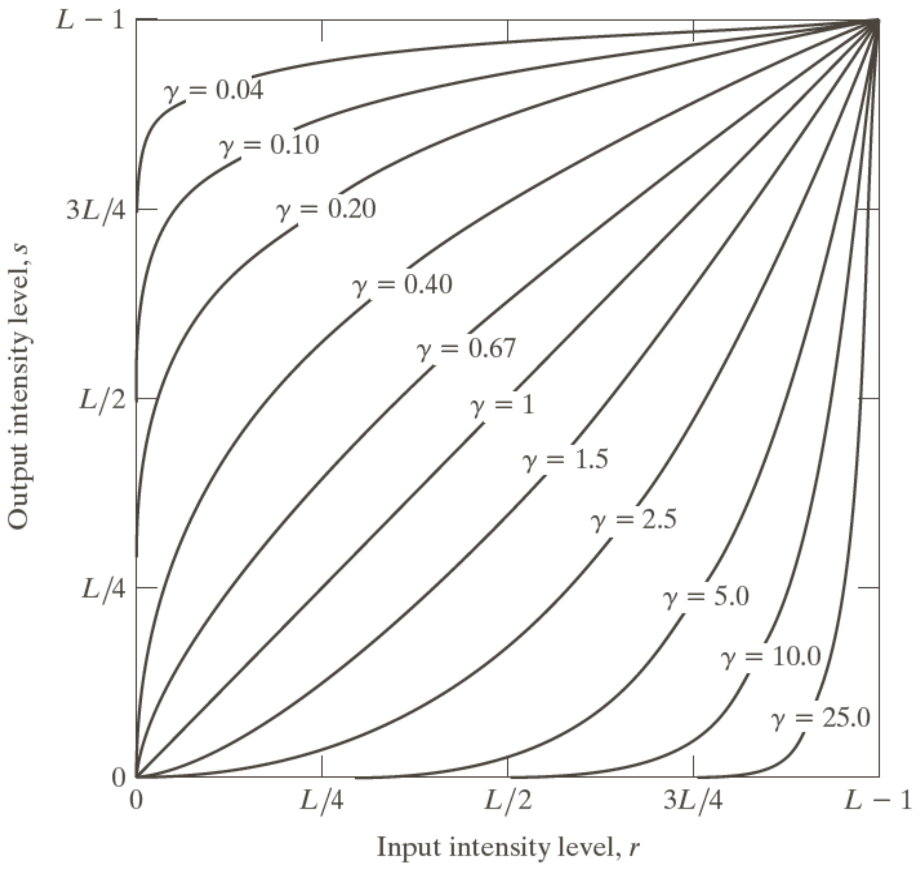


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases). All curves were scaled to fit in the range shown.

Unlike the log function, however, we notice here a family of possible transformation curves obtained simply by varying ϒ.

Power-law (Gamma) Transformations

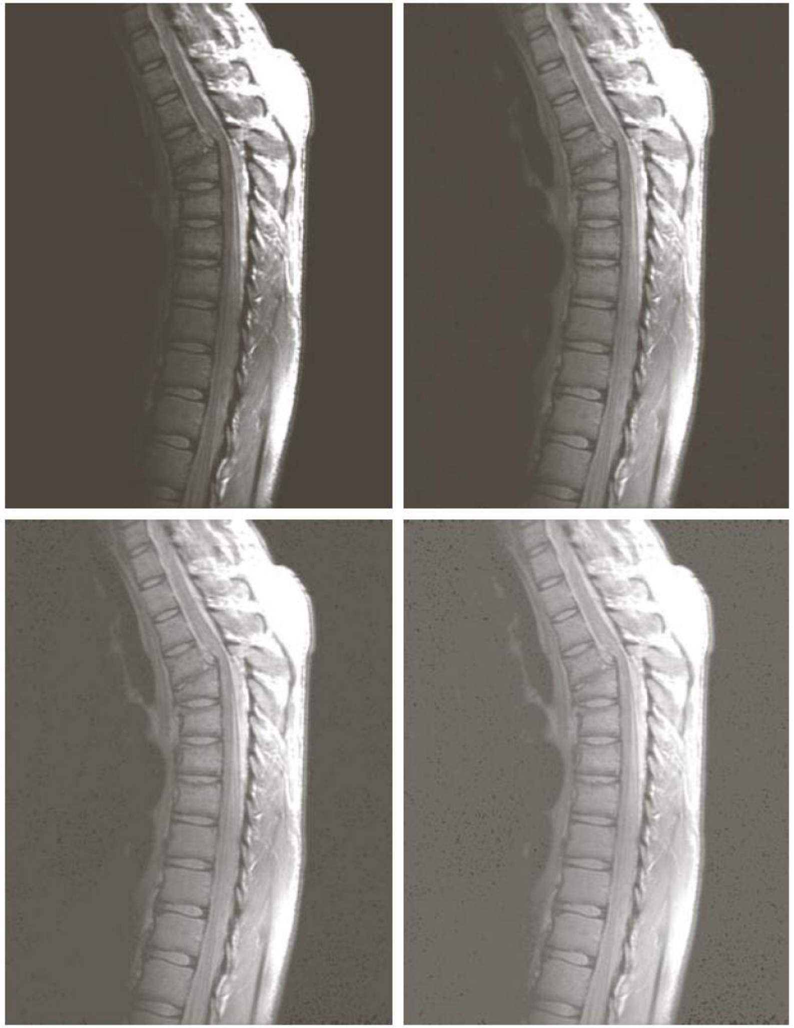


FIGURE 3.8 (a) Magnetic resonance image (MRI) of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4,$ and 0.3, respectively. (Original image courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt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

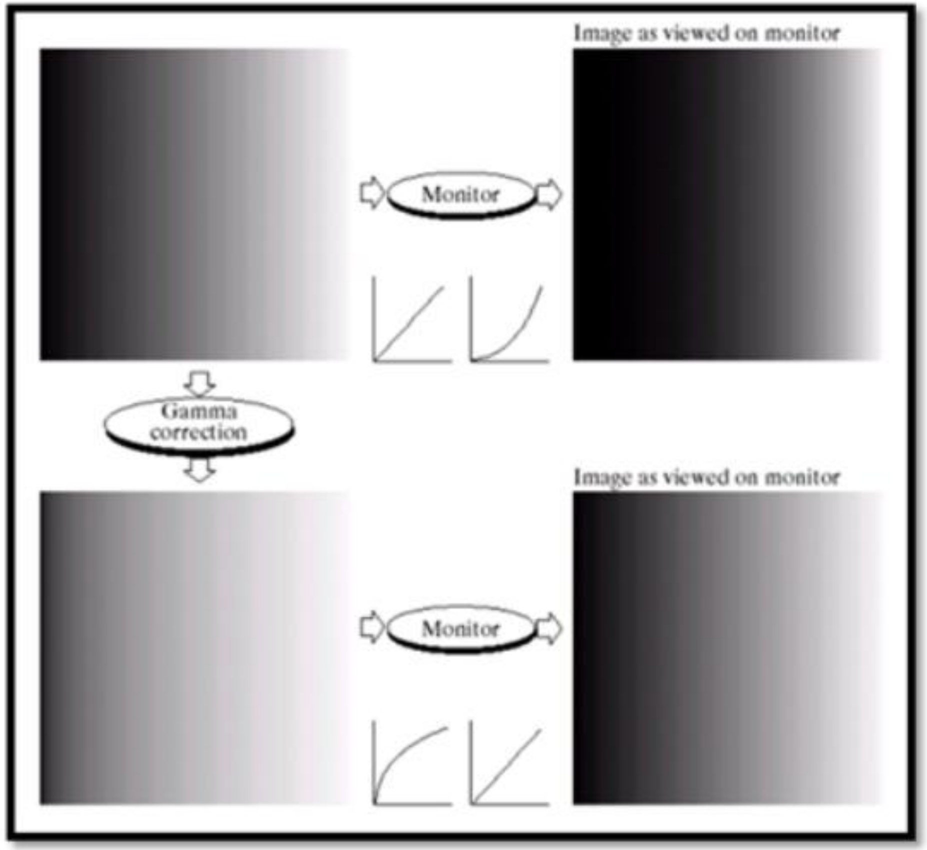
- By convention, the exponent in the power-law equation is referred to as ***gamma***.
- The process used to correct these power-law response phenomena is called ***gamma correction***.

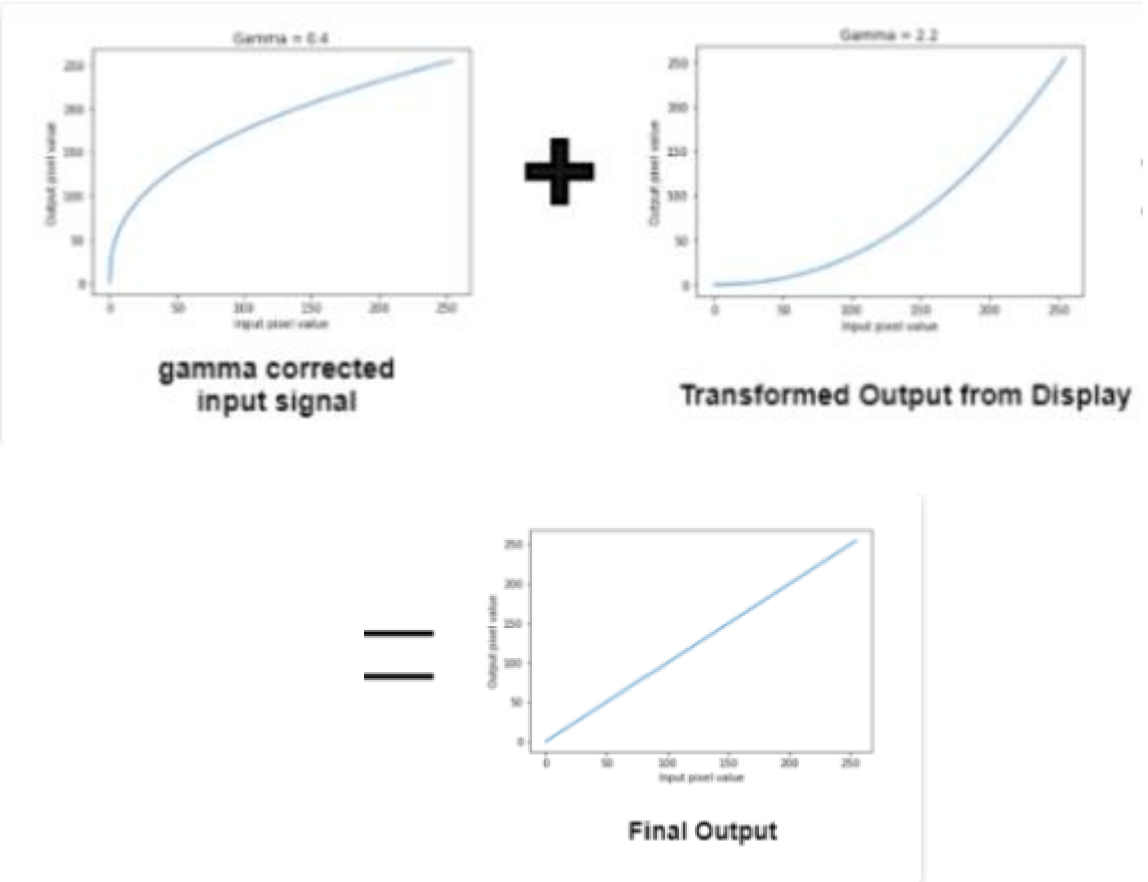
Another example of Gamma Correction

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.)

Gamma of CRT is between 1.8 to 2.5



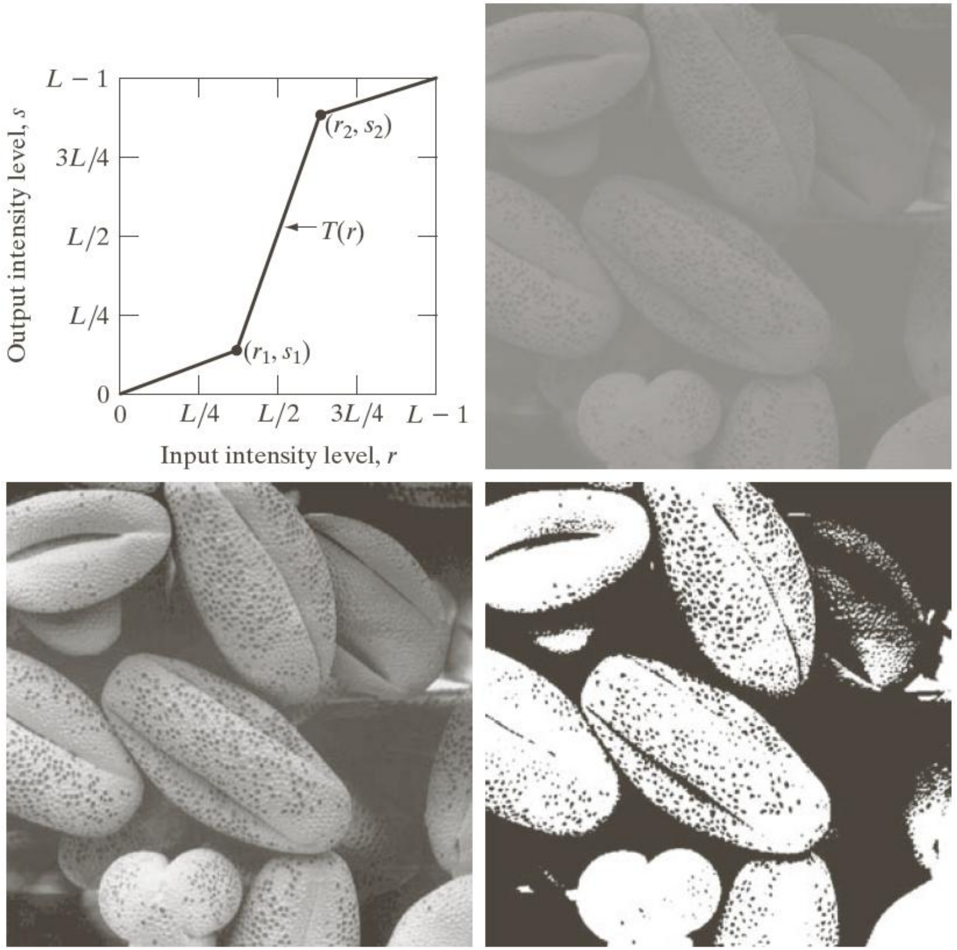


Piecewise-Linear Transformation Functions

1. Contrast Stretching
2. Intensity-level slicing
3. Bit-Plane slicing

Contrast Stretching function: is one of the simplest piecewise linear functions. Law-contrast images can result from poor illumination, lack of the dynamic range in the imaging sensor, or even the wrong setting of the lens aperture during image acquisition. ***Contrast Stretching****:* is a process that expands the range of intensity levels in an image.

Contrast Stretching Transformations



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.)

Contrast Stretching

- The locations of (r1,s1) and (r2,s2) control the shape of the transformation function.

- If r1=s1, r2=s2, the transformation is a linear function that produces no changes in intensity levels.
- If r1=r2, s1=0, s2=L-1, the transformation becomes a ***thresholding function*** that creates a binary image as in Fig.3.2(b).

- Intermediate values of (r1,s1) and (r2,s2) produce various degrees of spread in the intensity levels of the out put image, thus affecting its contrast.

Contrast Stretching

- When (r1, s1) = (r_{min}, 0) and (r2, s2) = (r_{max}, L-1), this is known as **Min-Max Stretching.**

- Lower value of the input image is mapped to 0 and the upper value is mapped to 255. All other intermediate values are reassigned new intensity values according to the following formulae

$$Xnew = \frac{Xinput - Xmin}{Xmax - Xmin} \times 255$$

Intensity-level slicing

- Highlighting a specific range if intensities in an image often is of interest.
- Has two approaches:
  - First approach: display two values (black and white). Lets say all values in the range of interest is white and all other values is black as show in Fig.3.11(a).
  - Second approach: based on transformation in Fig.3.11(b), brightens or (darkens) the desired range of intensities, but leaves all other intensity levels in the image unchanged.

Intensity-level slicing

a b

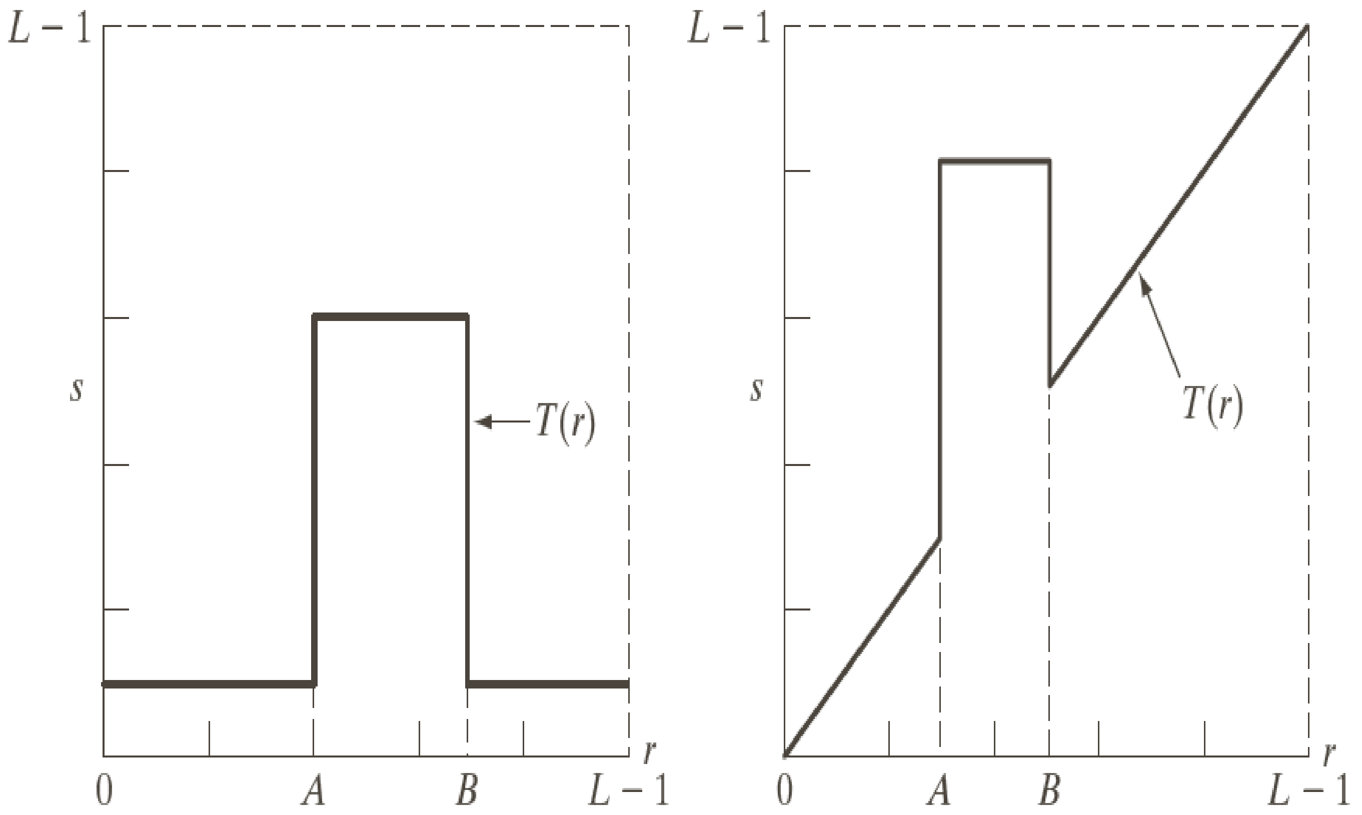
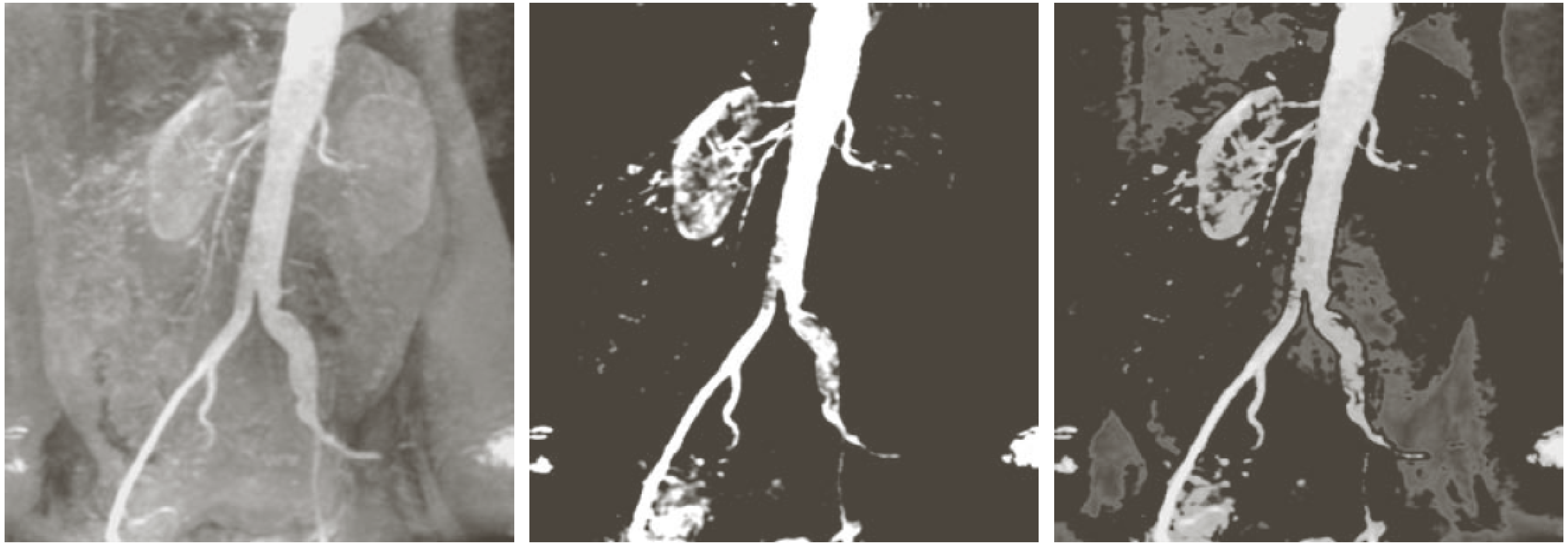


FIGURE 3.11 (a) This transformation highlights intensity range [*A*, *B*] and reduces all other intensities to a lower level. (b) This transformation highlights range [*A*, *B*] and preserves all other intensity levels.

Intensity-level slicing

- Figure 3.12(a) shows an aortic angiogram near the kidney area. The objective of this example is to use the intensity-level slicing to highlight the major blood vessels that appear brighter.

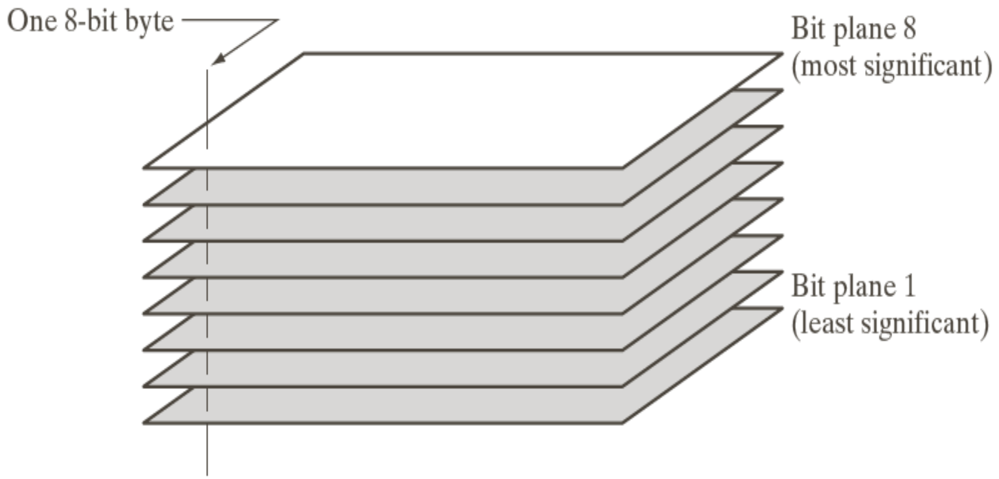


a b c

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 area set to black, 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

- Pixels are digital numbers composed of bits. For example, the intensity of each pixel in a 256-level gray-scale image is composed of 8-bits (i.e. one byte).
- Instead of highlighting intensity-level ranges, we could highlight the contribution made to total image appearance by specific bits. As Fig.3.13 illustrates, an 8-bit image may be considered as being composed of eight 1-bit planes, with plane1 containing the lowest order bit of all pixels in the image and plane 8 all the highest-order bits.



Bit-Plane slicing

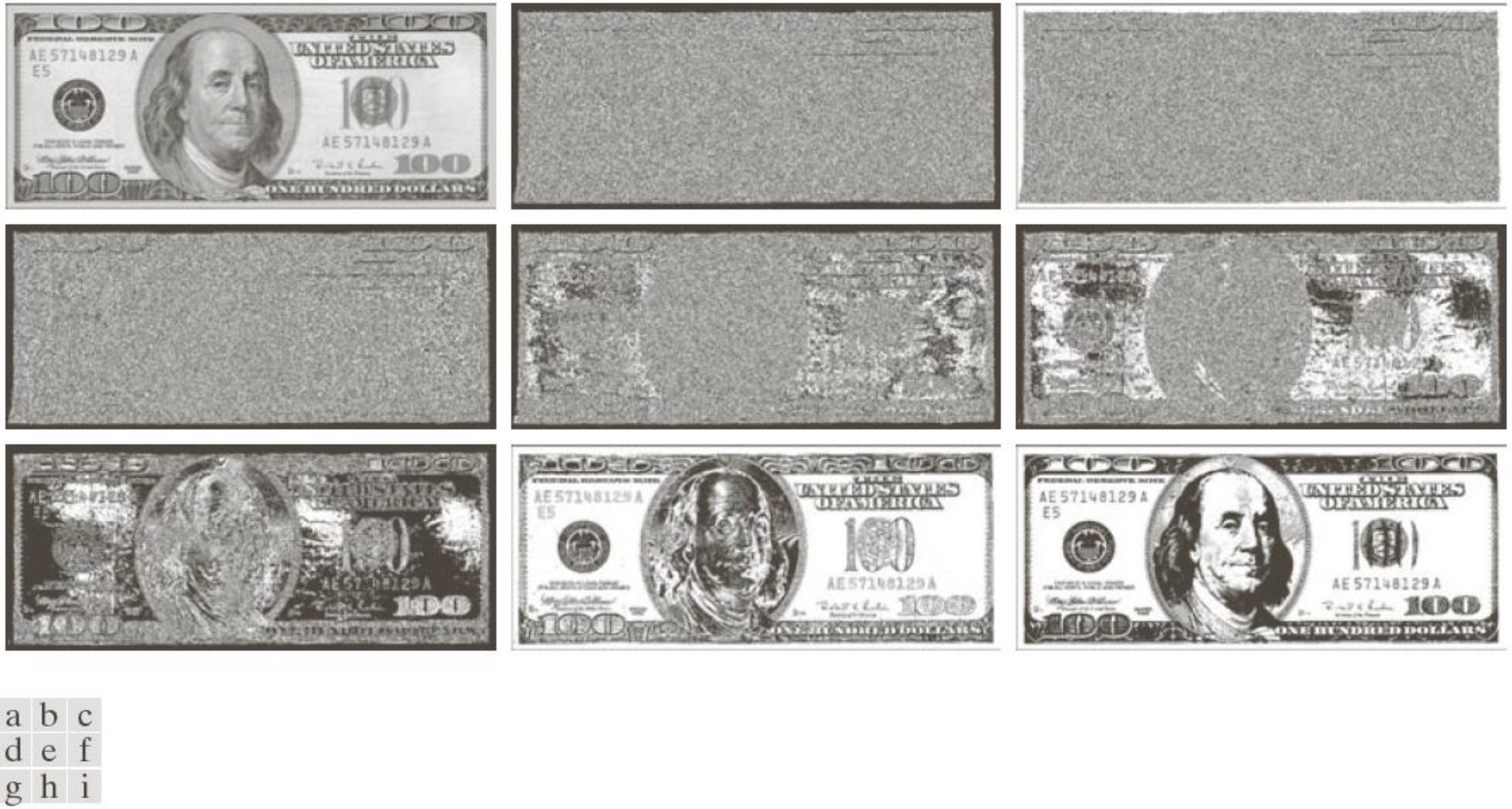


FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

- Observe that the four higher-order bit planes, especially the last row, contain significant amount of the visually significant data.
- The higher-order planes contribute to more suitable intensity details in the image.

Reconstruction

- Four highest order bit planes would allow us to reconstruct the original image in acceptable details.
- Four planes instead of the original image requires 50% less storage

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).

- https://www.imageeprocessing.com/2012/11/bit-plane-slicing.html
- https://theailearner.com/image-processing/