Introduction to Digital Image Processing with MATLAB® Asia Edition

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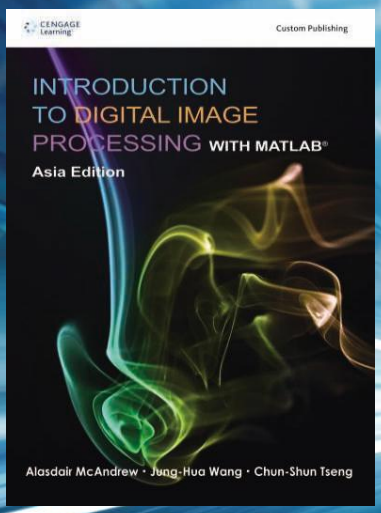

Chapter 1: Introduction

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1.1 Images and Pictures

- Human have evolved very precise visual skills:
  - ✓We can identify a face in an instant
  - ✓We can differentiate colors
  - ✓We can process a large amount of visual information very quickly

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1.2 What Is Image Processing?

- **Image processing** involves changing the nature of an image in order to either
  1. improve its pictorial information for human interpretation, or
  2. render it more suitable for autonomous machine perception

1.2 What Is Image Processing?

Condition 1.

- Enhancing the edges of an image to make it appear sharper (Figure 1.1)
- Note how the second image appears cleaner; it is a more pleasant image
- Sharpening edges is a vital component of printing

FIGURE 1.1

(a) (b)

FIGURE 1.1 *Image sharpening. (a) The original image. (b) Result after sharpening.*

1.2 What Is Image Processing?

- removing noise from an image, noise being random errors in the image (Figure 1.2)
- removing motion blur from an image. An example is given in Figure 1.3
- In Figure 1.3(b), it is easier to read the number plate and to see the spikes on the fence behind the car, as well as other details not at all clear in the original image Figure 1.3(a).

FIGURE 1.2

(a) (b)

FIGURE 1.2 *Removing noise from an image. (a) The original image. (b) After removing noise.*

FIGURE 1.3

(a) (b)

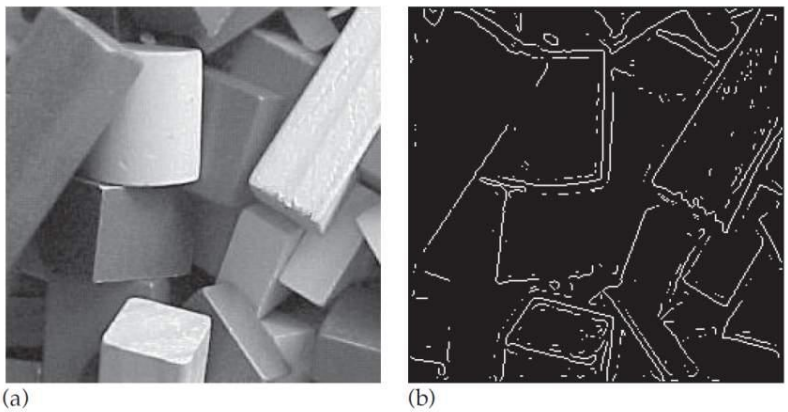
FIGURE 1.3 *Image deblurring. (a) The original image. (b) After removing the blur.*

1.2 What Is Image Processing?

Condition 2.

- Obtaining the edges of an image (Figure 1.4)
- Once we have the edges we can measure their spread and the area contained within them
- We can also use edge-detection algorithms as a first step in edge enhancement

FIGURE 1.4



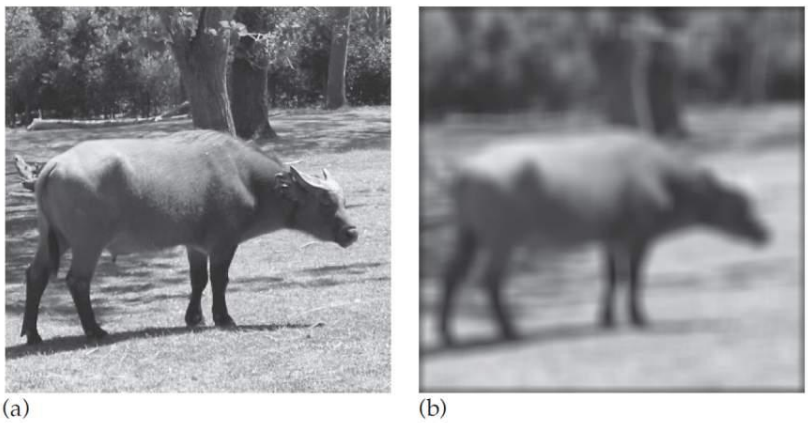
(a) (b)

FIGURE 1.4 *Finding edges in an image. (a) The original image. (b) Its edge image.*

1.2 What Is Image Processing?

- For measurement or counting purposes, we may not be interested in all the detail in an image (Figure 1.5)
- We could, for example, measure the size and shape of the animal without being distracted by unnecessary detail

FIGURE 1.5



(a) (b)

FIGURE 1.5 *Blurring an image. (a) The original image. (b) Blurring to remove detail.*

1.3 Image Sampling and Acquisition

- **Sampling** refers to the process of digitizing a continuous function
- e.g., $y = \sin(x) + \frac{1}{3}\sin(3x)$
  - ✓ sample it at 10 evenly spaced values of *x* only (Figure 1.6)
  - ✓ sample it at 100 points, as shown in Figure 1.7

FIGURE 1.6

FIGURE 1.6 *Sampling a function—undersampling.*

FIGURE 1.7

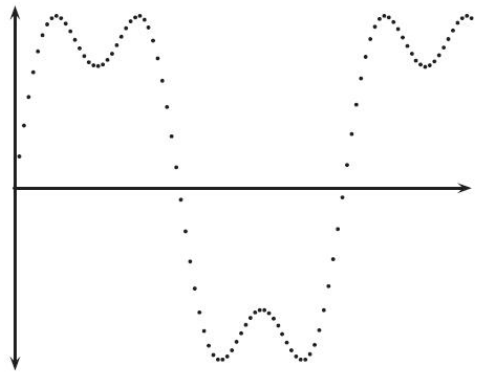
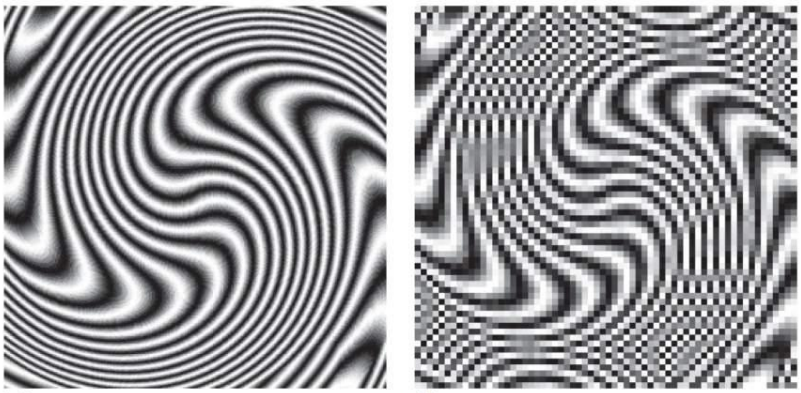


FIGURE 1.7 *Sampling a function with more points.*

1.3 Image Sampling and Acquisition

- **Nyquist criterion** which says, in effect, that a continuous function can be reconstructed from its samples provided that the sampling frequency is at least twice the maxi-mum frequency in the function

FIGURE 1.8



(a) (b)

FIGURE 1.8 *Effects of sampling. (a) Correct sampling; no aliasing. (b) An undersampled version with aliasing.*

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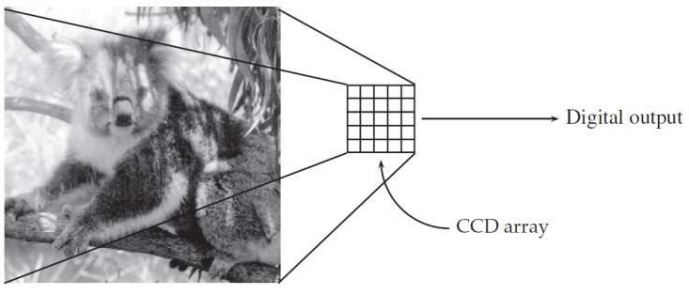
FIGURE 1.9

- **Image Acquisition**
  - ✓ CCD CAMERA



Original scene

FIGURE 1.9 *Capturing an image with a CCD array.*

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FIGURE 1.10

✓ FLAT-BED SCANNER

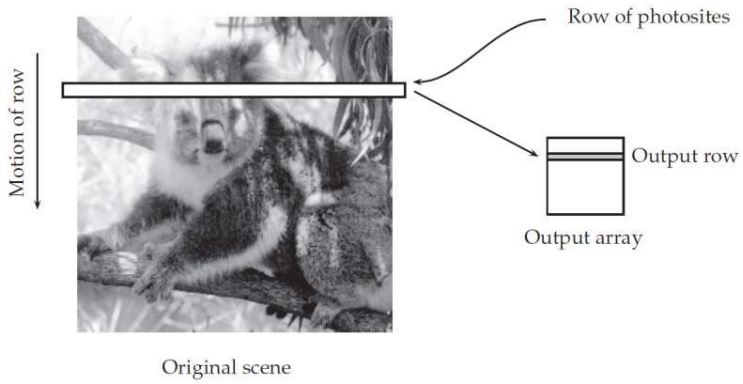

FIGURE 1.10 *Capturing an image with a CCD scanner.*

FIGURE 1.11

✓ OTHER ENERGY SOURCES

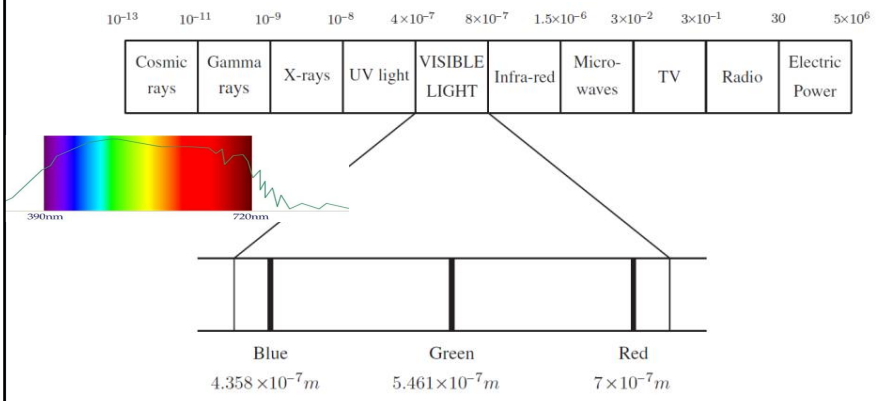

FIGURE 1.11 *The electromagnetic spectrum.*

FIGURE 1.12

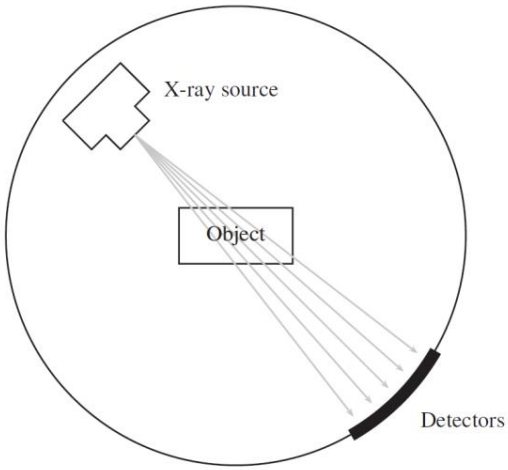

FIGURE 1.12 *X-ray tomography.*

1.4 Images and Digital Images

- We may consider this image as being a two-dimensional function $f(x, y)$
- We may assume that in such an image, brightness values can be any real numbers in the range 0.0 (black) to 1.0 (white)
- The $f(x, y)$ values in a digital image take only integer values ranging from 1 to 256 each and the brightness values ranging from 0 (black) to 255 (white)

FIGURE 1.13

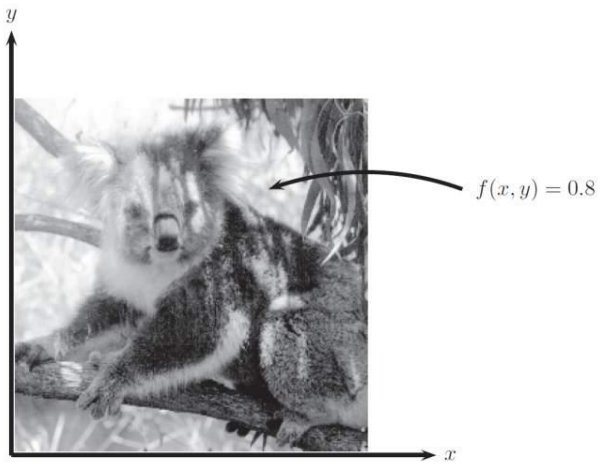

FIGURE 1.13 *An image as a function.*

FIGURE 1.14

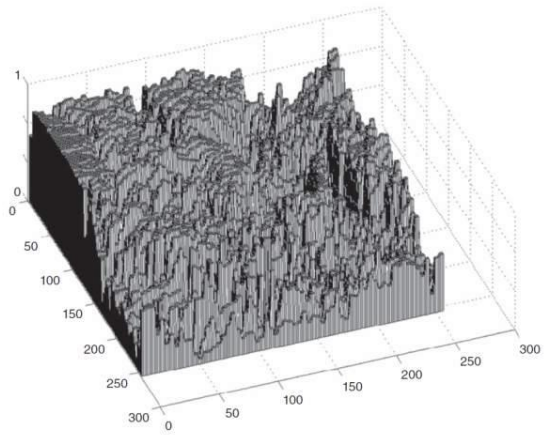

FIGURE 1.14 *The image of Figure 1.13 plotted as a function of two variables.*

1.4 Images and Digital Images

- A **digital image** can be considered as a large array of sampled points from the continuous image
- These points are the **pixels**, which constitute the digital image
- The pixels surrounding a given pixel constitute its **neighborhood**.

FIGURE 1.15

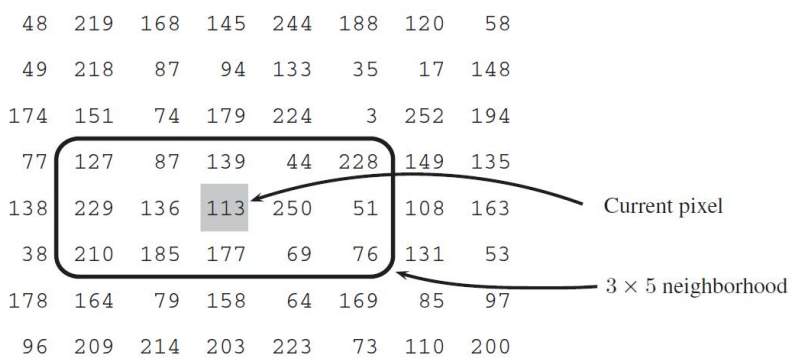

FIGURE 1.15 *Pixels with a neighborhood.*

1.5 Some Applications

- Medicine
- Agriculture
- Industry
- Law enforcement

1.6 Aspects of Image Processing

- **IMAGE ENHANCEMENT**
  - ✓ sharpening or deblurring an out-of-focus image
  - ✓ highlighting edges,
  - ✓ improving image contrast or brightening an image, and
  - ✓ removing noise
- **IMAGE RESTORATION**
  - ✓ removing of blur caused by linear motion,
  - ✓ removal of optical distortions, and
  - ✓ removing periodic interference

1.6 Aspects of Image Processing

- **IMAGE SEGMENTATION**
  - ✓ finding lines, circles, or particular shapes in an image, and
  - ✓ identifying cars, trees, buildings, or roads in an aerial photograph
- A given algorithm may be used for both image enhancement or for image restoration

1.7 An Image-Processing Task

- Acquiring the image
- Preprocessing
- Segmentation
- Representation and description
- Recognition and interpretation

FIGURE 1.16

- **Binary**

1	1	0	0	0	0
0	0	1	0	0	0
0	0	1	0	0	0
0	0	0	1	0	0
0	0	0	1	1	0
0	0	0	0	0	1

FIGURE 1.16 *A binary image.*

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FIGURE 1.17

- **Grayscale**

236	221	192	100	89	105	46	69	204	214	223
216	217	221	169	61	149	92	214	248	241	244
235	216	218	255	153	249	147	251	227	229	224
232	211	236	250	163	248	173	247	241	246	240
226	220	211	241	170	100	217	243	240	242	255
232	215	225	255	198	45	237	242	217	204	157
224	213	215	244	169	43	47	71	69	12	69
231	209	219	238	239	246	245	243	250	240	185
230	215	221	245	238	241	244	244	236	241	252
229	214	218	241	236	243	235	237	241	236	237
231	206	225	240	238	237	239	237	234	241	240

FIGURE 1.17 *A grayscale image.*

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FIGURE 1.18

- **True color or red-green-blue**

190	189	186	187	186	188	188
188	187	185	186	186	188	189
185	186	184	184	185	187	190
186	186	186	186	186	186	186
186	186	185	186	186	185	185
186	185	186	186	185	187	186
186	186	186	184	185	187	186
185	185	187	186	186	187	186

Red

207	208	207	208	207	206	206
207	208	208	209	207	206	207
206	209	207	207	206	208	208
207	207	207	207	207	207	207
207	207	206	207	207	206	206
207	206	207	209	208	208	207
207	207	207	207	208	208	207
208	206	208	207	207	208	207

Green

217	223	226	227	226	226	226
222	225	226	227	226	226	227
223	227	225	225	225	227	228
226	228	228	228	228	226	226
226	228	227	228	228	225	225
226	227	228	227	226	227	226
226	226	228	225	226	227	226
226	225	227	226	226	227	226

Blue

FIGURE 1.18 *A true color image.*

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FIGURE 1.19

- **Indexed**

4	5	5	5	5	5
5	4	5	5	6	6
5	5	5	0	8	9
5	5	5	5	11	11
5	5	5	8	16	20
8	11	11	26	33	20
11	20	33	33	58	37

Indices

0.1211	0.1211	0.1416
0.1807	0.2549	0.1729
0.2197	0.3447	0.1807
0.1611	0.1768	0.1924
0.2432	0.2471	0.1924
0.2119	0.1963	0.2002
0.2627	0.2588	0.2549
0.2197	0.2432	0.2588
⋮	⋮	⋮

Color map

FIGURE 1.19 *An indexed color image.*

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1.9 Image File Sizes

- A 512 × 512 binary image

$$\begin{aligned} 512 \times 512 \times 1 &= 262{,}144 \text{ bits} \quad \text{(Divided by 8)} \\ &= 32768 \text{ bytes} \\ &= 32.768 \text{ Kb} \\ &\approx 0.033 \text{ Mb} \end{aligned}$$

- A grayscale image

$$\begin{aligned} 512 \times 512 \times 1 &= 262{,}144 \text{ bytes} \\ &= 262.14 \text{ Kb} \\ &\approx 0.262 \text{ Mb.} \end{aligned}$$

1.9 Image File Sizes

- A Color image

$$\begin{aligned} 512 \times 512 \times 3 &= 786{,}432 \text{ bytes} \\ &= 786.43 \text{ Kb} \\ &\approx 0.786 \text{ Mb.} \end{aligned}$$

1.10 Image Perception

- We should be aware of the limitations of the human visual system
  - ✓ **Observed intensities** vary as to the background
  - ✓ We may observe nonexistent intensities as bars in continuously varying gray levels
  - ✓ Our visual system tends to undershoot or overshoot around the boundary of regions of different intensities

FIGURE 1.20

FIGURE 1.20 *A gray square on different backgrounds.*

FIGURE 1.21

FIGURE 1.21 *Continuously varying intensities.*