Digital Image Processing

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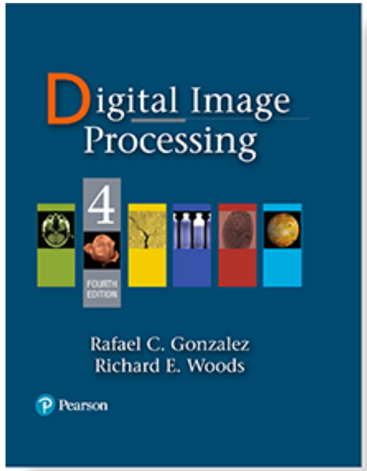
Digital Image Processing

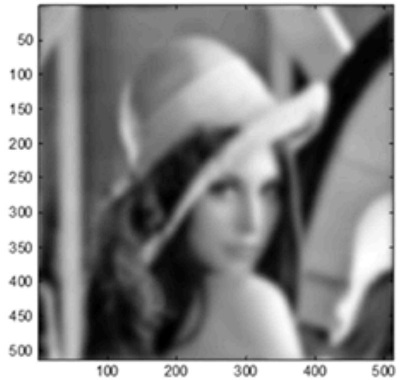
Most popular textbook

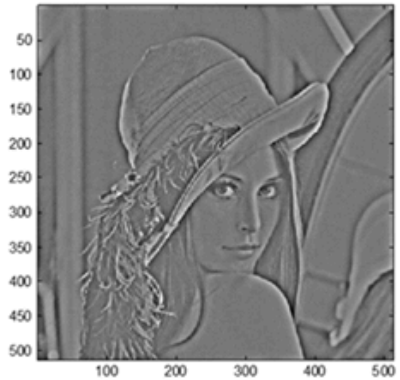
- R.C. Gonzalez and R.E. Woods, Digital Image Processing, 4th edition, 2018.



Most famous image

- Lena (512 x 512)





Digital Image Processing

What will I teach?

- Digital image fundamentals
  - Image format (grayscale/color image)
  - Image sampling and quantization

- Spatial domain image processing
  - Point processing
    - image enhancement
    - thresholding
    - histogram
  - Mask processing (spatial filtering)
    - smoothing
    - edge detection and sharpening

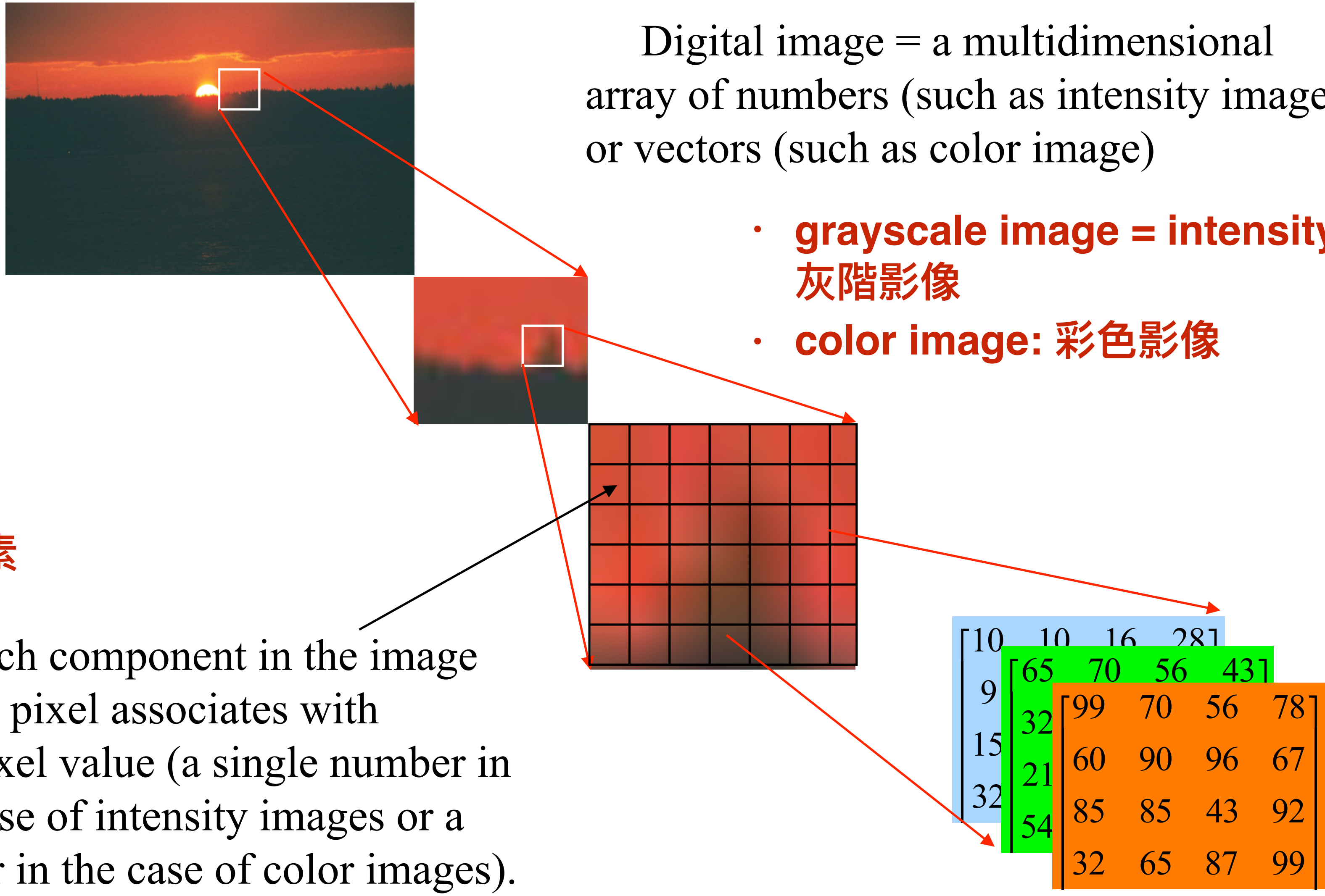
Digital Image Fundamentals

Image Format

Digital image = a multidimensional array of numbers (such as intensity image) or vectors (such as color image)

- **grayscale image = intensity image: 灰階影像**
- **color image: 彩色影像**

Pixel: 像素



Each component in the image called pixel associates with the pixel value (a single number in the case of intensity images or a vector in the case of color images).

Image Format

For grayscale image
- **Intensity: 0 ~ 255**
- **1 byte for 1 pixel**

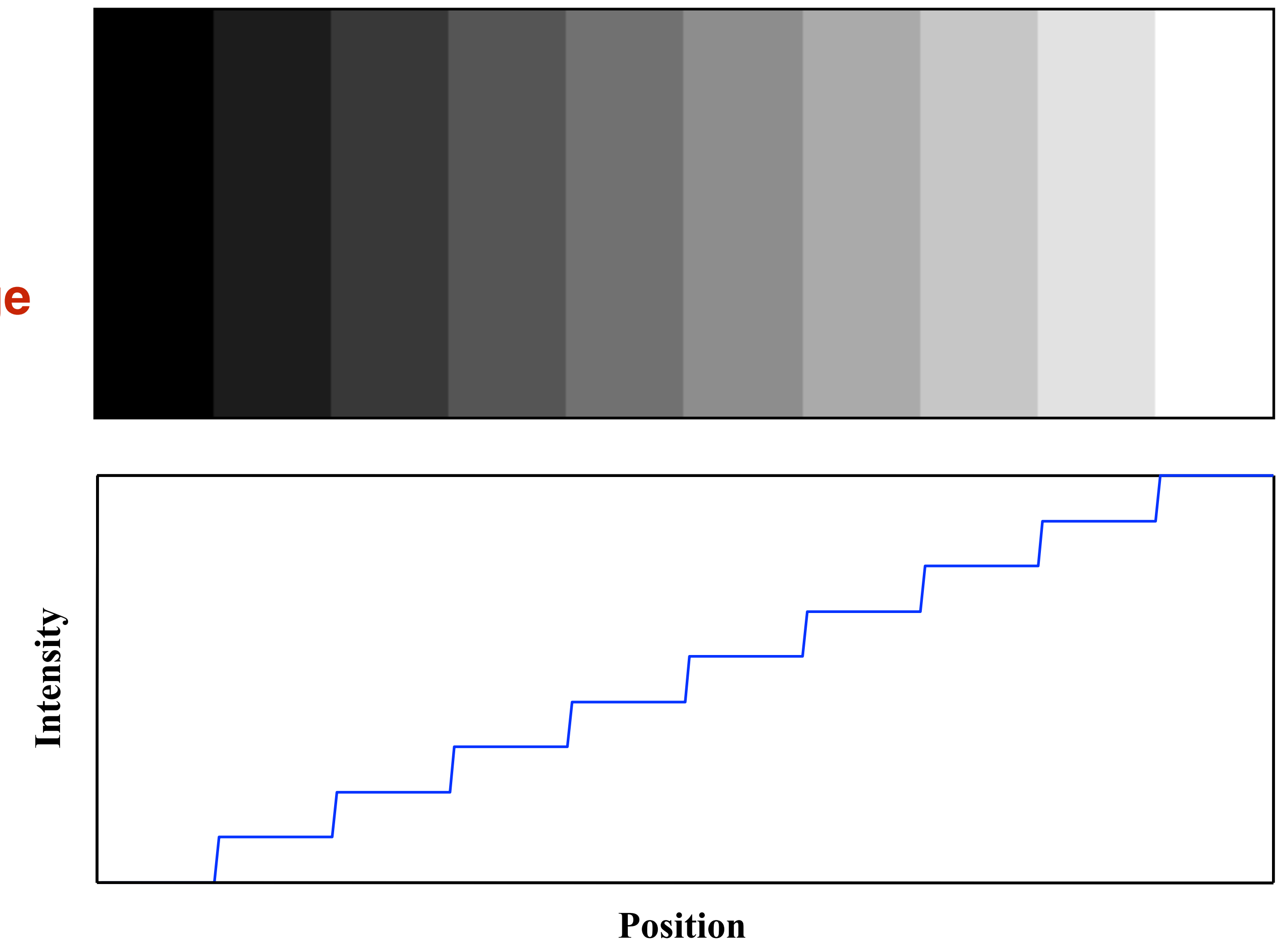
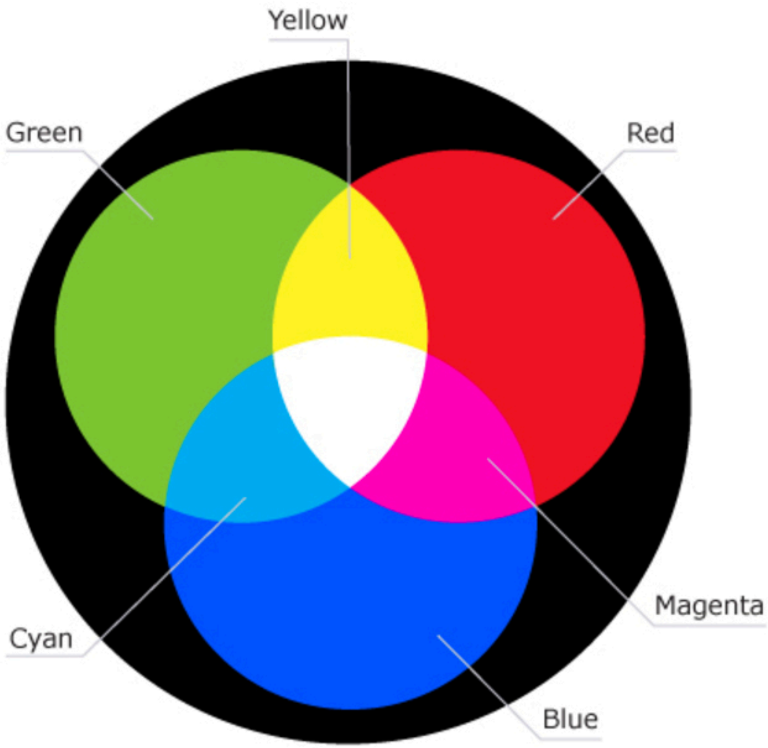
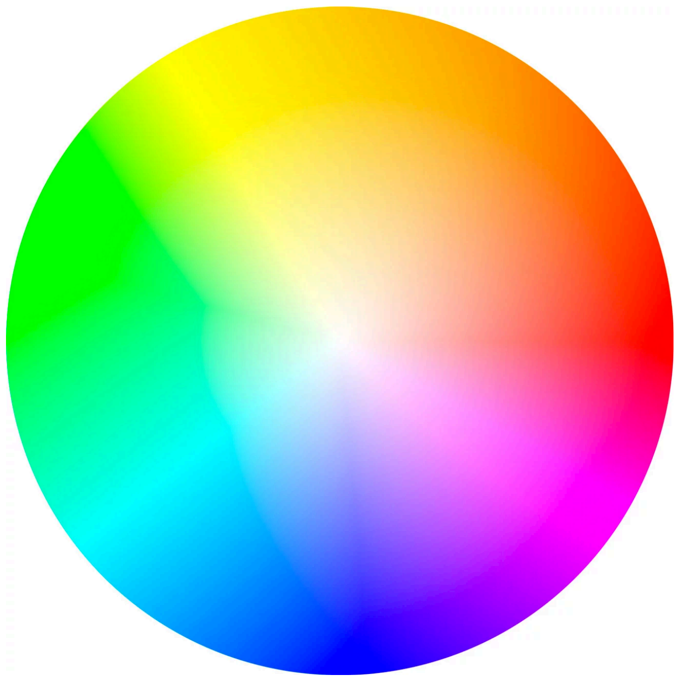


Image Format

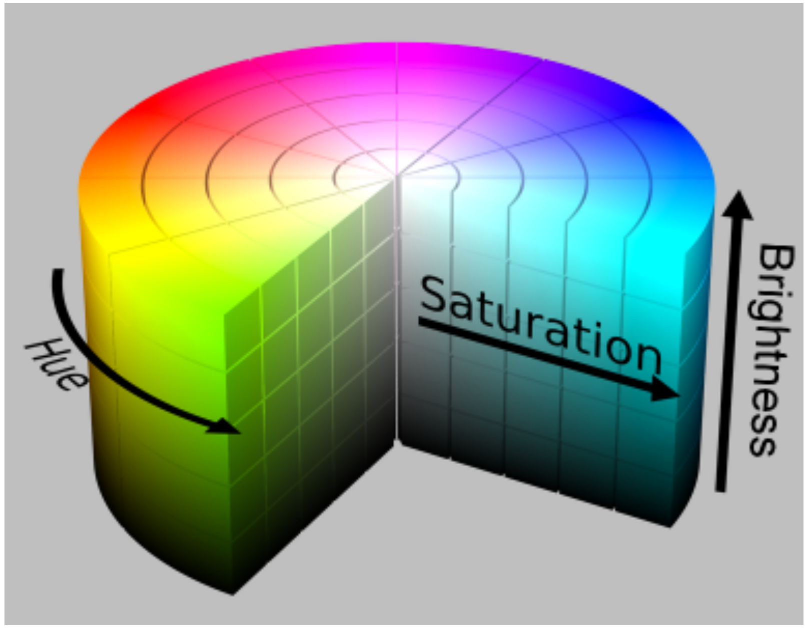




For color image

- **R: 0 ~ 255**
- **G: 0 ~ 255**
- **B: 0 ~ 255**
- **3 byte for 1 pixel, ex: 0x0000FF =** 

Image Format



For color image (HSI color model)

- **H: Hue**
- **S: Saturation**
- **I: Intensity**

Steps to be followed:

1. Read a RGB image
2. Represent the RGB image in the range [0 1]
3. Find HSI components

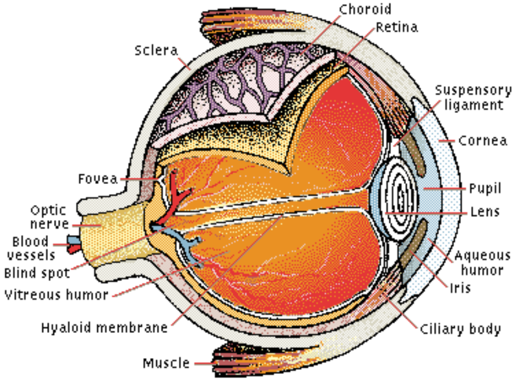
$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{\left[(R-G)^2+(R-B)(G-B)\right]^{\frac{1}{2}}} \right\}$$

4. H(Hue)= $\begin{cases} \theta & \text{If } B<=G \\ 360-\theta & \text{If } B>G \end{cases}$

5. S(Saturation)= 1- $\frac{3}{(R+G+B)}[\min(R,G,B)]$

6. I(Intensity)= $\frac{1}{3}(R+G+B)$

Brightness Adaptation of Human Eye: Simultaneous Contrast



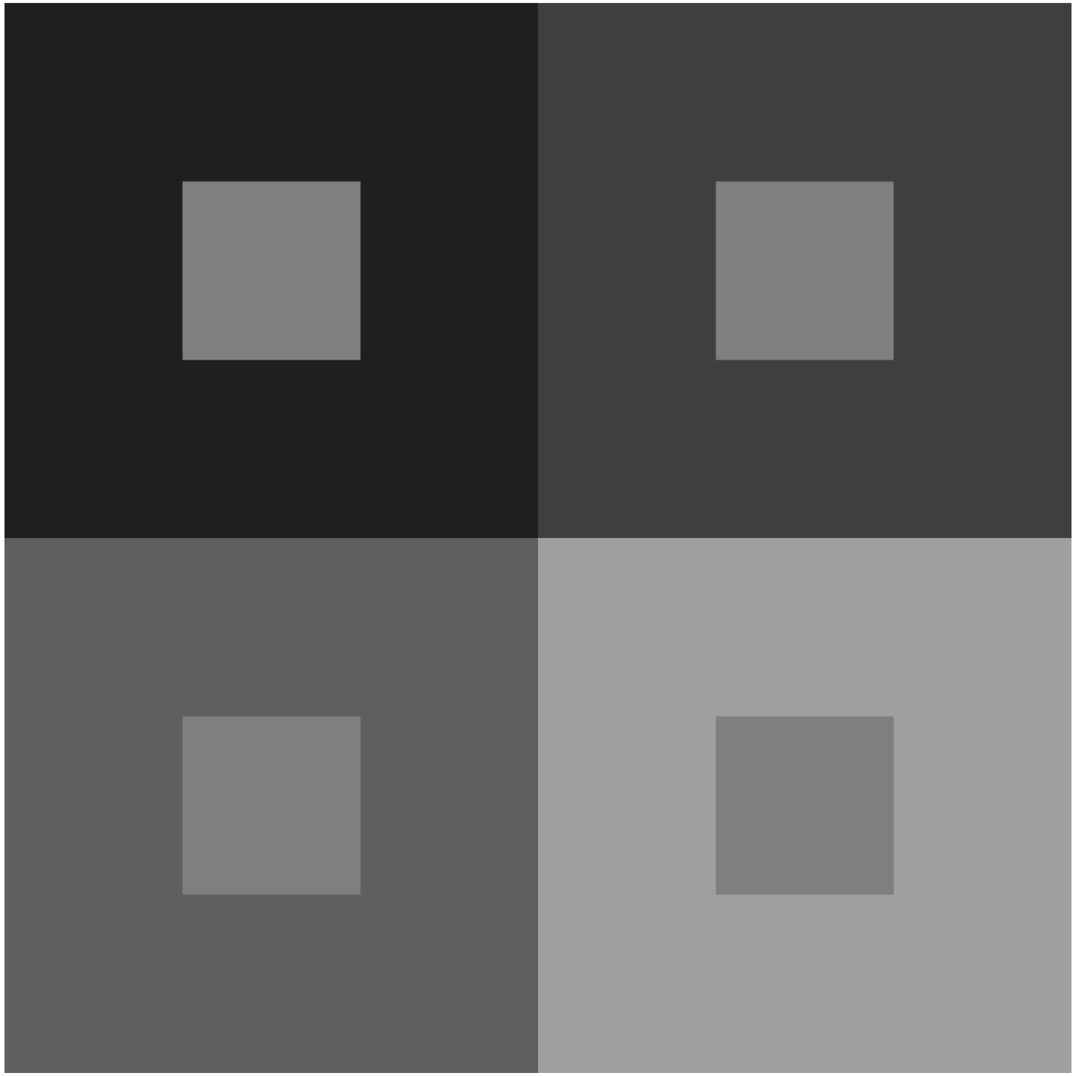
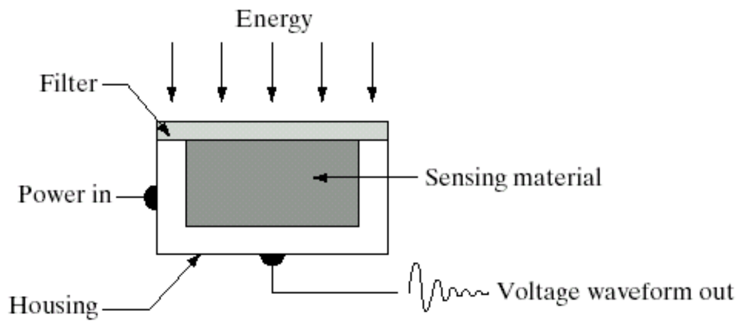
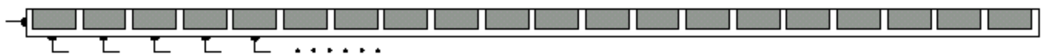


Image Sensors

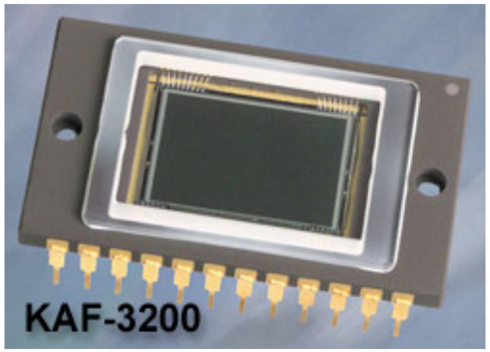


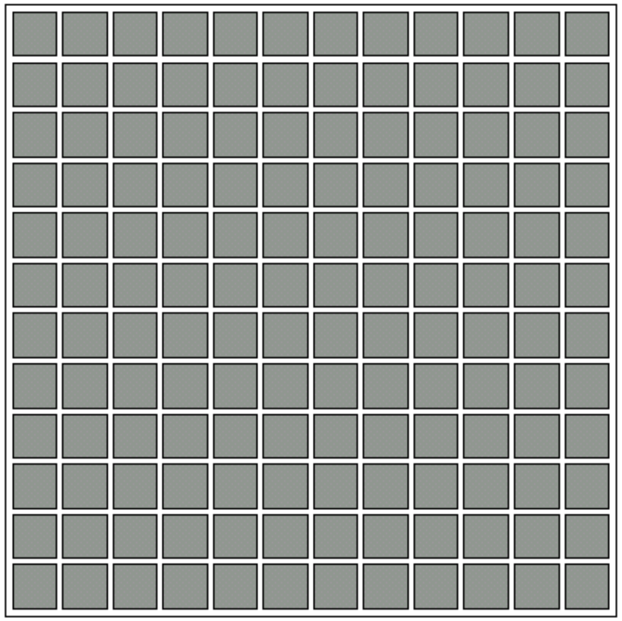
Single sensor



Line sensor

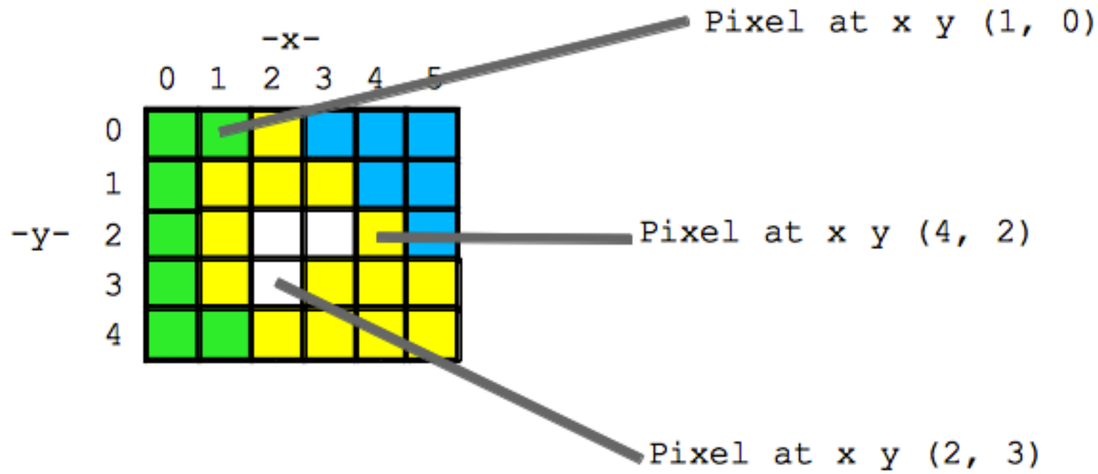
Charge-Coupled Device (CCD)





Array sensor

Fundamentals of Digital Images

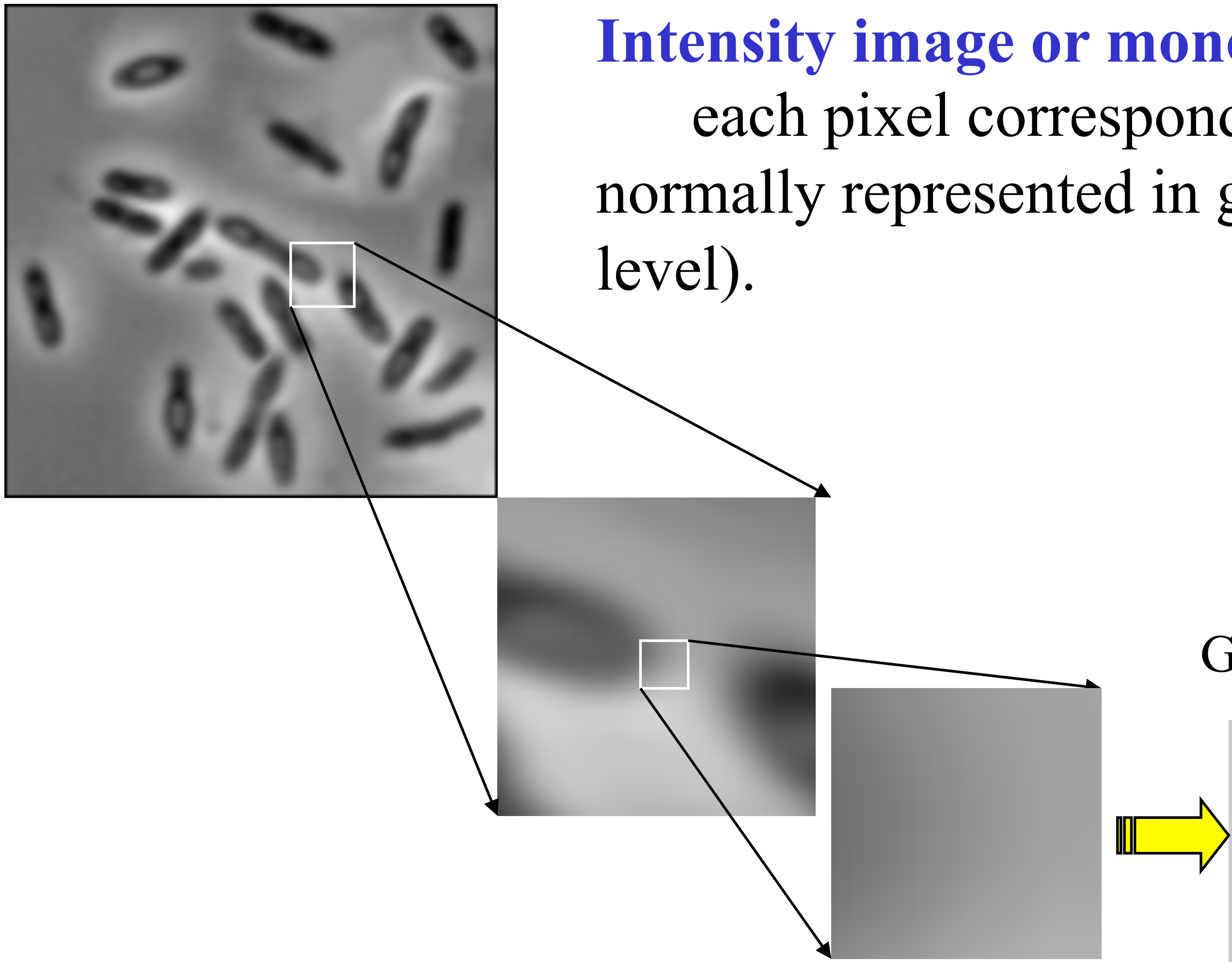


- **An image**: **a multidimensional function of spatial coordinates**.
- **Spatial coordinate**: (x,y) for 2D case such as photograph,
  (x,y,z) for 3D case such as CT scan images
  (x,y,t) for movies
- The function f may represent intensity (for monochrome images) or color (for color images) or other associated values.

Digital Image Types : Intensity Image

Intensity image or monochrome image

each pixel corresponds to light intensity normally represented in gray scale (gray level).

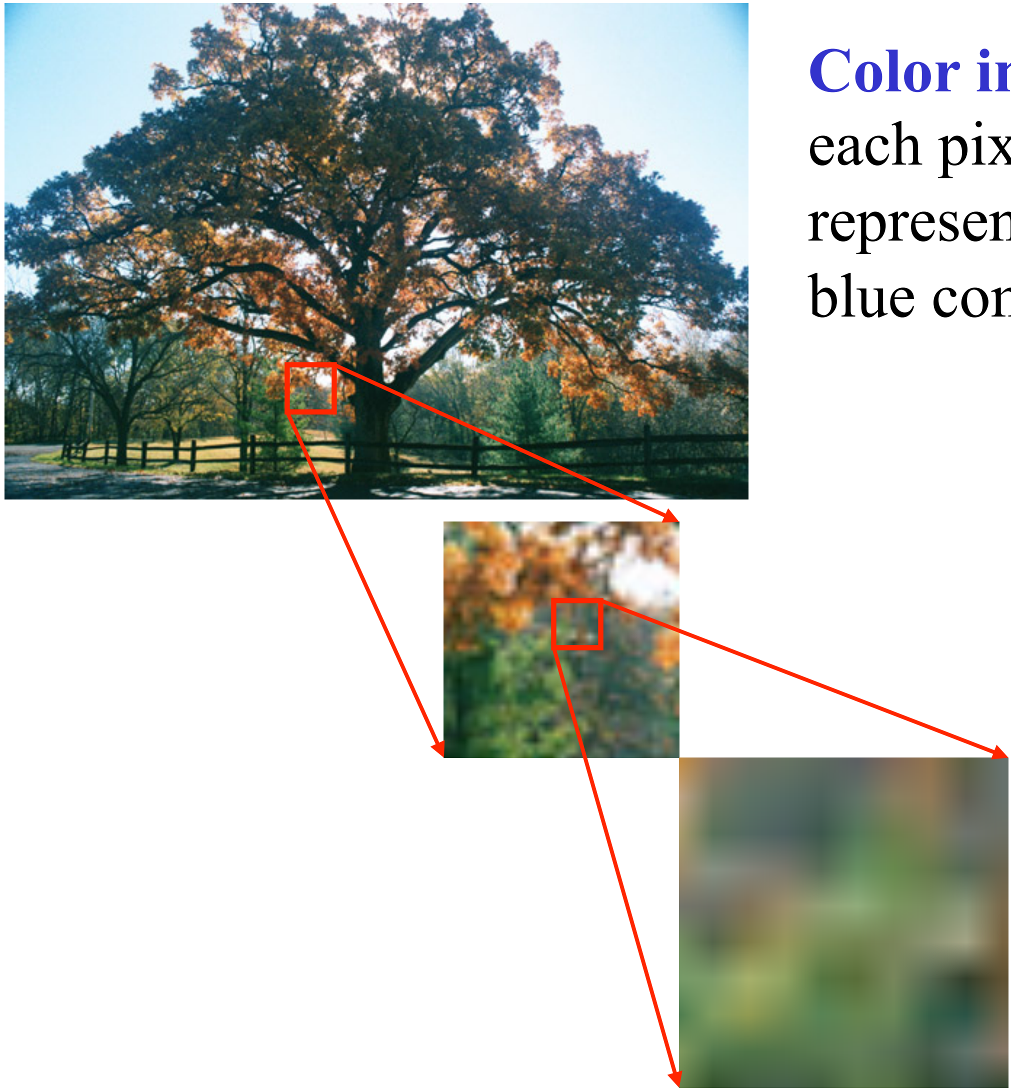


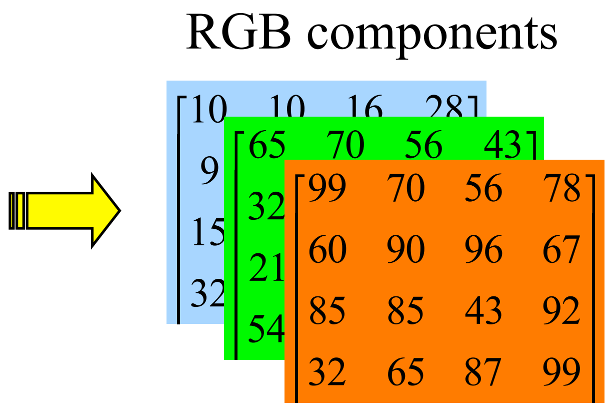
Gray scale values

$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 6 & 26 & 37 \\ 15 & 25 & 13 & 22 \\ 32 & 15 & 87 & 39 \end{bmatrix}$$

Digital Image Types : RGB Image

Color image or RGB image: each pixel contains a vector representing red, green and blue components.





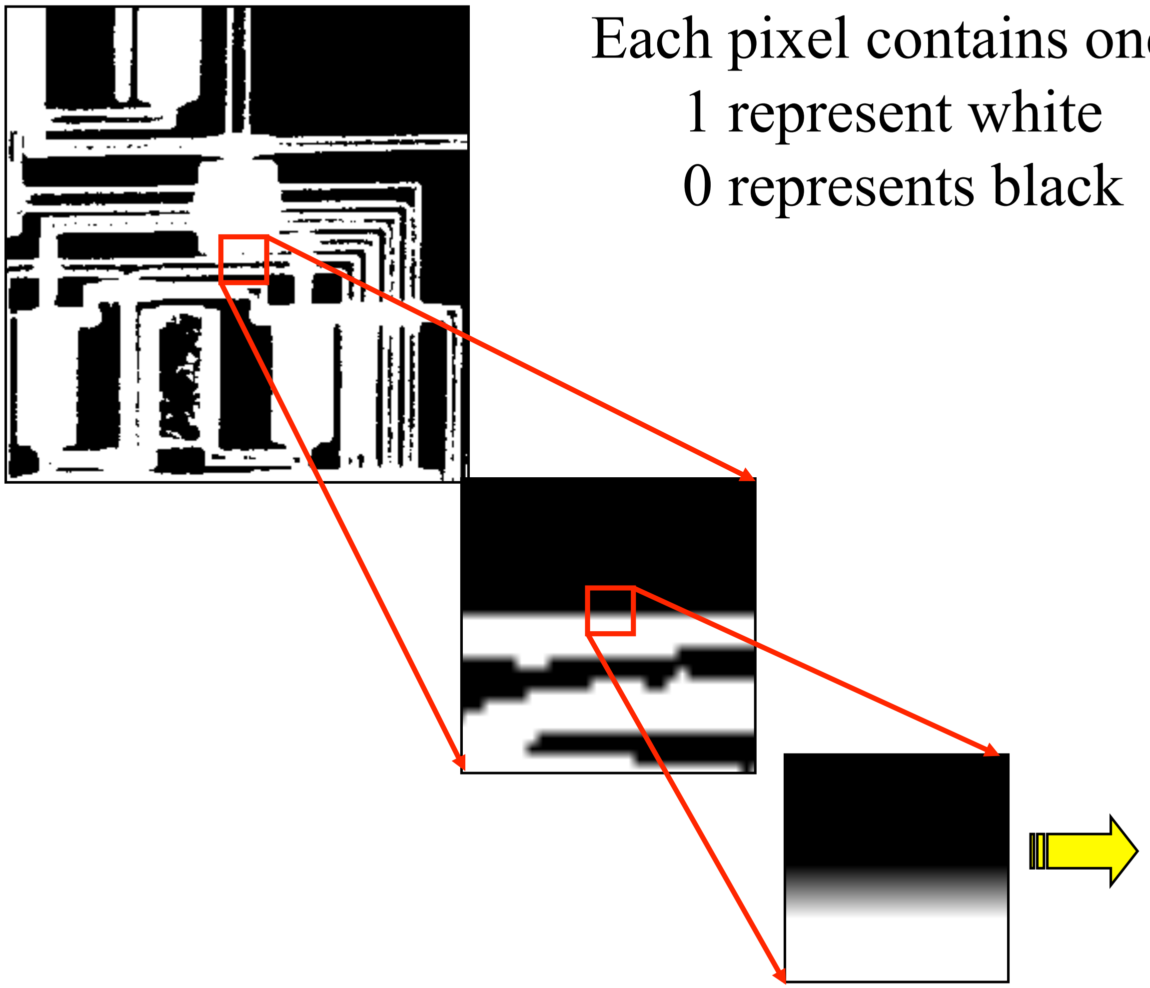
Digital Image Types : Binary Image

Binary image or black and white image

Each pixel contains one bit :

1 represent white

0 represents black



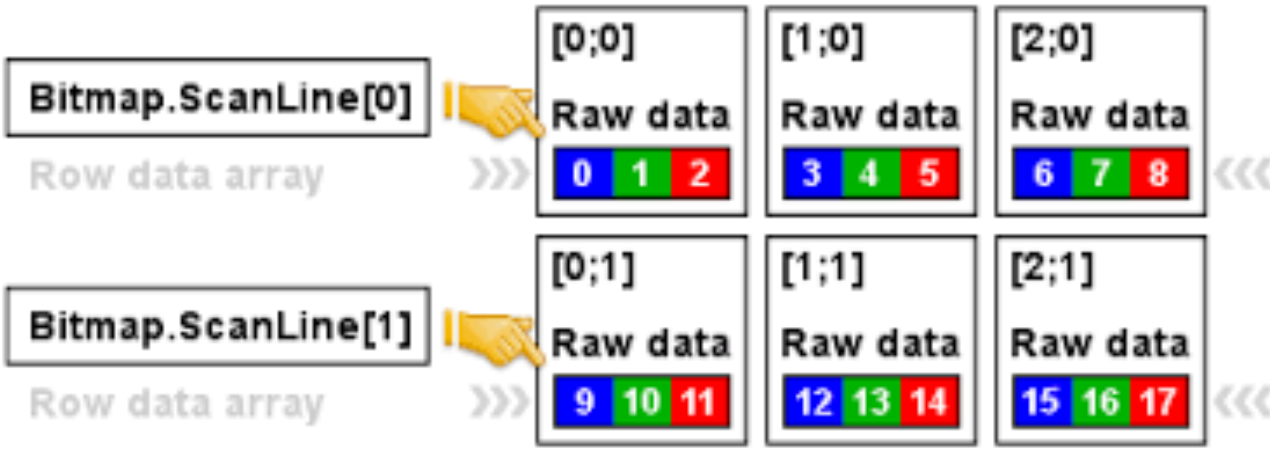
Binary data

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

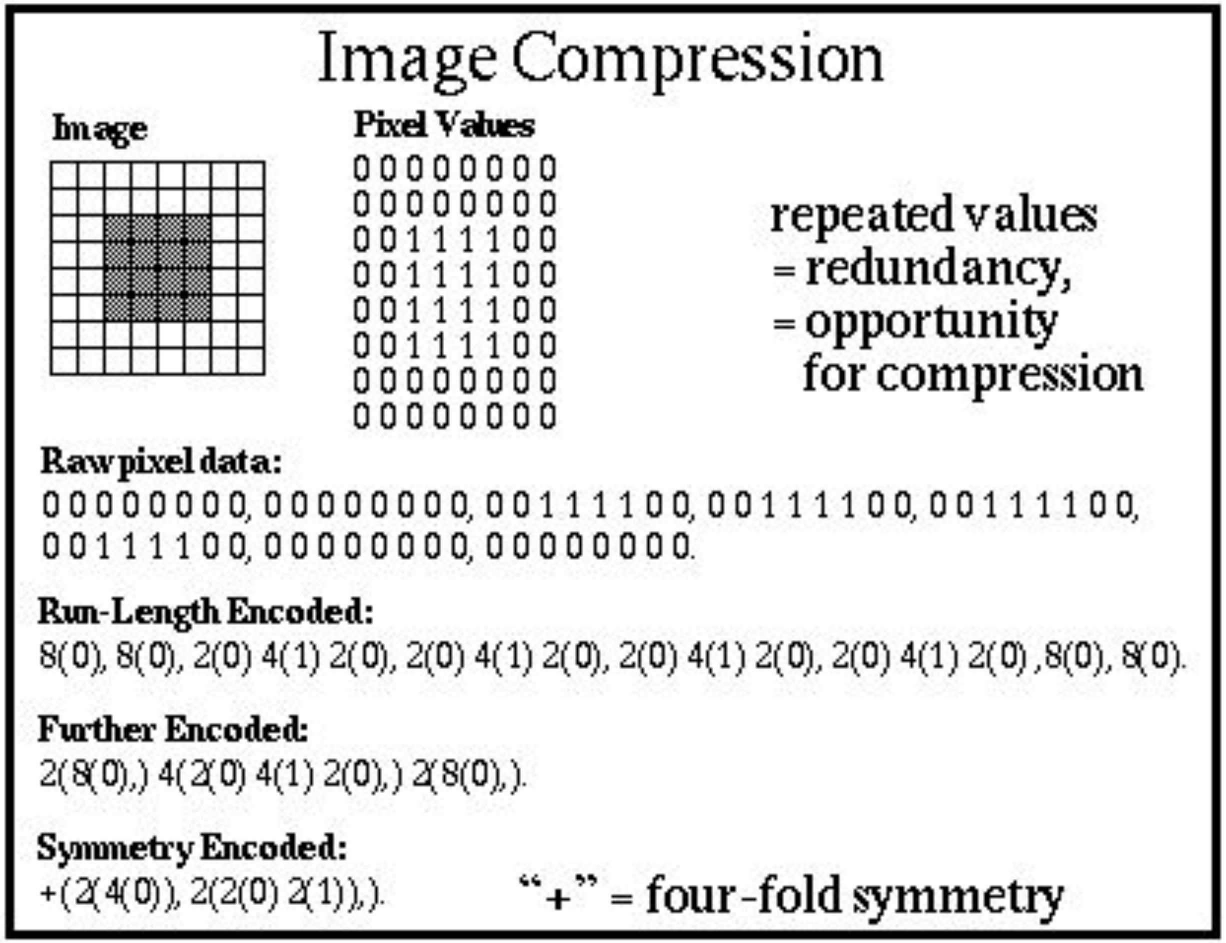
Digital Image Format: Bitmap (BMP)

A typical BMP file usually contains the following blocks of data:

- **BMP File Header:** Stores general information about the BMP file.
- **DIB header:** Stores detailed information about the bitmap image.
- **Color Palette:** Stores the definition of the colors being used for indexed color bitmaps.
    - Image pixels are stored with a color depth of 1, 4, 8, 16, 24, or 32 bits per pixel
- **Bitmap Data:** Stores the actual image, pixel by pixel.



Digital Image Format: Image compression



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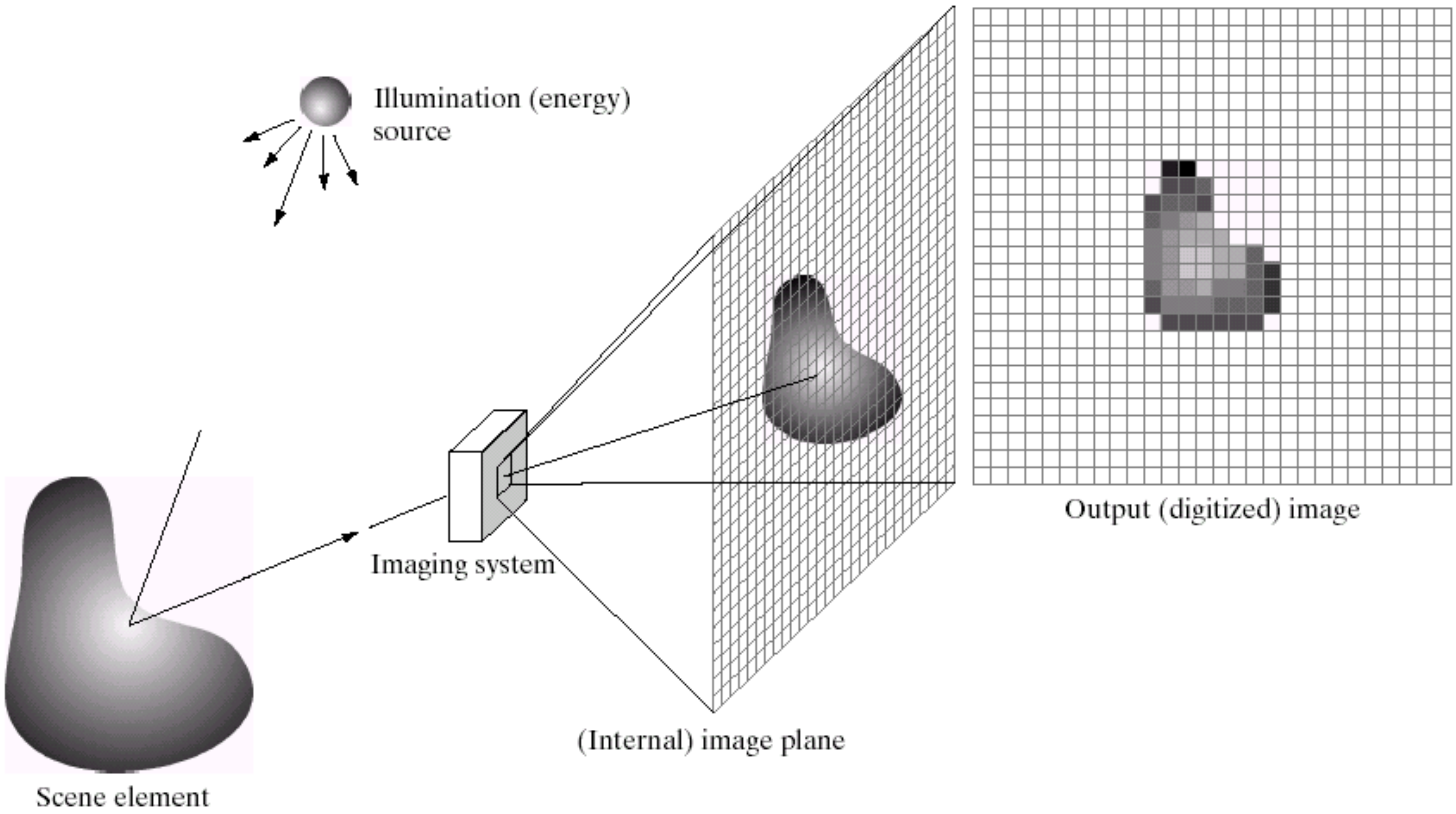
Digital Image Acquisition Process



Generating a Digital Image

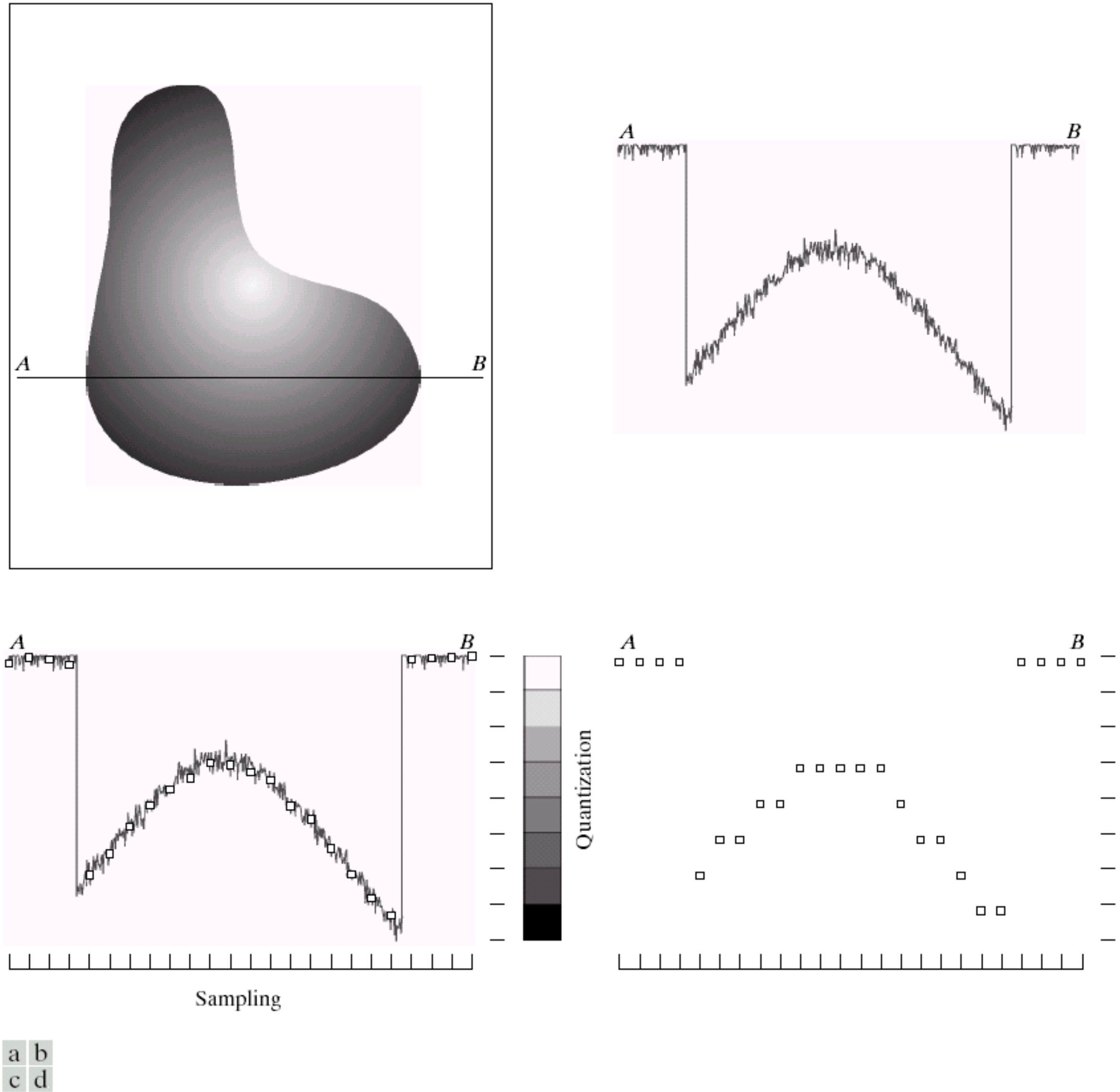
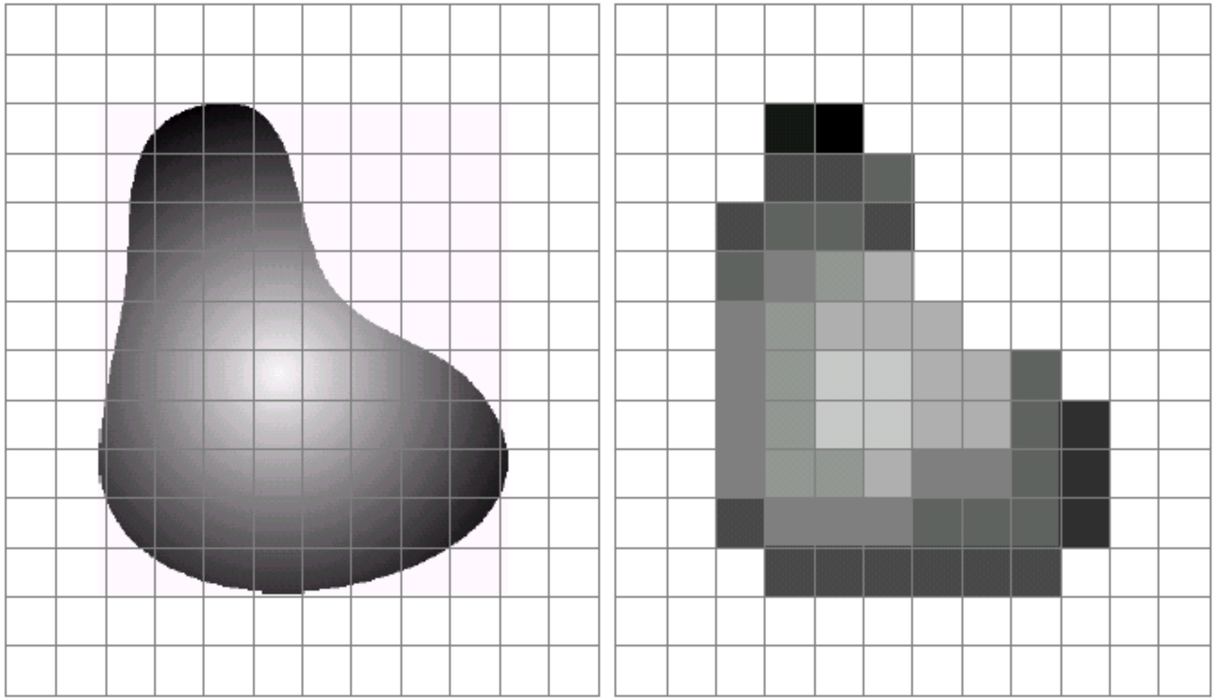


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Image Sampling and Quantization



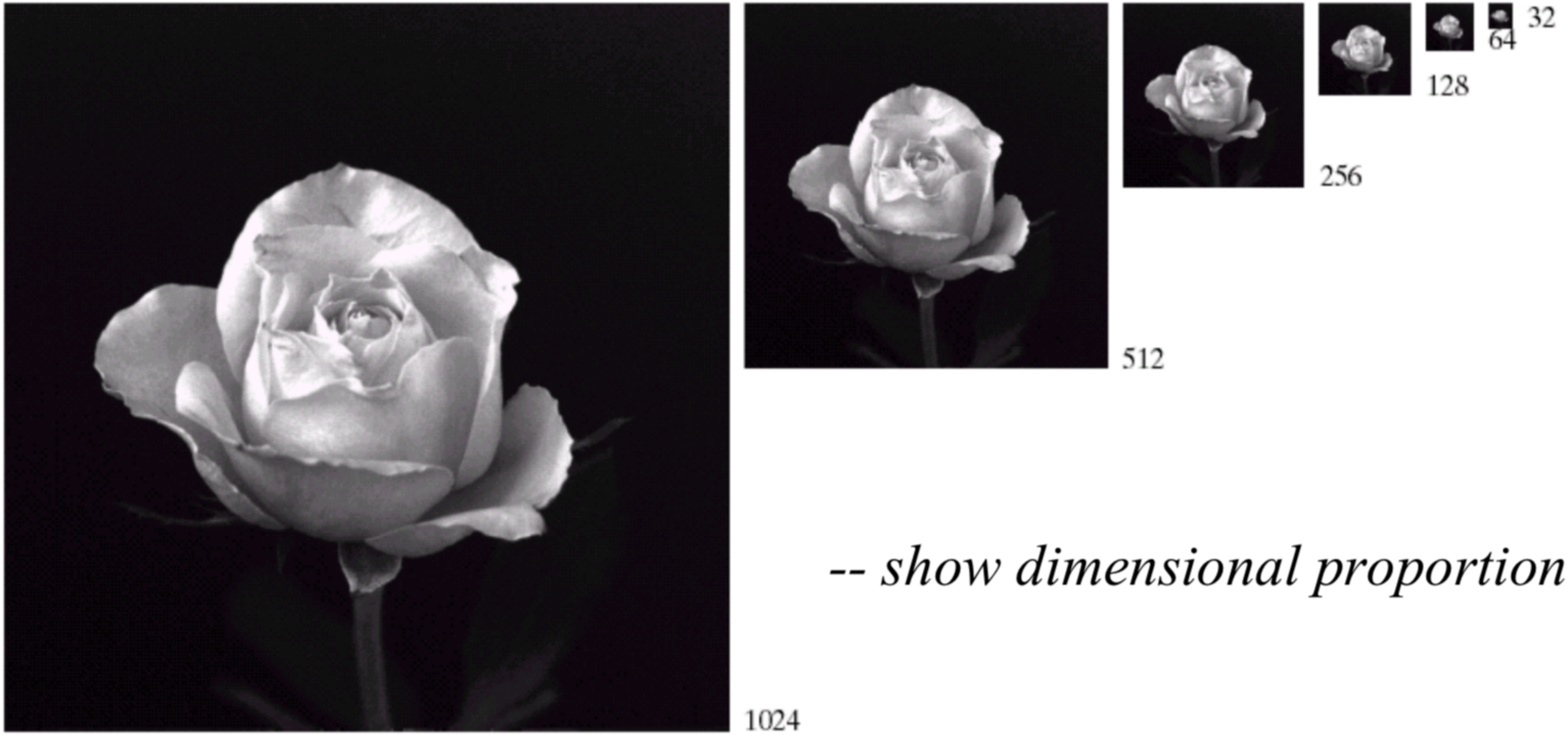
a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Image sampling: discretize an image in the spatial domain

Spatial resolution / image resolution: pixel size or number of pixels

Spatial Resolution



-- show dimensional proportion

FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

-- zoom-in to show the effects of subsampling

a b c
d e f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

Image Interpolation

- Nearest-Neighbor Interpolation

- Bilinear Interpolation

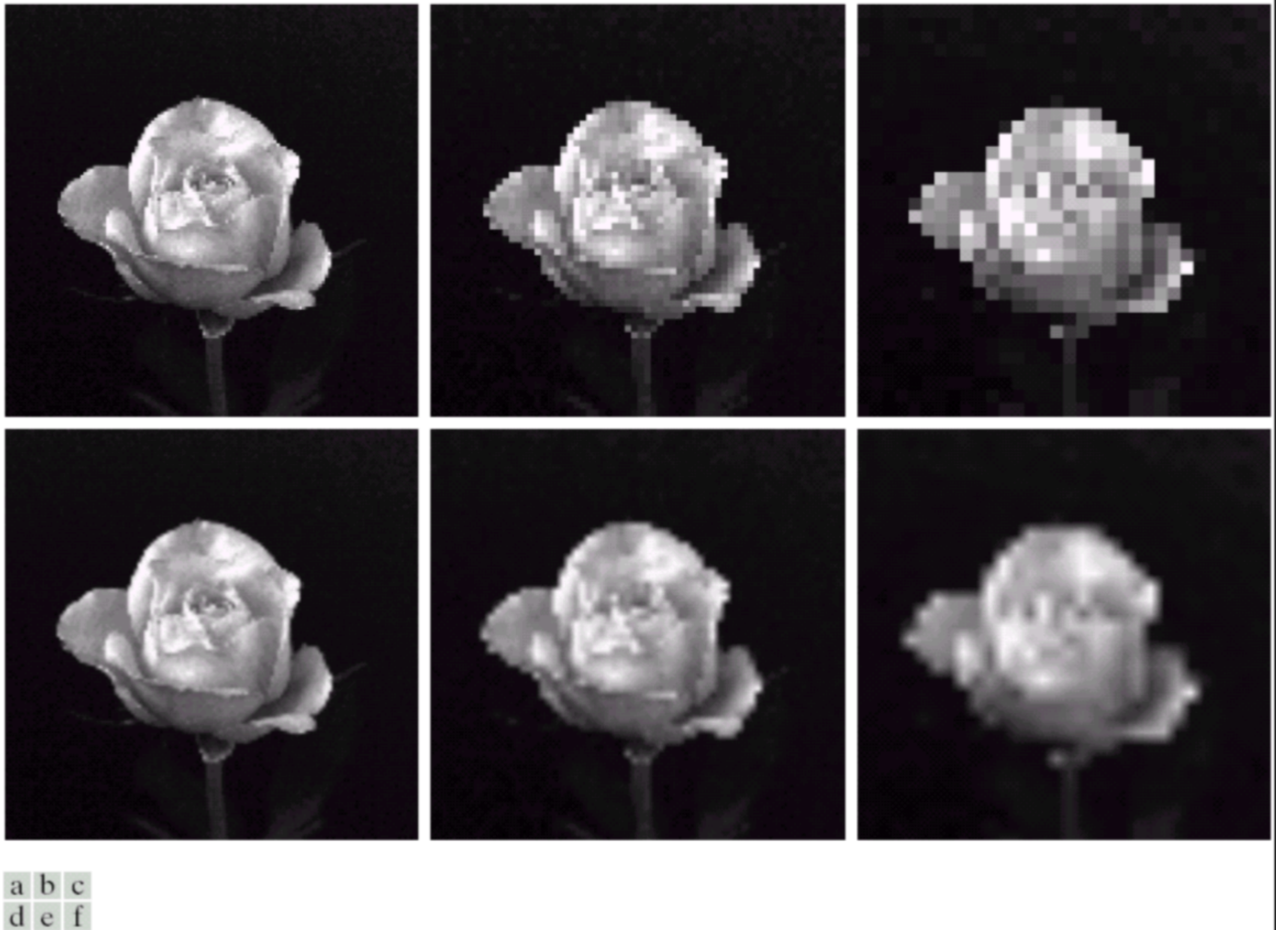
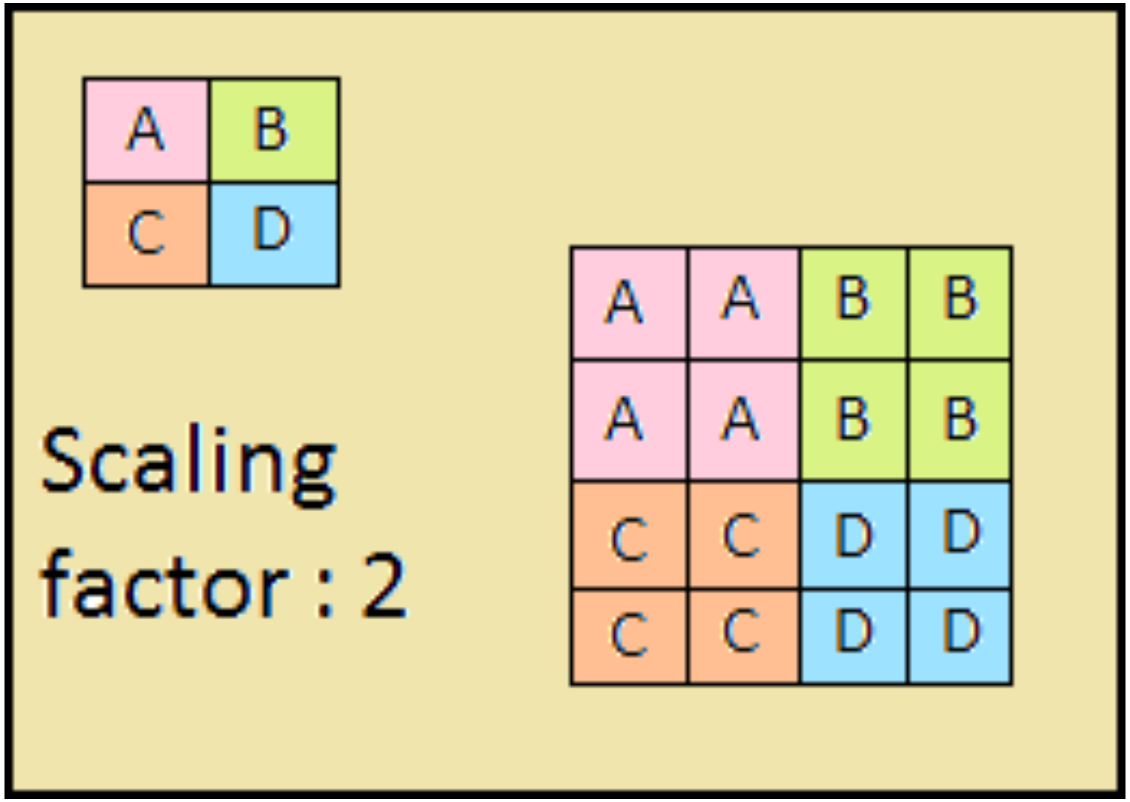


FIGURE 2.25 Top row: images zoomed from 128 × 128, 64 × 64, and 32 × 32 pixels to 1024 × 1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

Nearest-Neighbor Interpolation



Bilinear Interpolation

$$f(x, y_1) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{11}) + \frac{x - x_1}{x_2 - x_1} f(Q_{21}),$$
$$f(x, y_2) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{12}) + \frac{x - x_1}{x_2 - x_1} f(Q_{22}).$$

$$f(x, y) \approx \frac{y_2 - y}{y_2 - y_1} f(x, y_1) + \frac{y - y_1}{y_2 - y_1} f(x, y_2)$$