EE410
Digital Image Processing

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Image Model

- Image refers to a 2-D light intensity function denoted by $f(x,y)$.
- At spatial location (x_0,y_0), f gives the intensity (Brightness) of the image at that point. $f(x_0,y_0)$ is called the **gray level** (l)
- It is evident that l lies in the range L_{max} L_{min}

$$f(x,y) = i(x,y)r(x,y)$$

where

$0 < i(x,y) < \infty$ (illumination)

and

$0 < r(x,y) < 1$ (reflectance)

Image Model

- In practice, $L_{min} = i_{min}\, r_{min}$ and $L_{max} = i_{max}\, r_{max}$
- The interval $[L_{min}, L_{max}]$ is called the *gray scale*.
- It is common to shift this interval numerically to the interval (L levels): $[0, L-1]$, Where

  $L = 0$ is considered black

  $L = L-1$ is considered white in the gray scale

Digital Image

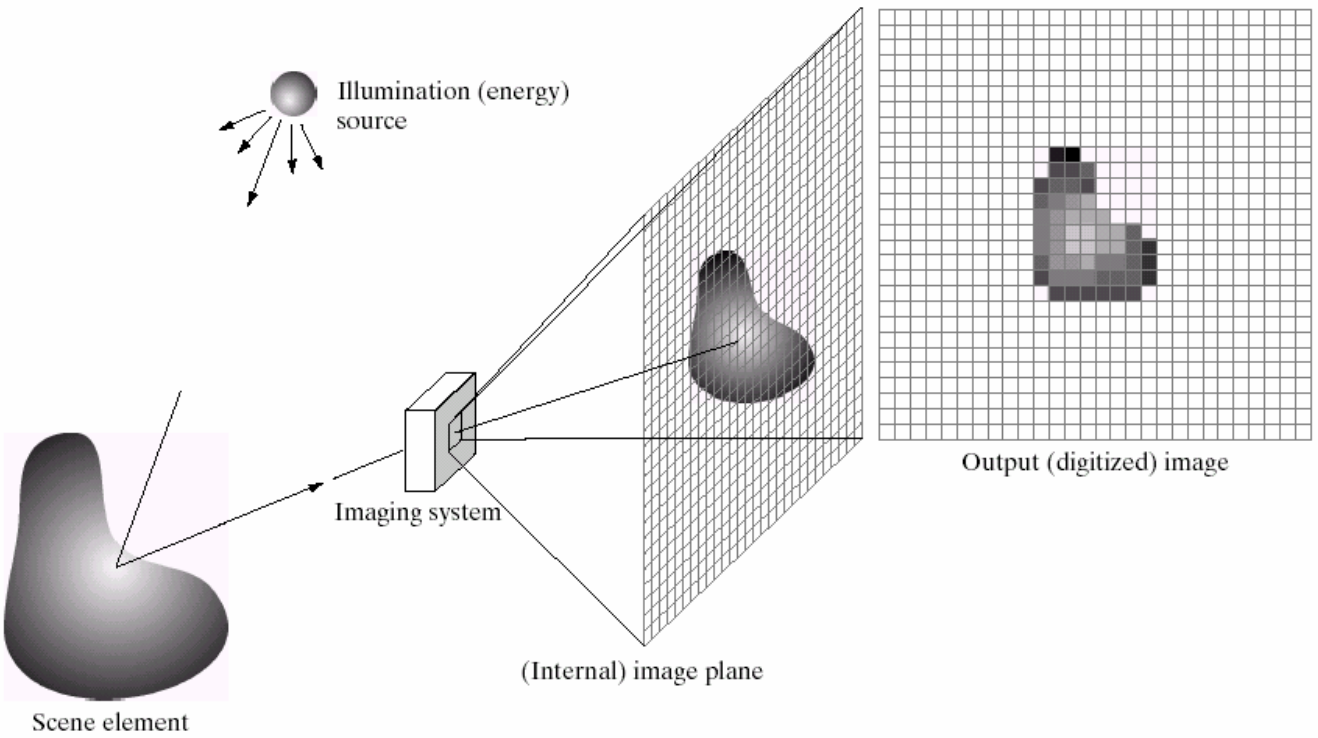
- Digital image is an analog image *f(x,y)* that has been discretized in
  - Space
  - Brightness
- *f(x,y)* can be
  - scalar function representing a monochrome image
  - vector valued function representing a colored image
- Each element of *f(x,y)* is called ***Pel*** or ***Pixel*** (Picture Element .)

Sampling and Quantization

- Sampling is digitizing the x and y coordinates (N×M points)
- Quantization is amplitude digitization into grey levels, normally, powers of 2
- Gray levels = 2^k, Number of bits = N×M×k

$$f(i,j) = \begin{bmatrix} f(0,0) & f(0,1) & . . & f(0,M-1) \\ f(1,0) & f(1,1) & . . & f(1,M-1) \\ . & & & \\ . & & & \\ f(N-1,0) & f(N-1,1) & . . & f(N-1,M-1) \end{bmatrix}$$

Image Digitization



a
b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Image Digitization

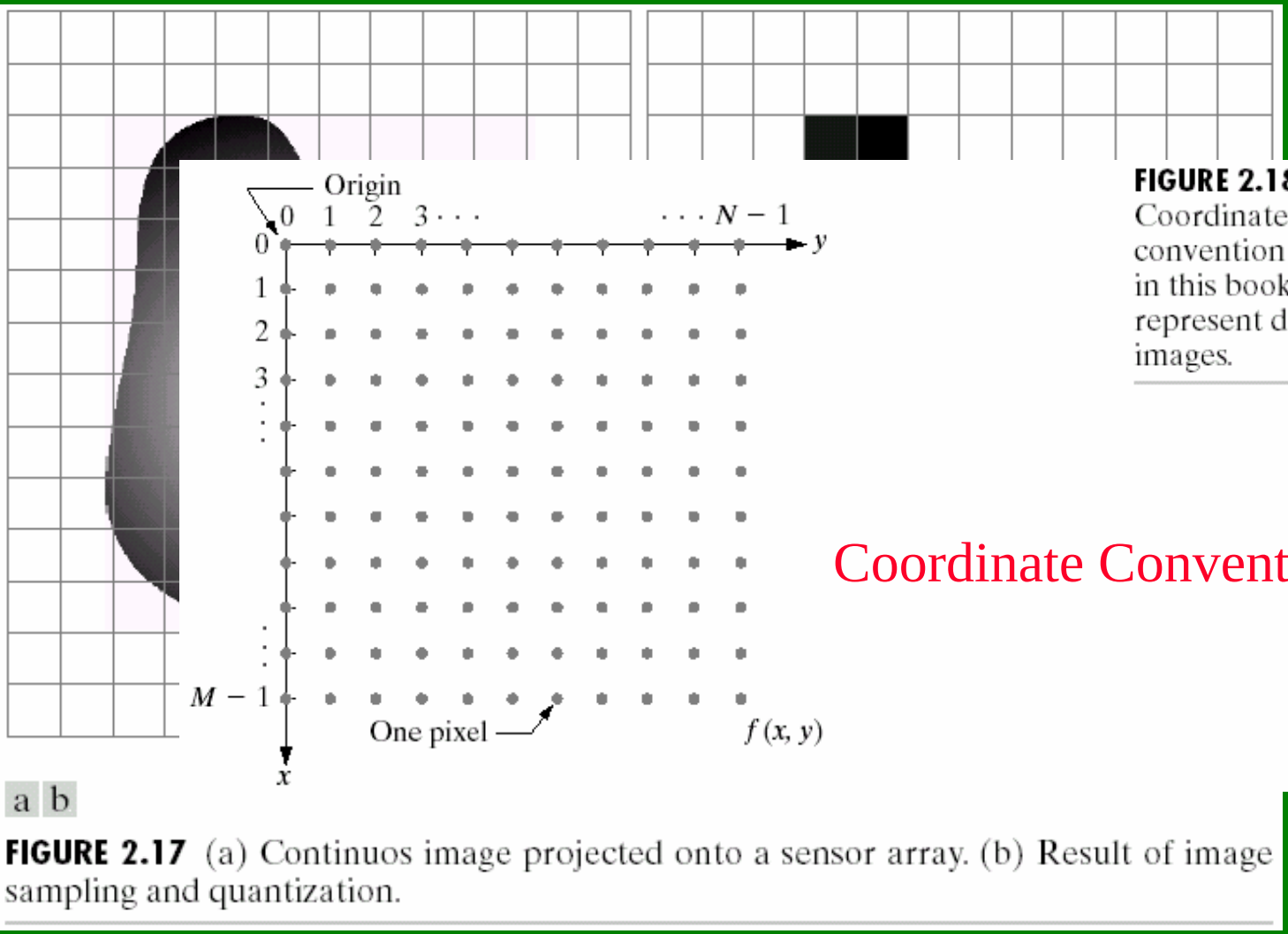


FIGURE 2.18 Coordinate convention used in this book to represent digital images.

Coordinate Convention

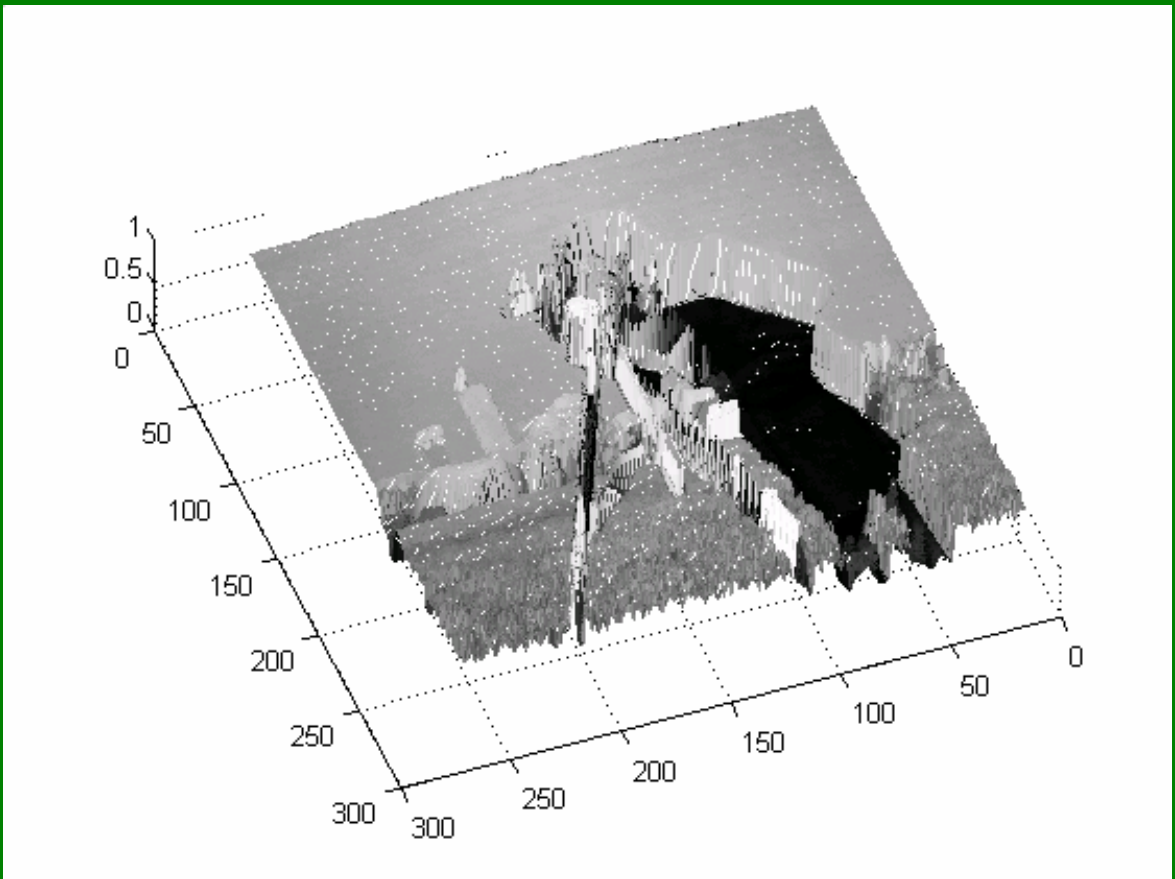
a b

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

This is a 256 × 256 digital image.

Image in 3-D Perspective

- A 2-D digital image represented in a 3-D perspective.



Picture Elements

11	11	11	11	12	12	12	11	10	11
12	12	13	13	13	14	13	13	14	14
13	12	12	12	12	13	14	15	15	13
13	12	12	12	13	15	14	15	14	12
12	11	12	13	16	15	14	15	13	12
12	12	13	14	16	15	16	13	12	12
12	14	16	15	15	14	14	13	12	12
13	16	15	14	13	13	14	13	13	12
12	14	13	12	12	13	13	13	12	11
11	11	11	11	12	15	15	13	11	8

Picture Elements (*pixels*) in grey-level values to be represented as an 8-bit unsigned integers

Gray levels = 2^k

Number of bits = N×M×*k*

For a square image= $N^2 \times k$

TABLE 2.1
Number of storage bits for various values of N and k.

N/k	1 ($L = 2$)	2 ($L = 4$)	3 ($L = 8$)	4 ($L = 16$)	5 ($L = 32$)	6 ($L = 64$)	7 ($L = 128$)	8 ($L = 256$)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

Example: 128 ×**128** ×**4 bits** = **65536 bits**

Example 1

- A common measure of transmission for a digital data is the *Baud rate* (# of bits transmitted by second).

Generally, transmission is accomplished in packets consisting of a start bit, a byte (8 bits) of information, and a stop bit.

Example 1

- How many minutes it would take to transmit a 1024X1024 image with 256 gray levels, using a 56Kbaud modem?
- Total bits = 1024×1024 ×[1+8+1]= 1048576 bits
- Time required= 1048576/56000=187.25sec=3.1min.

- Repeat for a phone digital subscriber line (DSL) at 750K baud?
- Answer = 14 seconds.

Example 2

- A square image was represented by 131072 bits.
- What is the image spatial size if each pixel was represented by 8 bits?

Ans. N^2=Total bits/k

=131072/8=16384

N=√16384=128 pixels