

Digital Image Processing

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Syllabus

- Introduction To Image Processing
- Digitization, Type Of Digital Image, Digital Image File Format.
- Spatial Domain, Frequency Domain, Region Of Interest Image Geometry.
- Zoom Algorithm
- Spatial Filters.
- Segmentation(edge-line Detection Technique.)
- Histogram.
- Frequency Transformation.

References

- Image Processing ,Principles and Applications ,Ajoy K. Ray
- Digital Image Processing Using Matlab,Rafael C. Gonzalez & Richard E. Woods, 3ndEdition (2009).
- Computer Vision and Image Processing: A Practical Approach Using CVIPTools –December 1, 1998 .
- <https://www.wpi.edu/>
- Internet lectures

Lecture 1

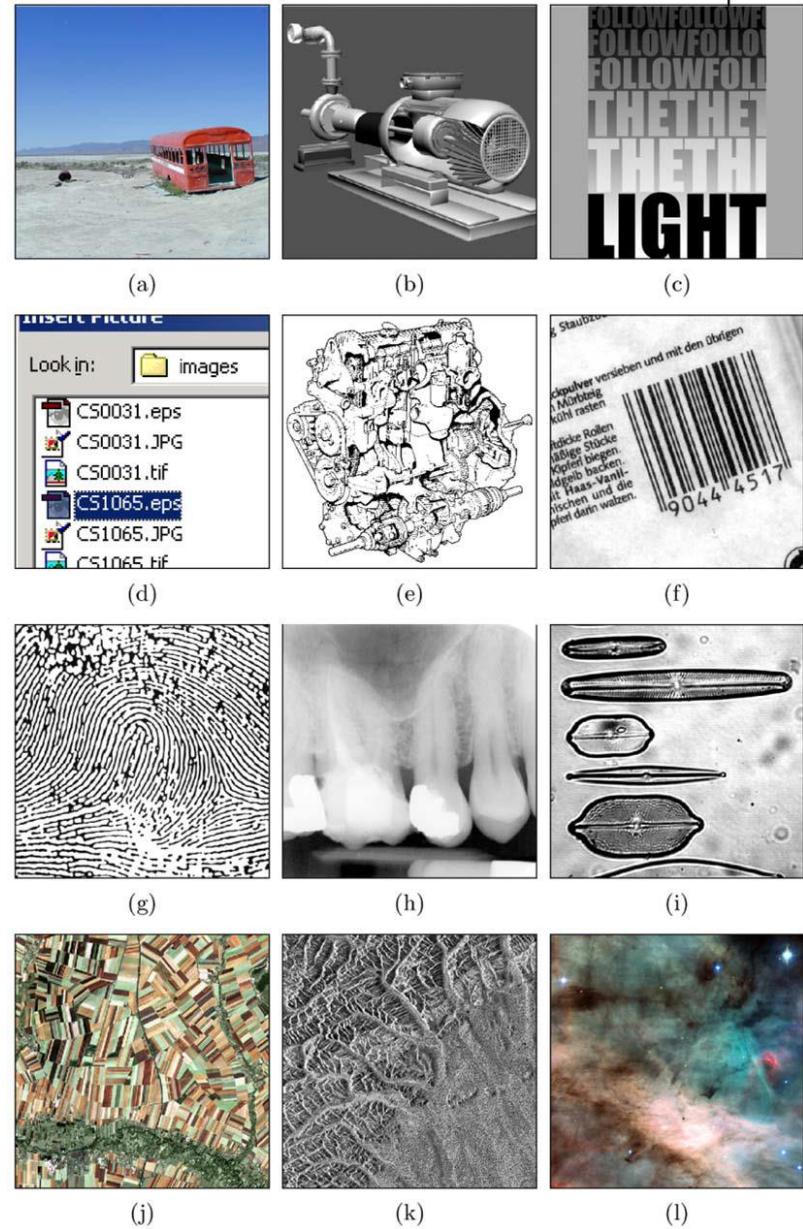
Introduction & Fundamentals

What is an Image?

- ✓ An image is a visual representation of something.
- ✓ An image is a picture that has been created or copied and stored in electronic form.
- ✓ An image can be described in terms of vector graphics or raster graphics.
- ✓ An image stored in raster form is sometimes called a bitmap.
An image map is a file containing information that associates different locations on a specified image with hypertext links.

Example of Digital Images

- a) Natural landscape
- b) Synthetically generated scene
- c) Poster graphic
- d) Computer screenshot
- e) Black and white illustration
- f) Barcode
- g) Fingerprint
- h) X-ray
- i) Microscope slide
- j) Satellite Image
- k) Radar image
- l) Astronomical object



Origins of Digital Image Processing



FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

Sent by submarine cable between London and New York, the transportation time was reduced to less than three hours from more than a week

Origins of Digital Image Processing



FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger* 7 took this image on July 31, 1964 at 9 :09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

Applications of Digital Image Processing

Some of the major fields in which digital image processing is widely used are mentioned below

- Image sharpening and restoration
- Medical field
- Remote sensing
- Transmission and encoding
- Machine/Robot vision
- Color processing
- Pattern recognition
- Video processing
- Microscopic Imaging
- Others

Sources for Images

- Electromagnetic (EM) energy spectrum
- Acoustic
- Ultrasonic
- Electronic
- Synthetic images produced by computer

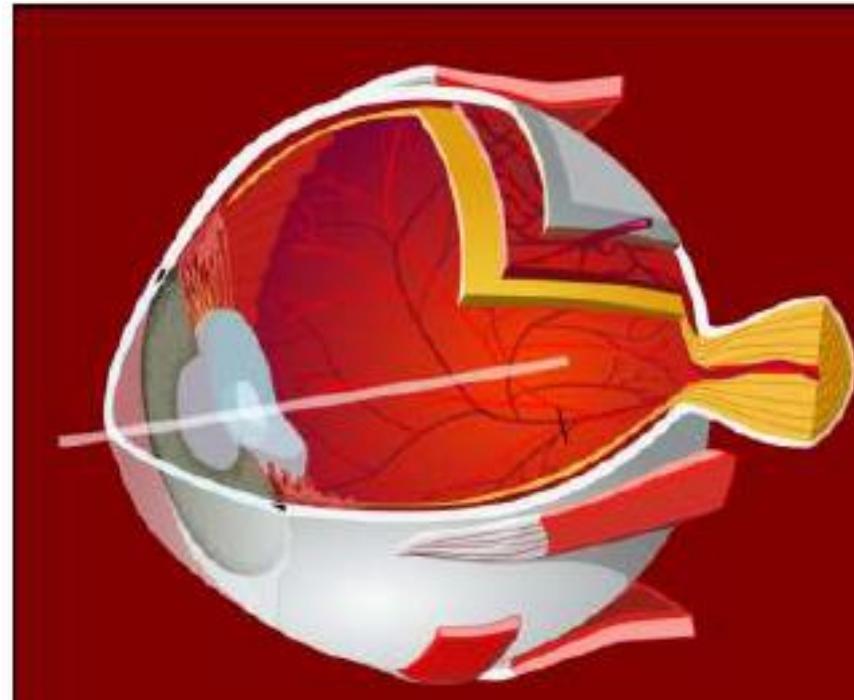
Optics and Human Vision

The physics of light

- ▶ Light
 - Particles known as photons
 - Act as 'waves'
- ▶ Two fundamental properties
 - ▶ Wavelength
 - ▶ Amplitude
- Frequency is the inverse of wavelength
- Relationship between wavelength (λ) and frequency (f)

$$\lambda = c / f$$

Where c = speed of light = 299,792,458 m / s



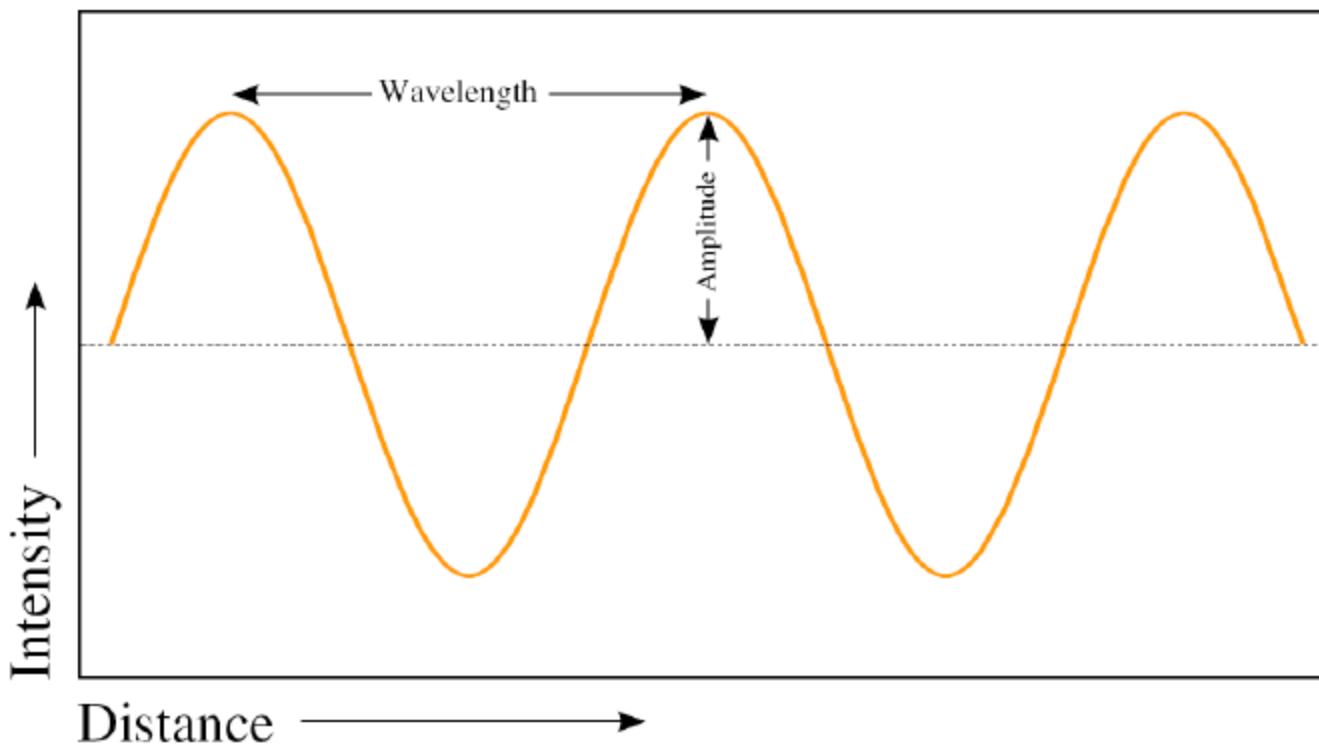
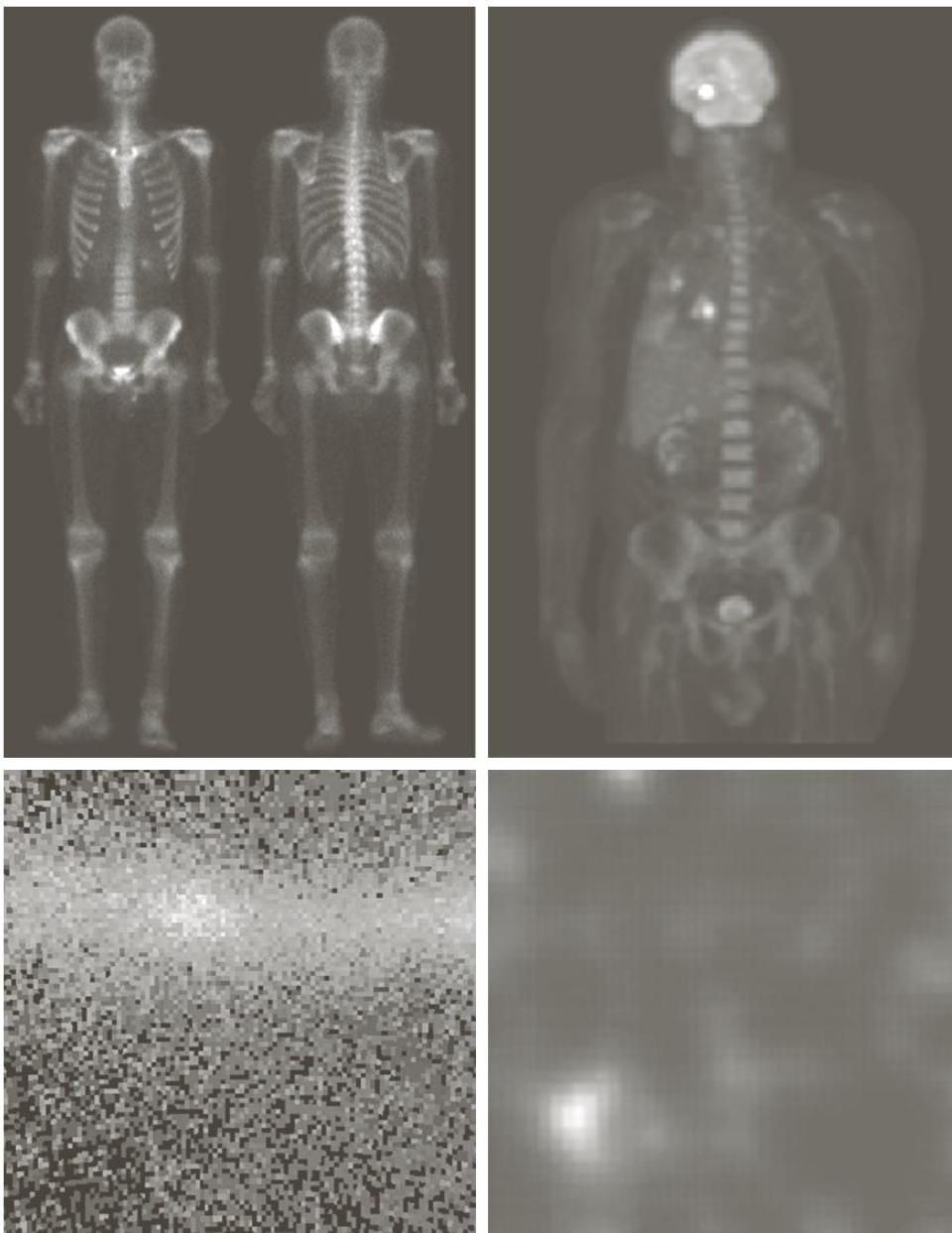


Diagram of a light wave.

Examples: Gama-Ray Imaging



a
b
c
d

FIGURE 1.6
Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve.
(Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

Examples: X-Ray Imaging

a
b
c
d
e
N
SCIE

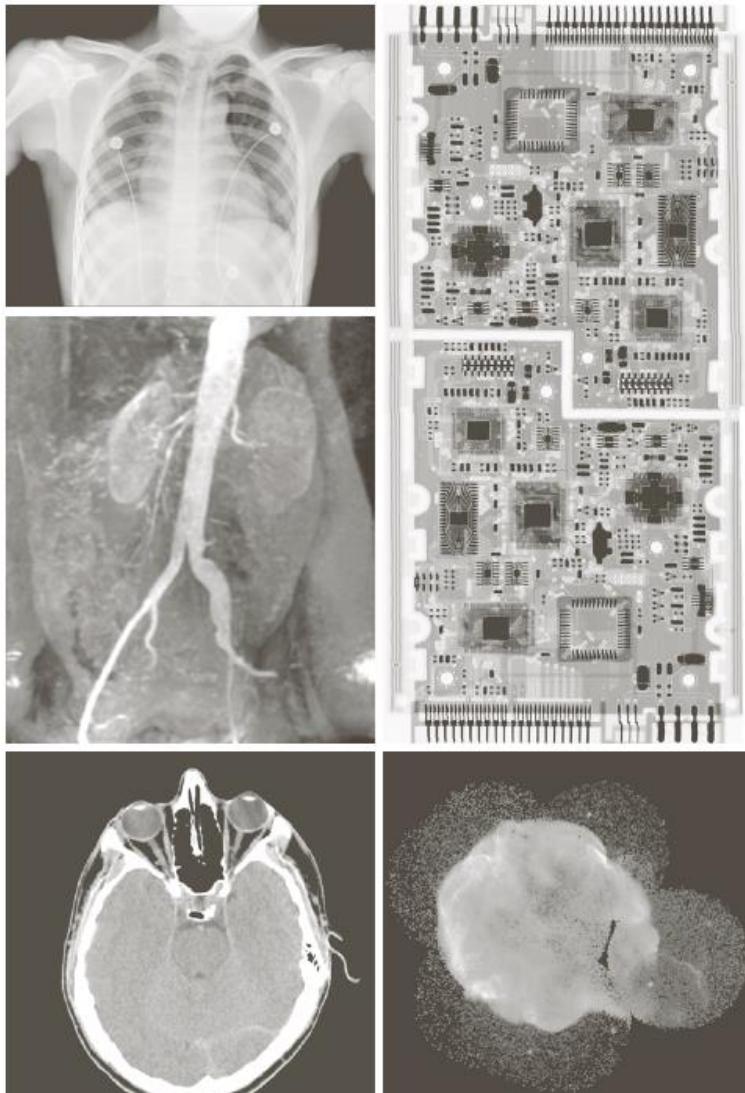
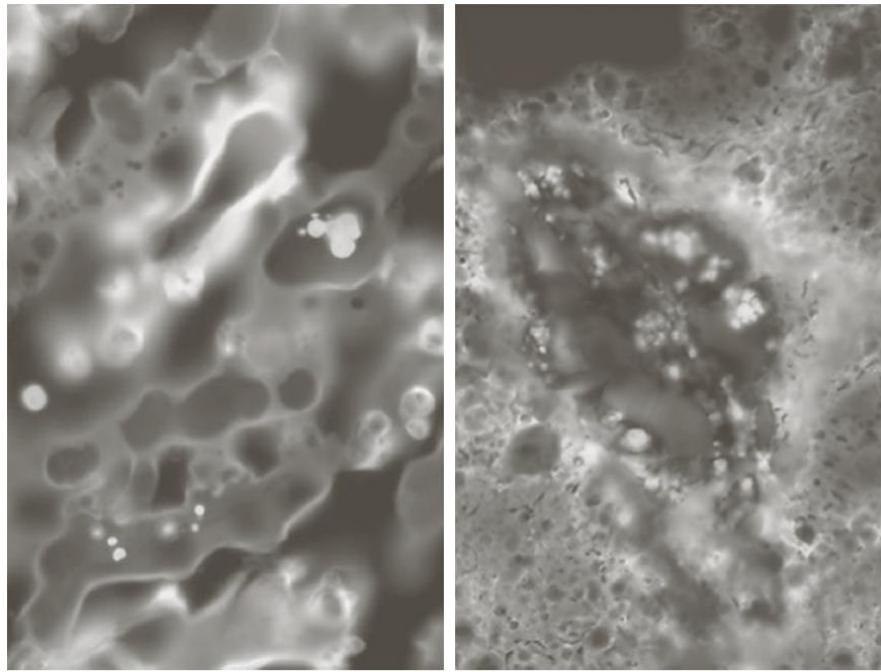


FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)



a | b
c

FIGURE 1.8
Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)

Examples: Ultraviolet Imaging

Examples: Light Microscopy Imaging

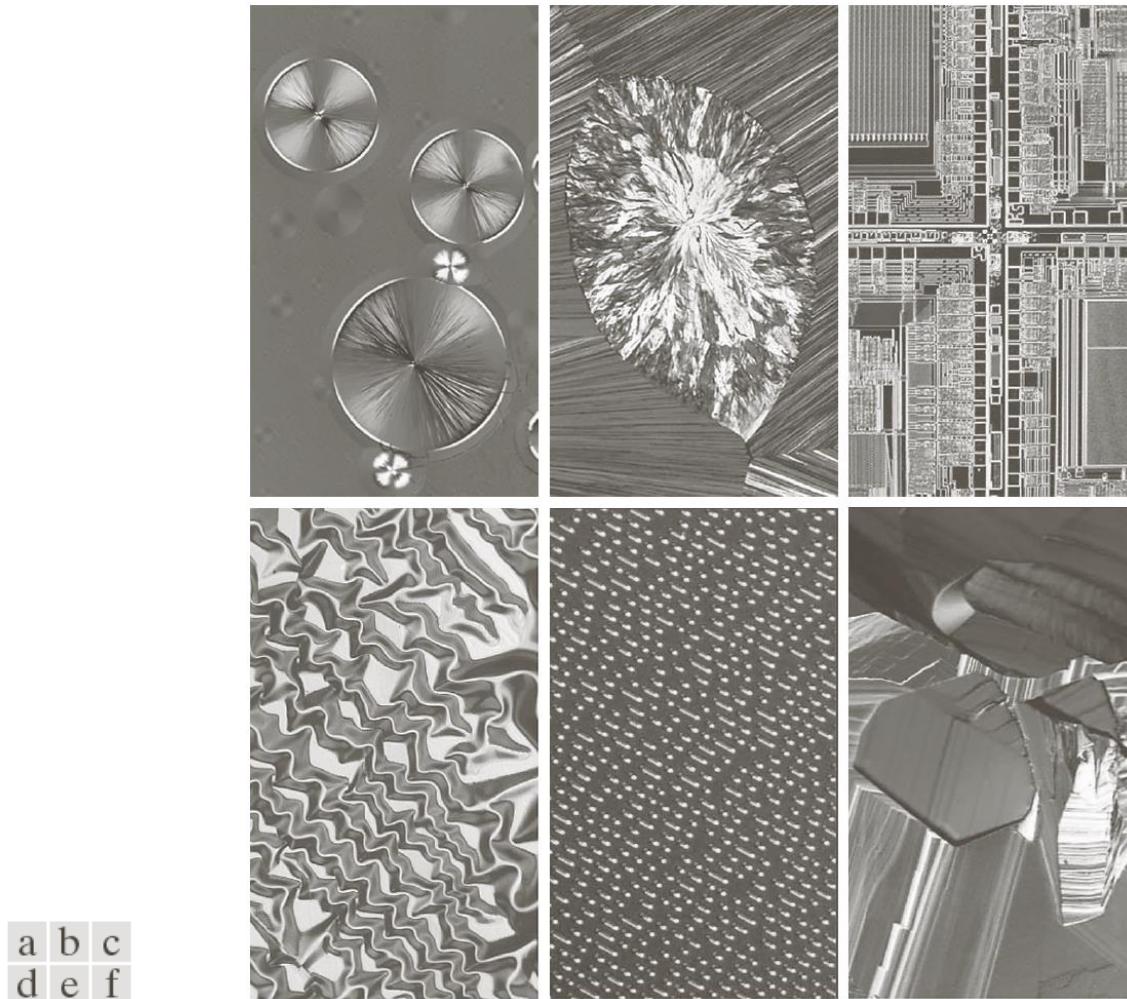


FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

Examples: Visual and Infrared Imaging

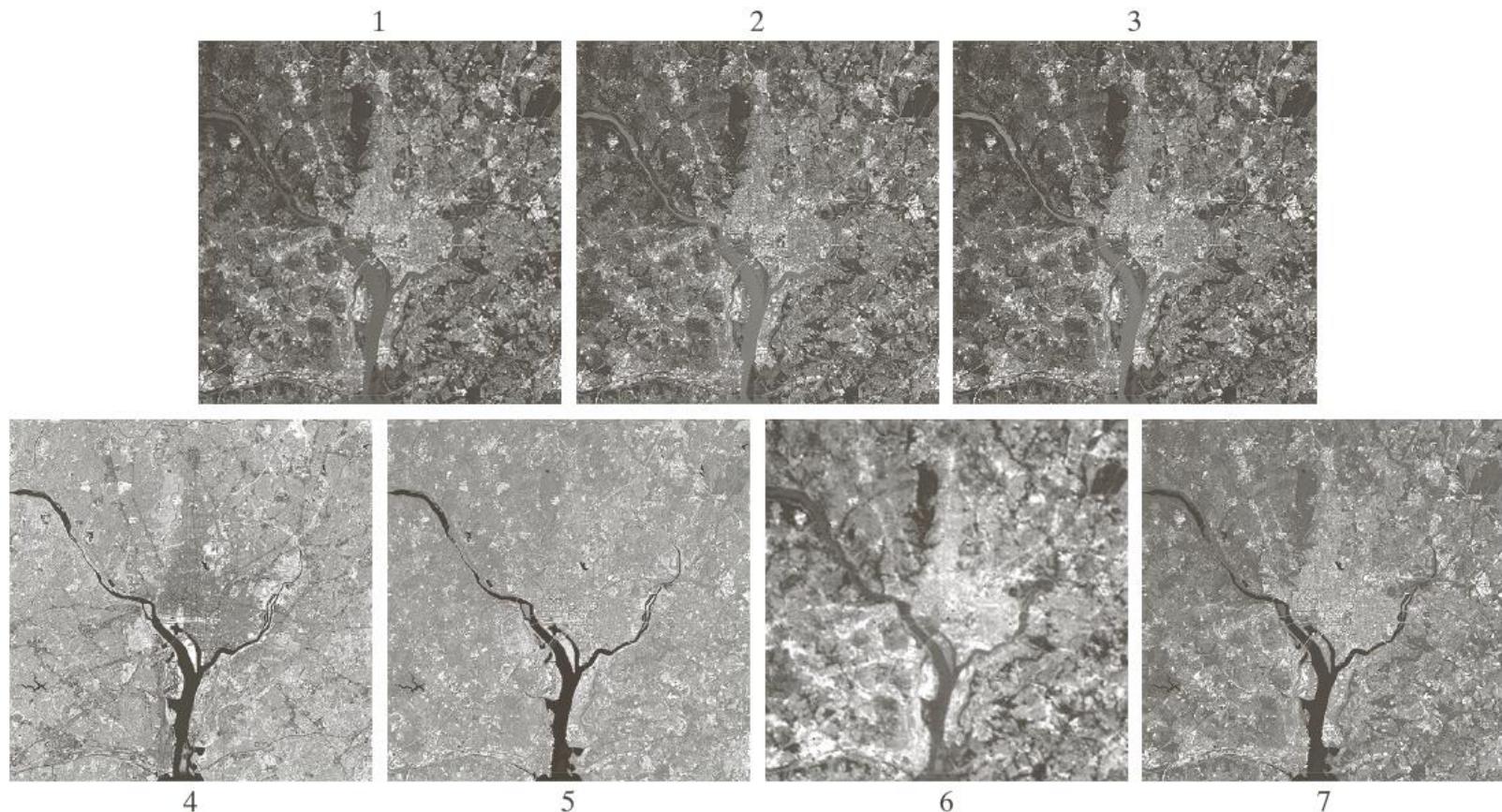
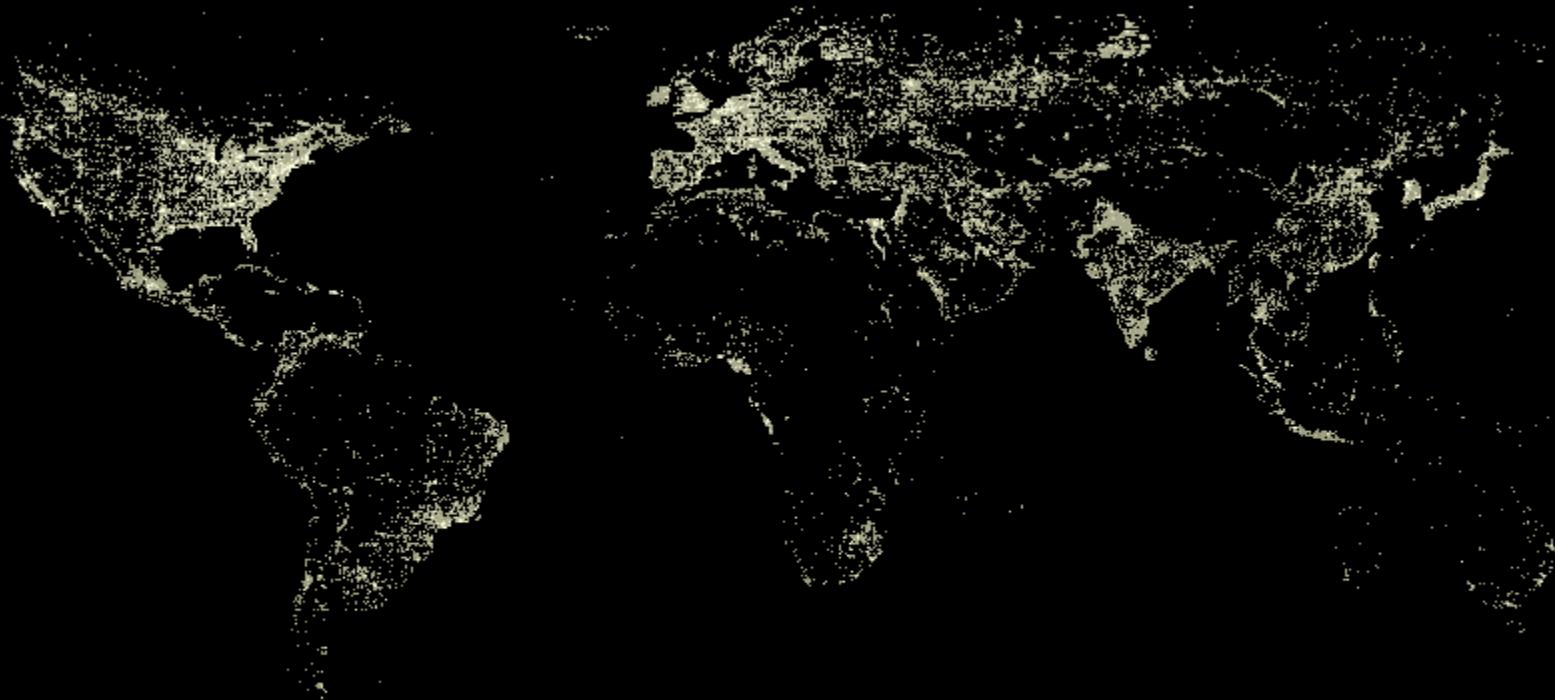


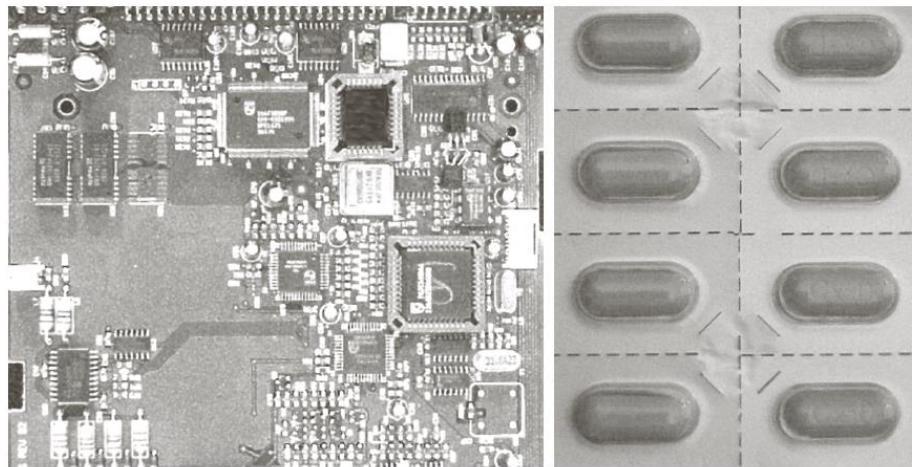
FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)



Examples: Infrared Satellite Imaging



Examples: Automated Visual Inspection



a
b
c
d
e
f

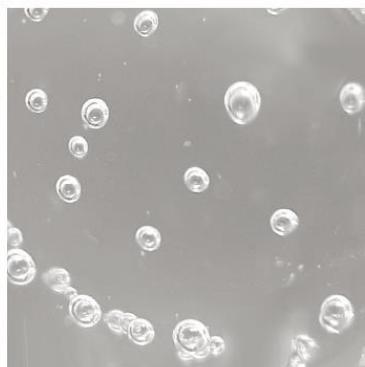
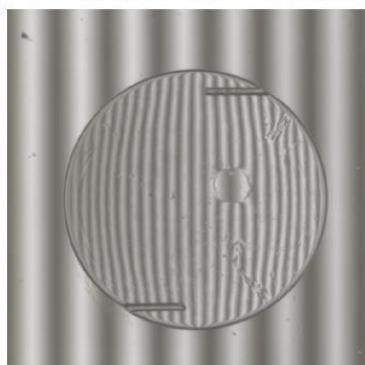
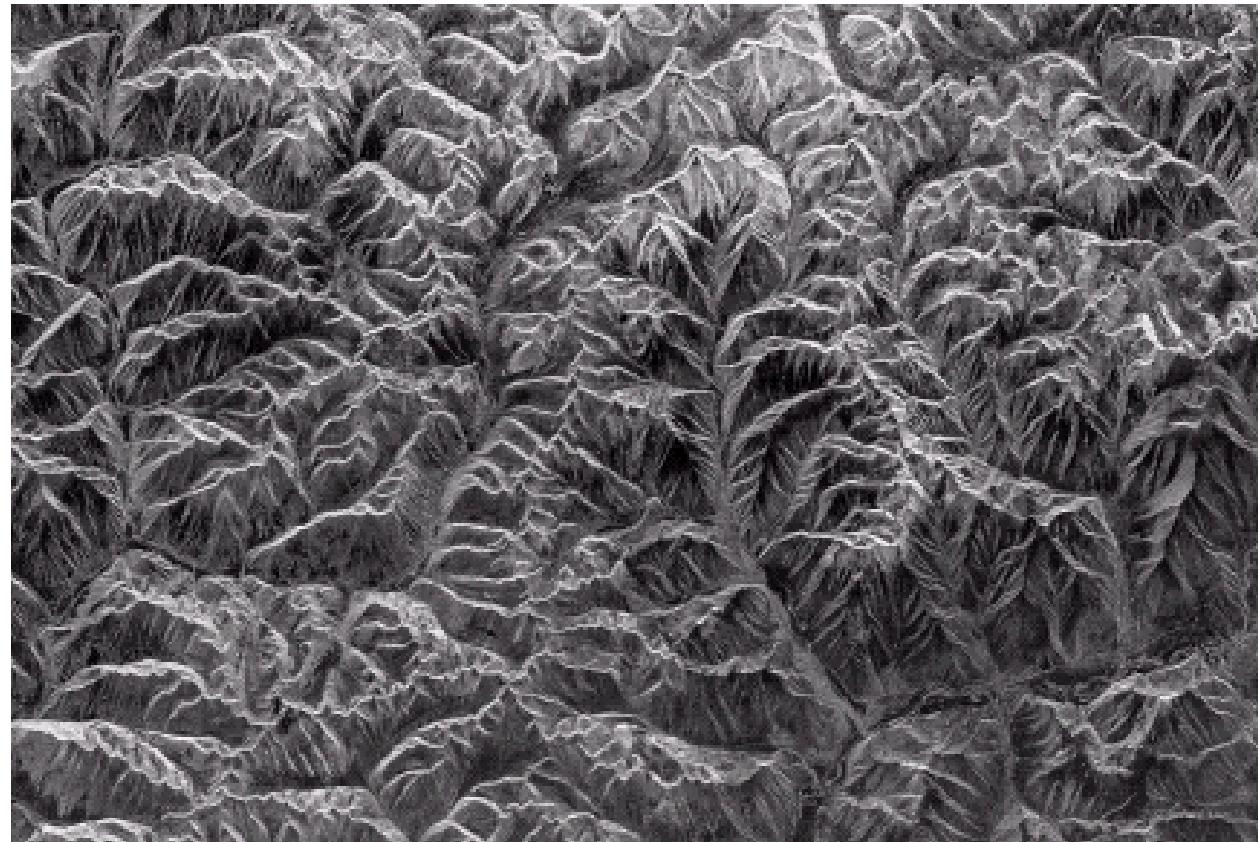


FIGURE 1.14
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

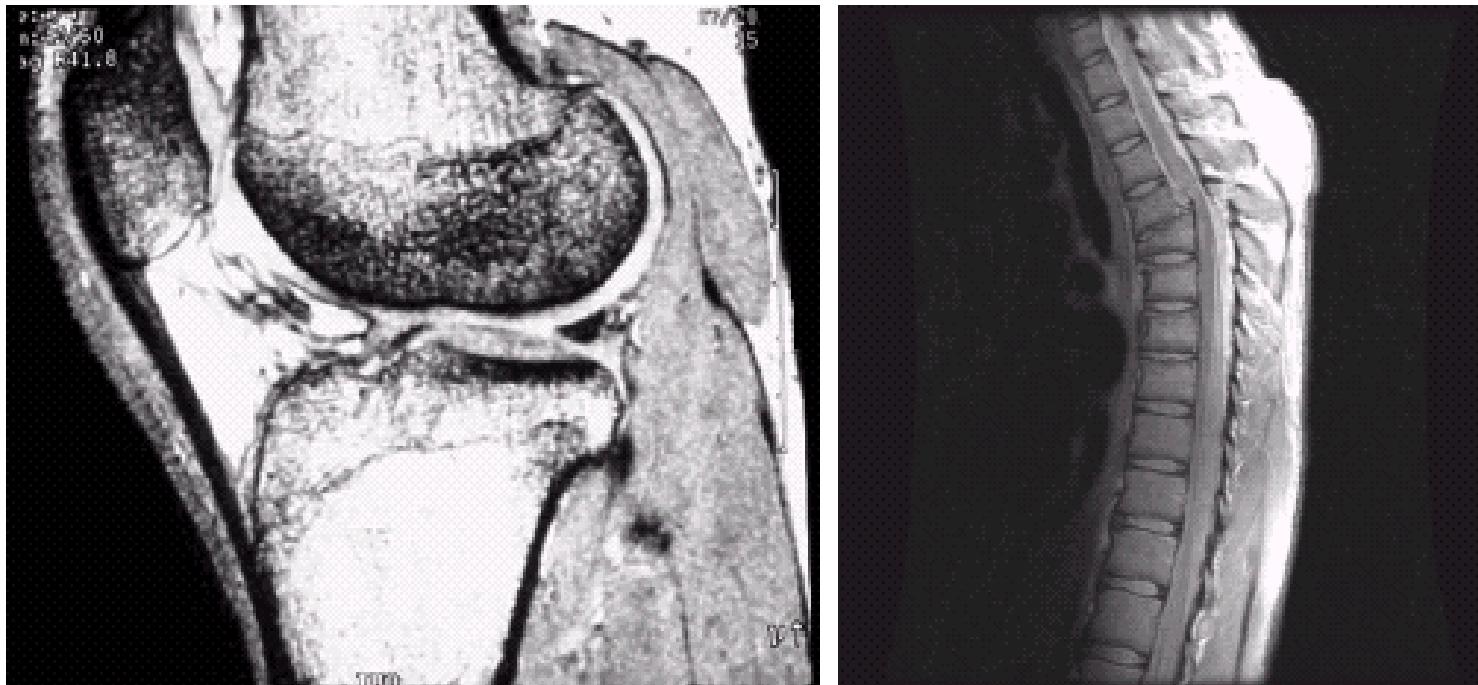


Example of Radar Image

FIGURE 1.16
Spaceborne radar
image of
mountains in
southeast Tibet.
(Courtesy of
NASA.)



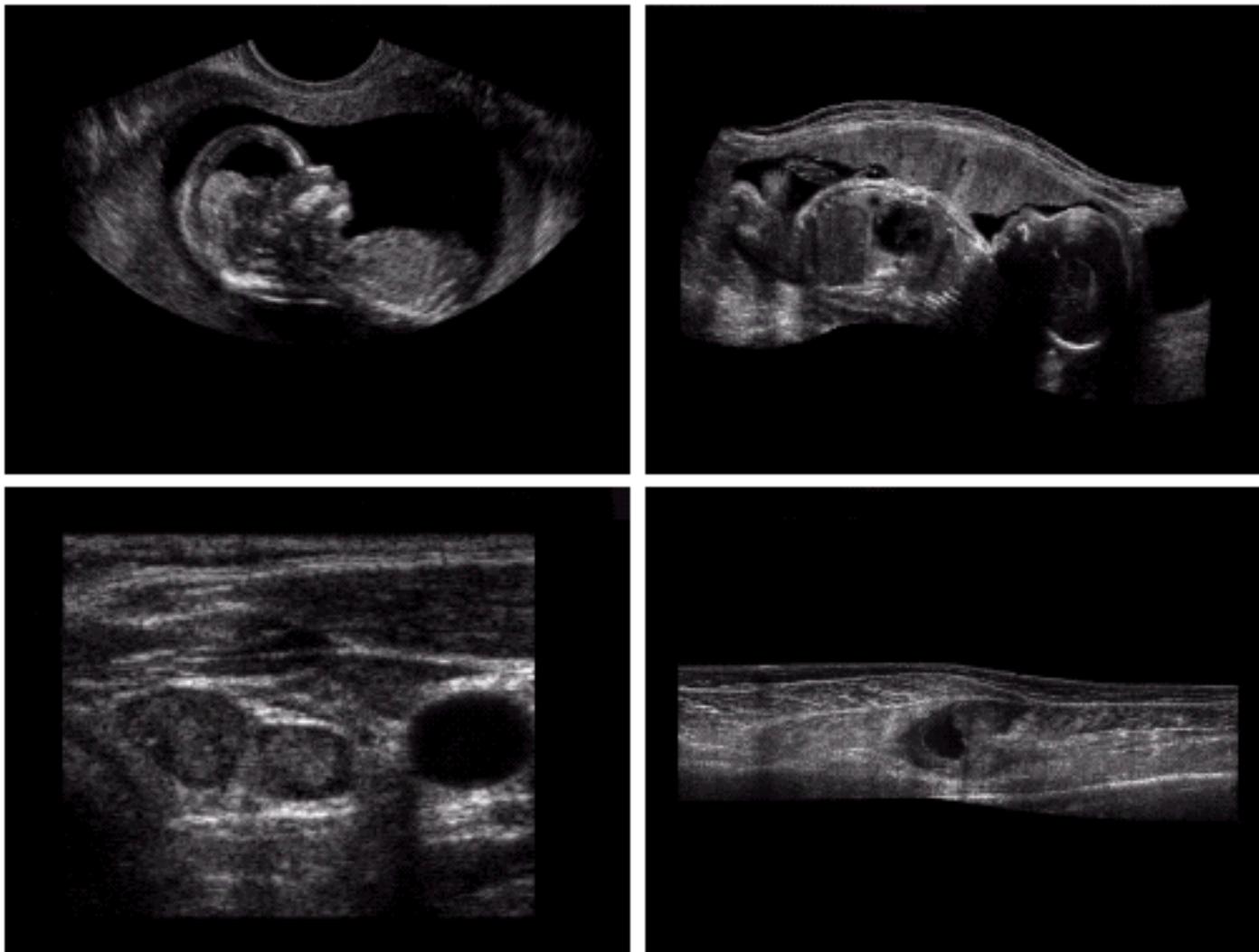
Examples: MRI (Radio Band)



a b

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

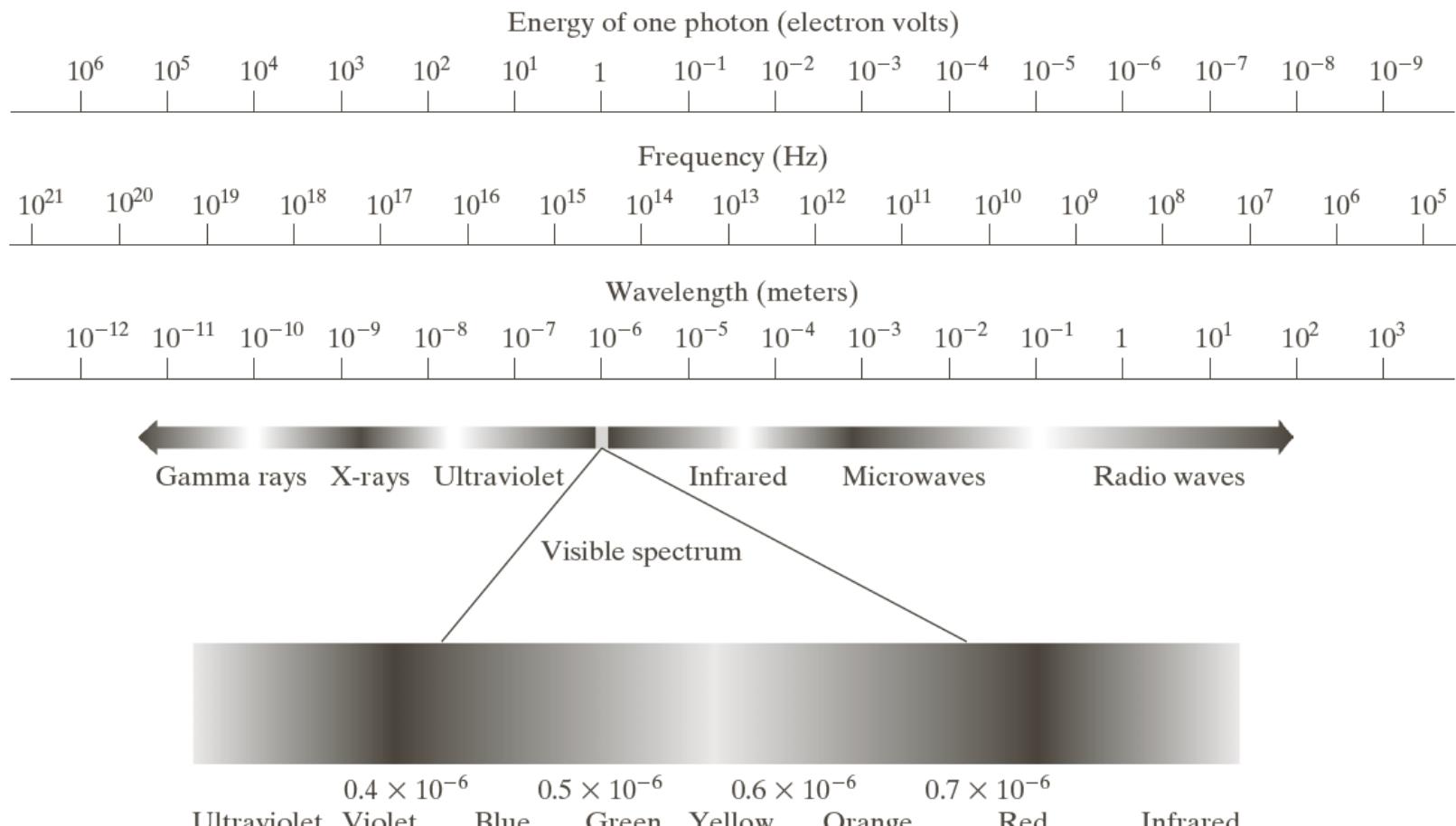
Examples: Ultrasound Imaging



a b
c d

FIGURE 1.20
Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Light and EM Spectrum



$$c = \lambda \nu$$

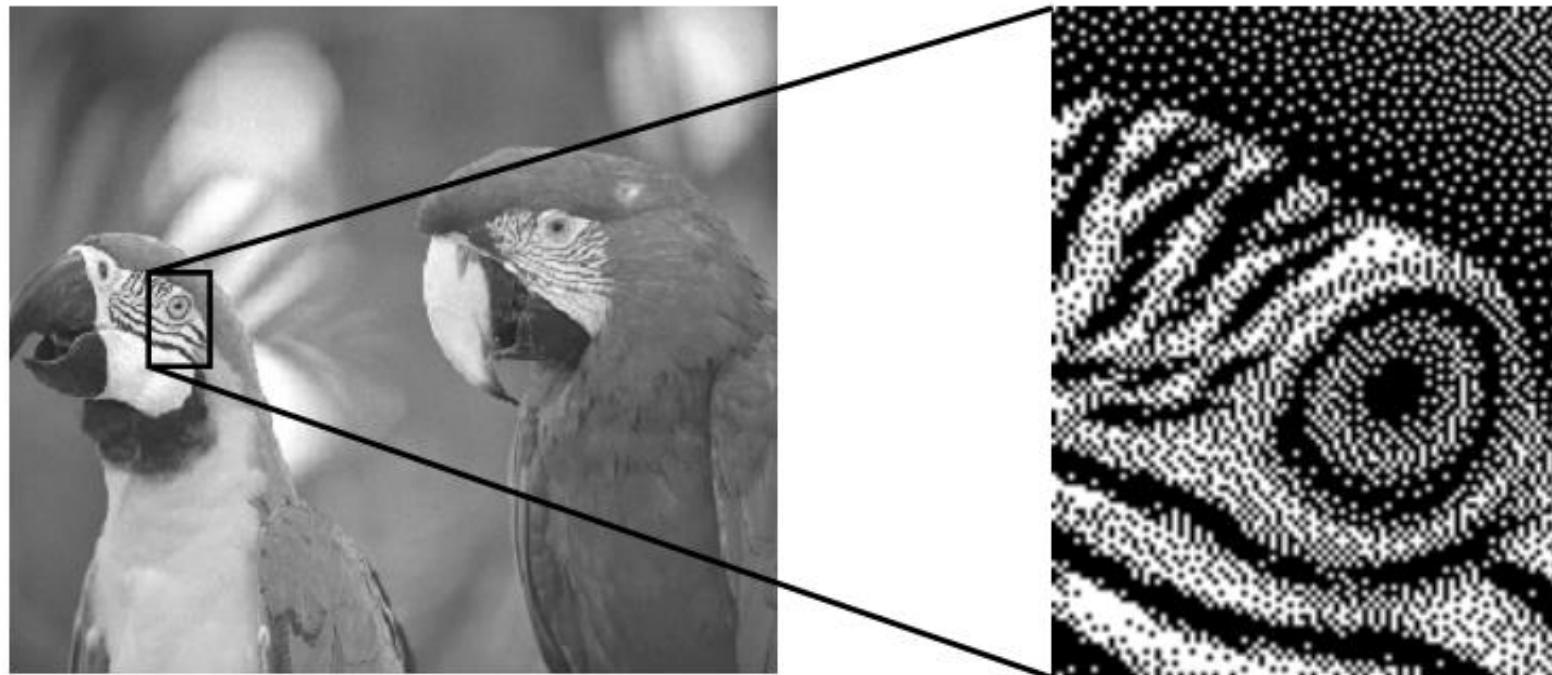
$$E = h\nu, \quad h: \text{Planck's constant.}$$

Digital image

Take any image. Look closer. Closer! What do you see? Dots!

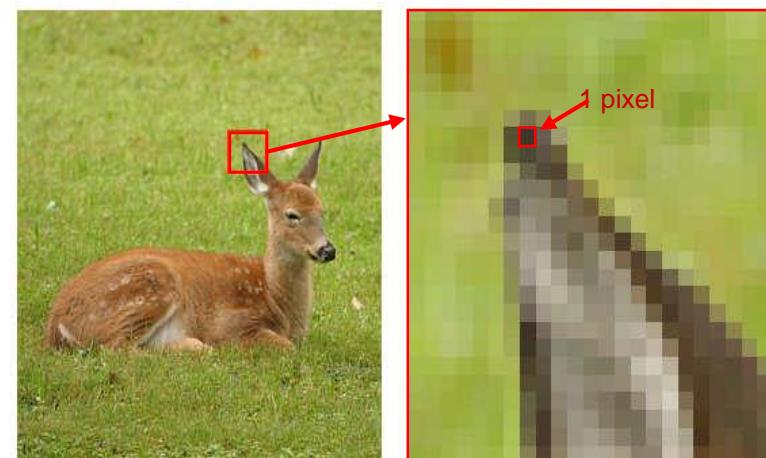
From far enough away, the dots are Indistinguishable to the average human eye.

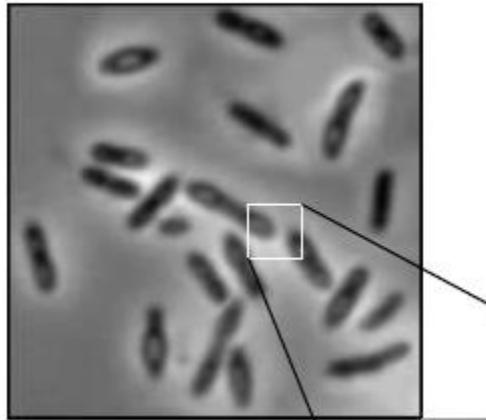
Called pixels, each are an individual color Pixels are the smallest sample of an image. Generally, more pixels translate to increased detail.



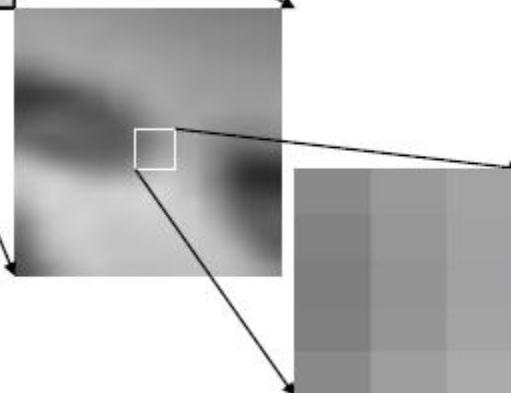
Digital image

- Digital images are made of picture elements called pixels.
- Typically, pixels are organized in an ordered rectangular array.
- The size of an image is determined by the dimensions of this pixel array.
- The image width is the number of columns, and the image height is the number of rows in the array.
- Thus the pixel array is a matrix of M columns x N rows.
- The coordinate system of image matrices defines x as increasing from left to right and y as increasing from top to bottom.





Intensity image or monochrome image
each pixel corresponds to light intensity
normally represented in gray scale (gray level).



Gray scale values

$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 6 & 26 & 37 \\ 15 & 25 & 13 & 22 \\ 32 & 15 & 87 & 39 \end{bmatrix}$$
A yellow arrow points from the 4x4 grid to a matrix of gray scale values enclosed in a gray border. The matrix contains four rows and four columns of numerical values representing the gray levels of the corresponding pixels in the 4x4 grid.



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

RGB components

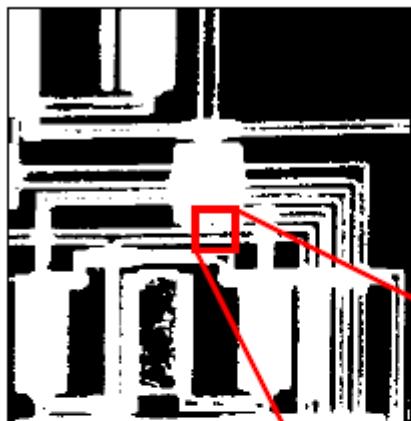
10	10	16	28
65	70	56	43
9	32	99	70
15	21	60	90
32	54	96	67
85	85	43	92
32	65	87	99

Binary image or black and white image

Each pixel contains one bit :

1 represent white

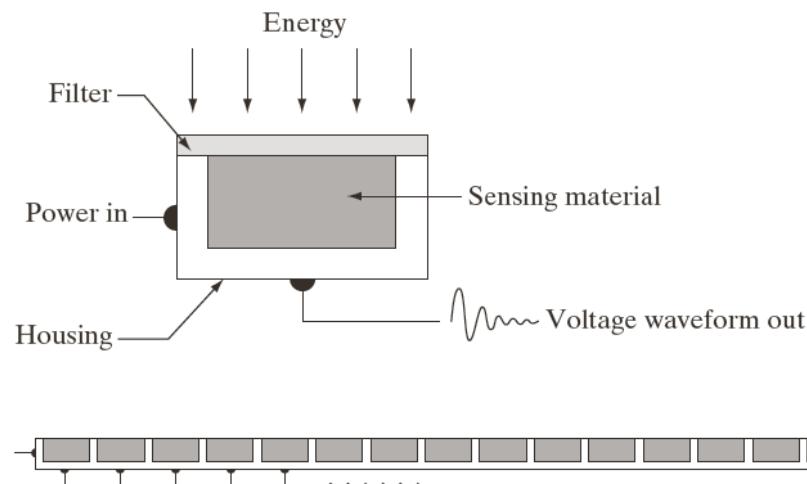
0 represents black



Binary data

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

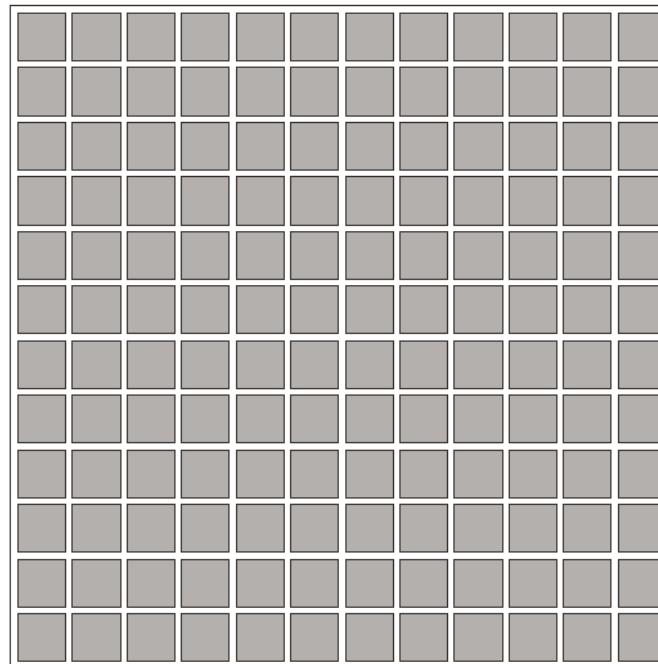
Image Acquisition



a
b
c

FIGURE 2.12
 (a) Single imaging sensor.
 (b) Line sensor.
 (c) Array sensor.

Transform
illumination
energy into
digital images



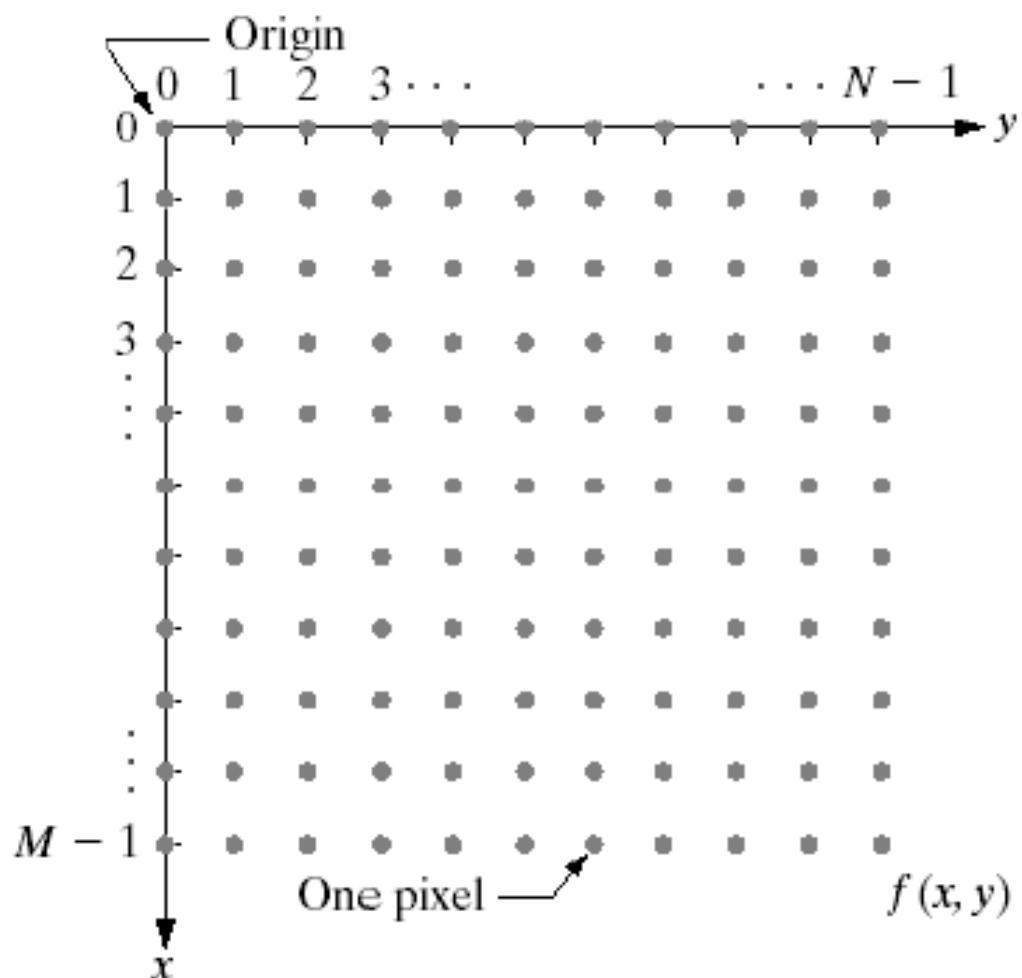


Image Acquisition Process

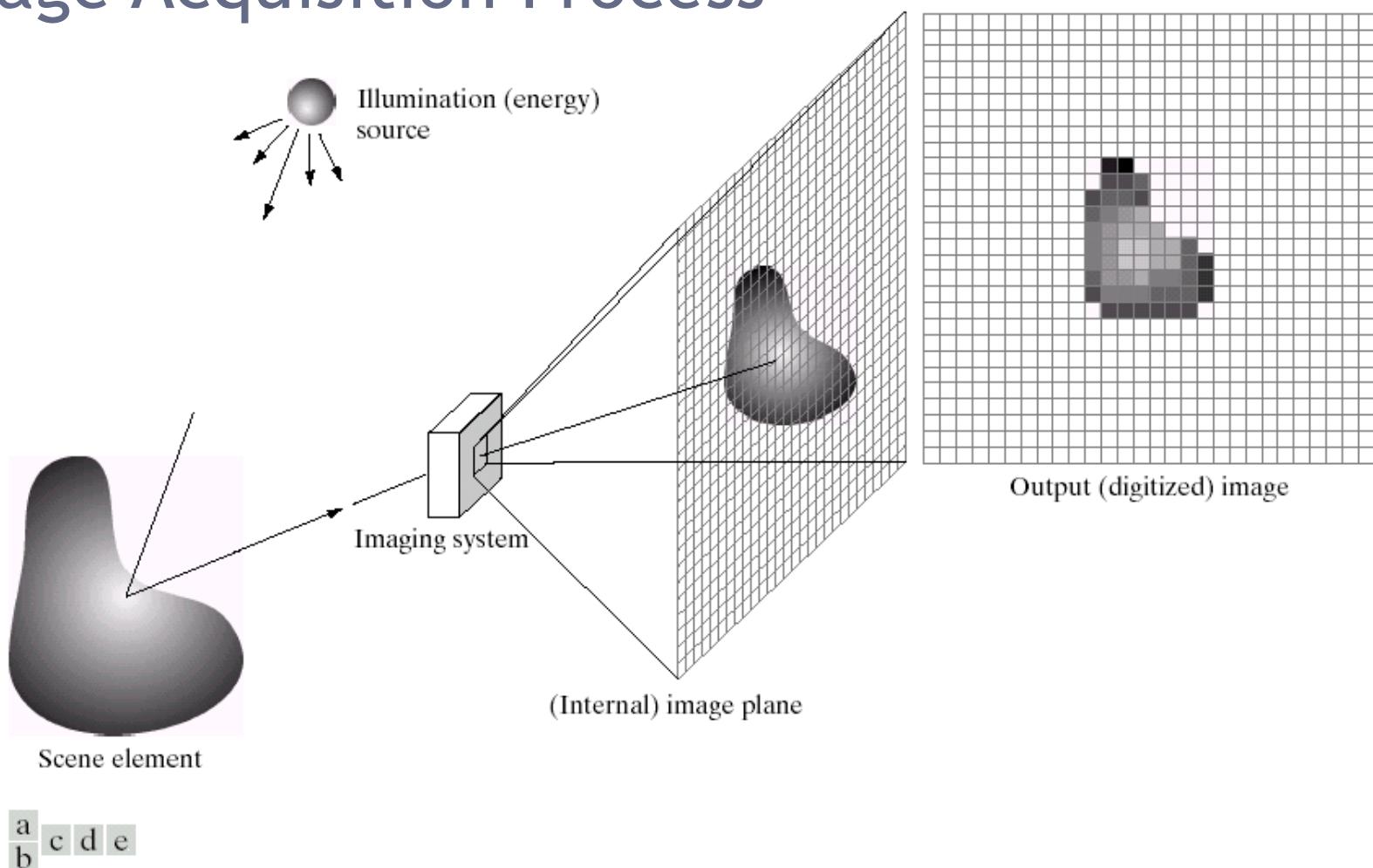
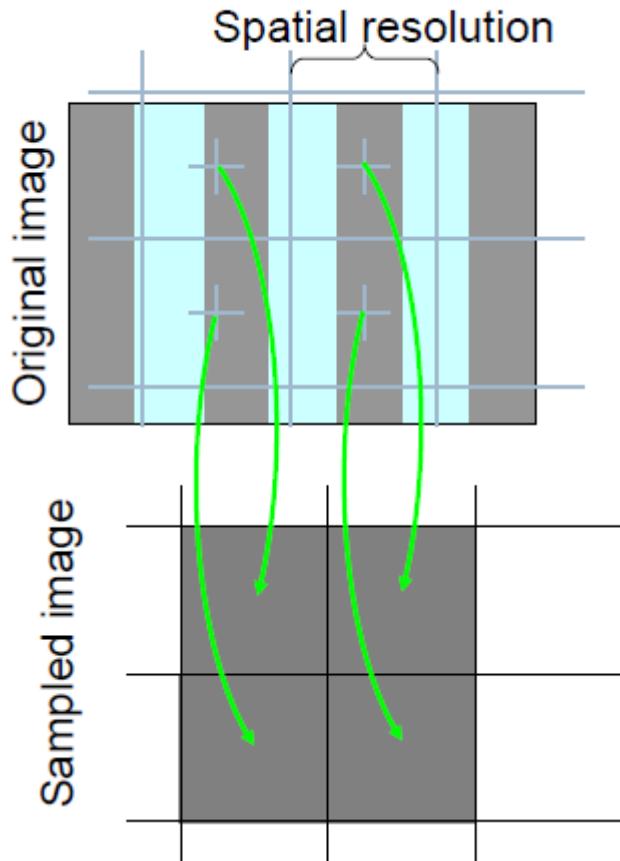
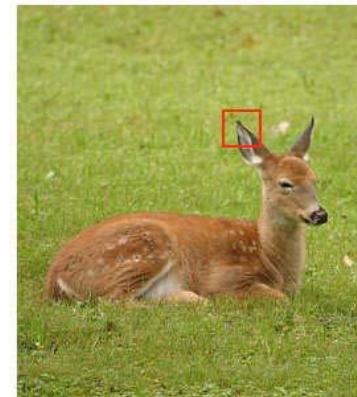
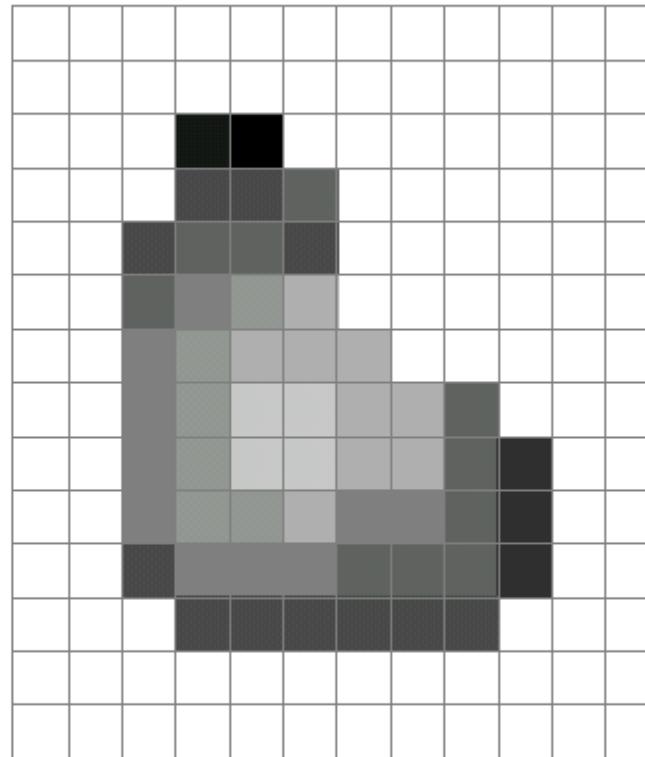
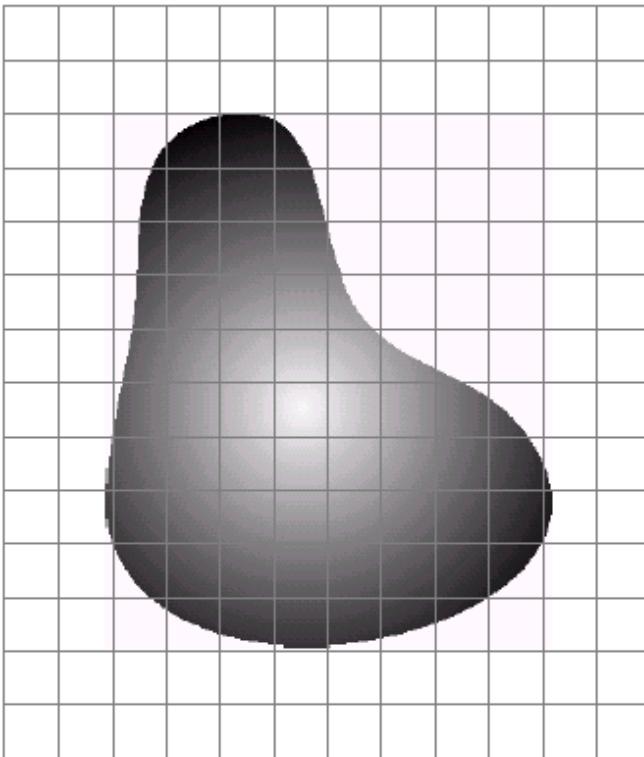


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy (“illumination”) source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

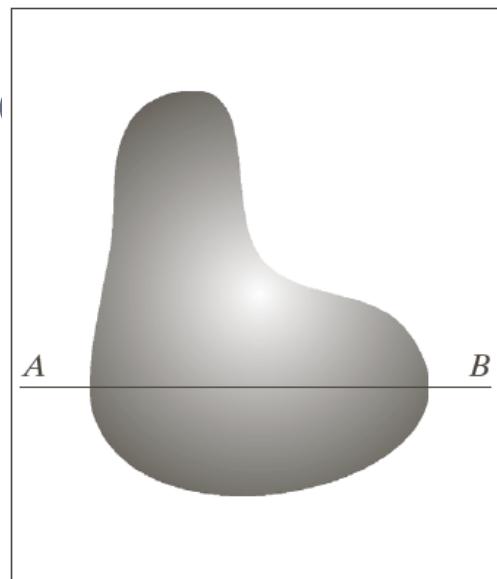


Digital Image?

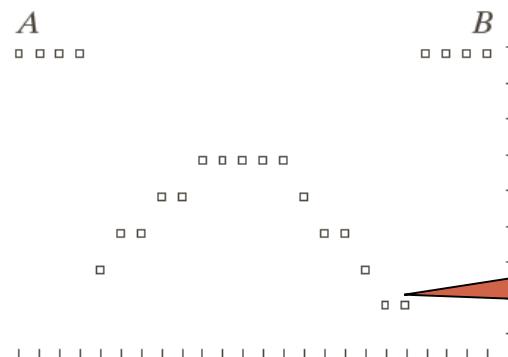
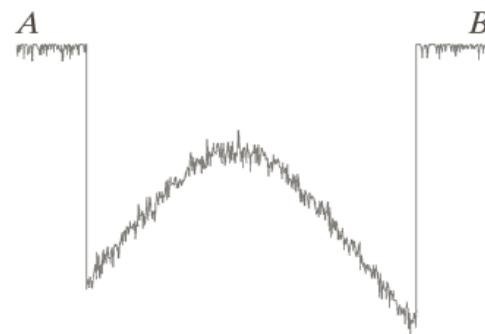
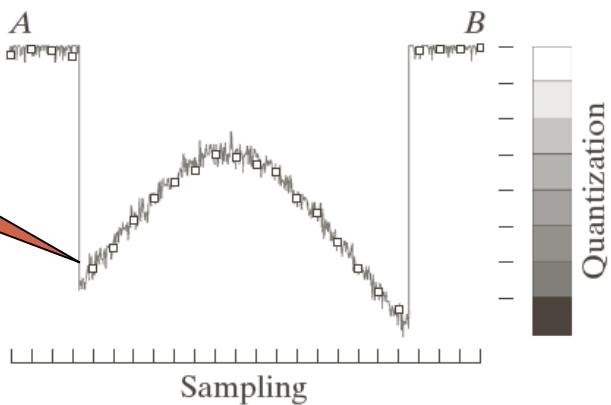
- *digitization* causes a digital image to become an *approximation* of a real scene



Image



Digitizing the coordinate values

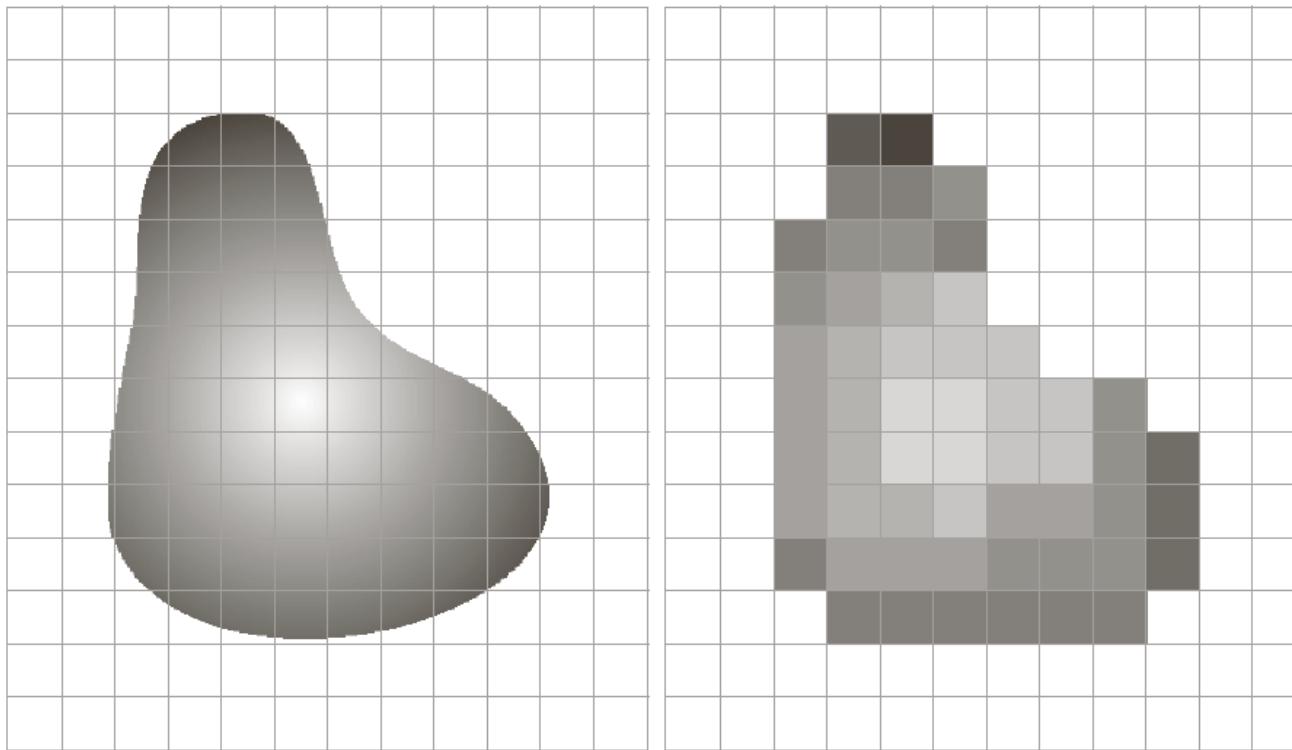


a	b
c	d

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.

Digitizing the amplitude values

Image Sampling and Quantization



a b

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

Representing Digital Images

- The representation of an $M \times N$ numerical array as

$$f(x, y) = \begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \dots & \dots & \dots & \dots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{bmatrix}$$

Representing Digital Images

- Discrete intensity interval $[0, L-1]$, $L=2^k$
- The number b of bits required to store a $M \times N$ digitized image

$$b = M \times N \times k$$

Digital Image

Common image formats include:

- 1 values per point/pixel (B&W or Grayscale)
- 3 values per point/pixel (Red, Green, and Blue)
- 4 values per point/pixel (Red, Green, Blue, + “Alpha” or Opacity)



Pixels and Depth

8 bpp [$2^8=256$; (256 colours)],

16 bpp [$2^{16}=65536$; (65,536 colours, known as **Highcolour**)],

24 bpp [$2^{24}=16777216$; (16,777,216 colours, known as **Truecolour**)].

48 bpp [$2^{48}=281474976710656$; (281,474,976,710,656 colors, used in many flatbed scanners and for professional work)



What is Digital Image Processing?

Digital image processing focuses on two major tasks

- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission and representation for autonomous machine .

What is image Processing?

- Algorithms that alter an input image to create new image
- Input is image, output is image
- Improves an image for human interpretation in ways including:
 - Image display and printing
 - Image editing
 - Image enhancement
 - Image compression

Example Operation: Noise Removal

Think of noise as white specks on a picture (random or non-random)

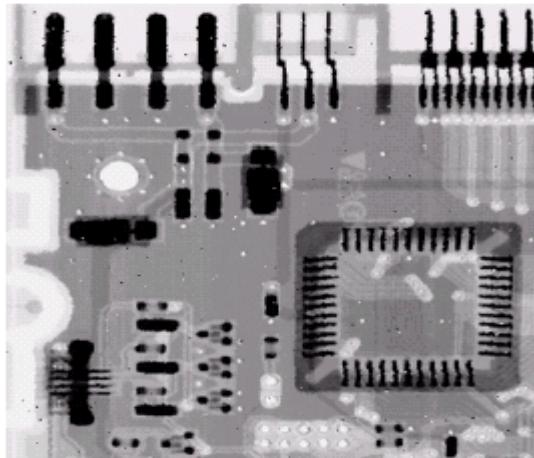
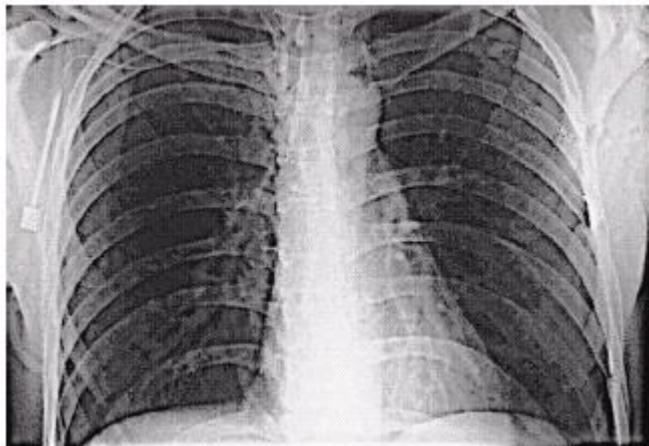
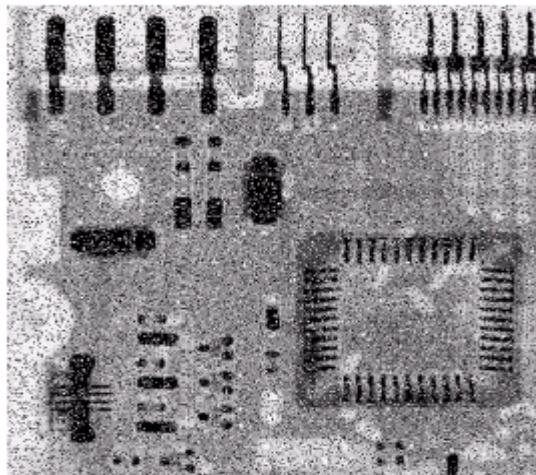
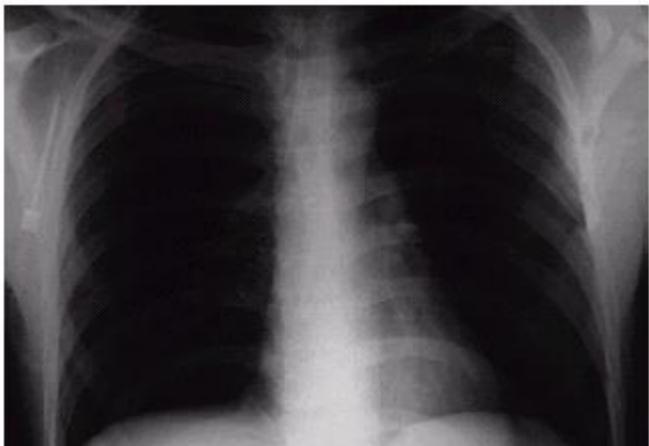
Noisy Image



Denoised Image



Examples: Noise Removal



Example: Contrast Adjustment



Low Contrast



Original Contrast



High Contrast

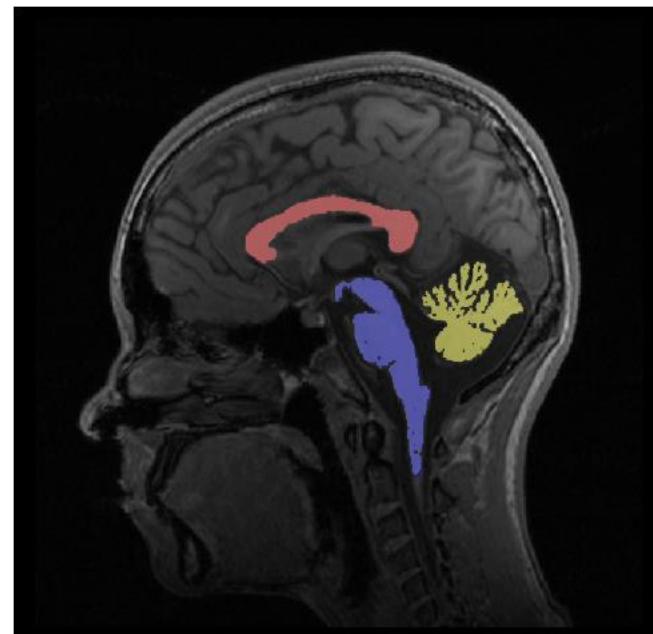
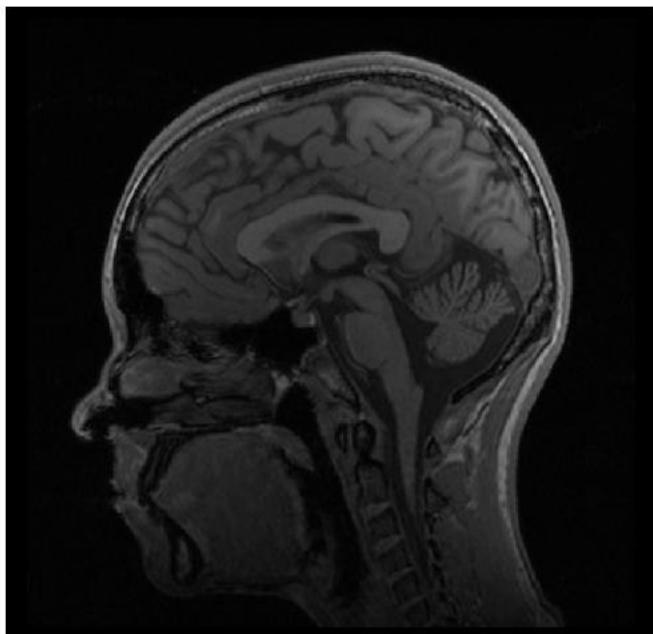
Example: Edge Detection



Example: Segmentation

Region

Detection,



Example: Image Inpainting

Inpainting? Reconstruct corrupted/destroyed parts of an image

Damaged Image

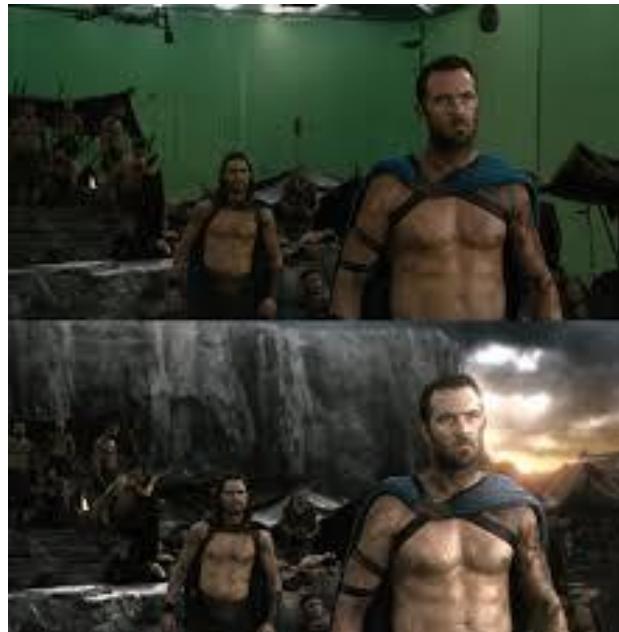


Restored Image



Credit: M. Bertalmio, G. Sapiro, V. Caselles, C. Ballester: *Image Inpainting*, SIGGRAPH 2000

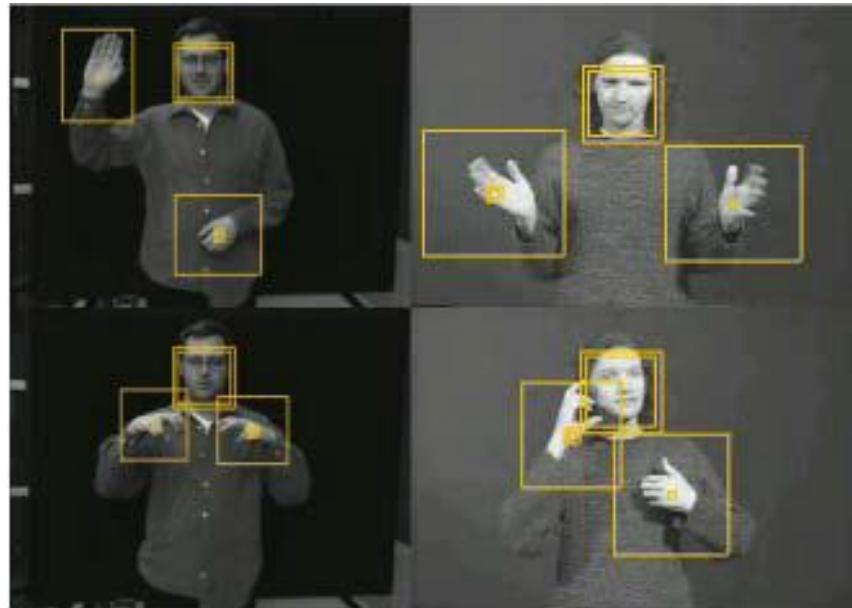
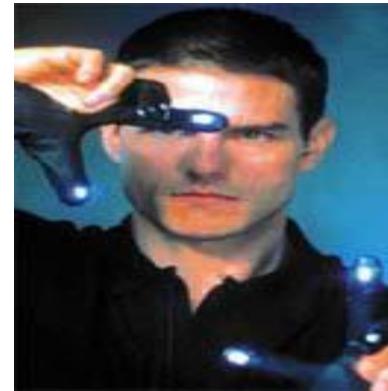
Examples: Artistic (Movie Special) Effects





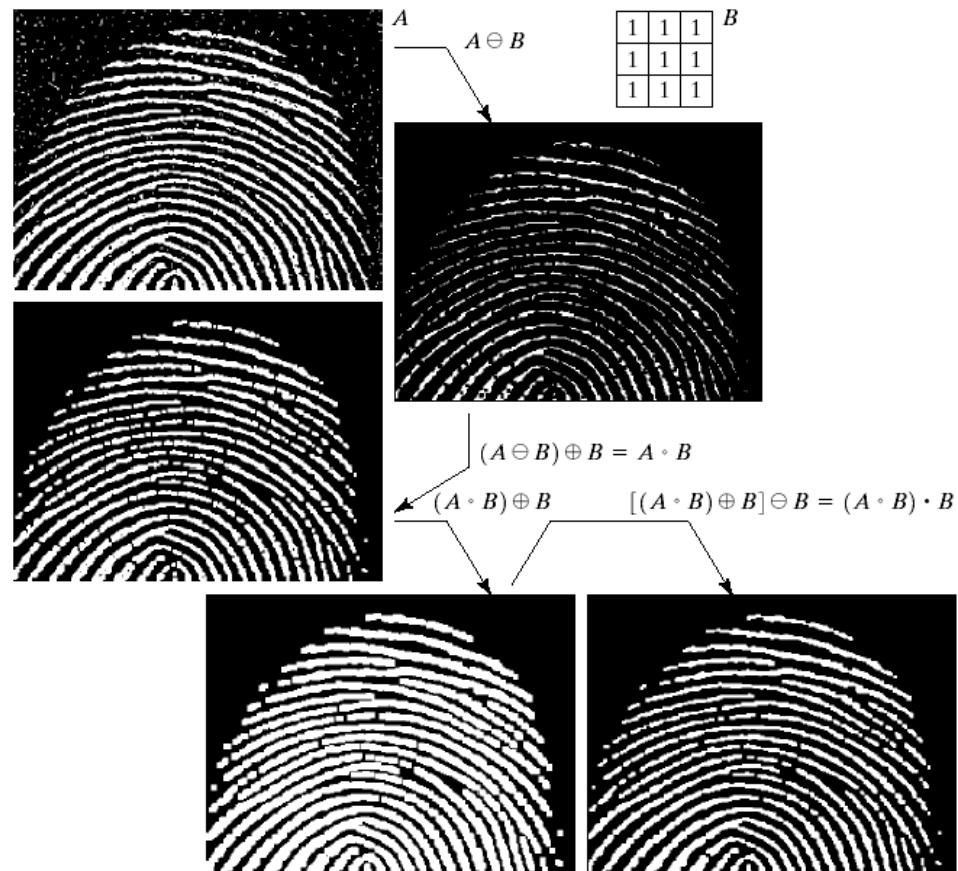
Applications of Image Processing:

- Face recognition
- Gesture recognition



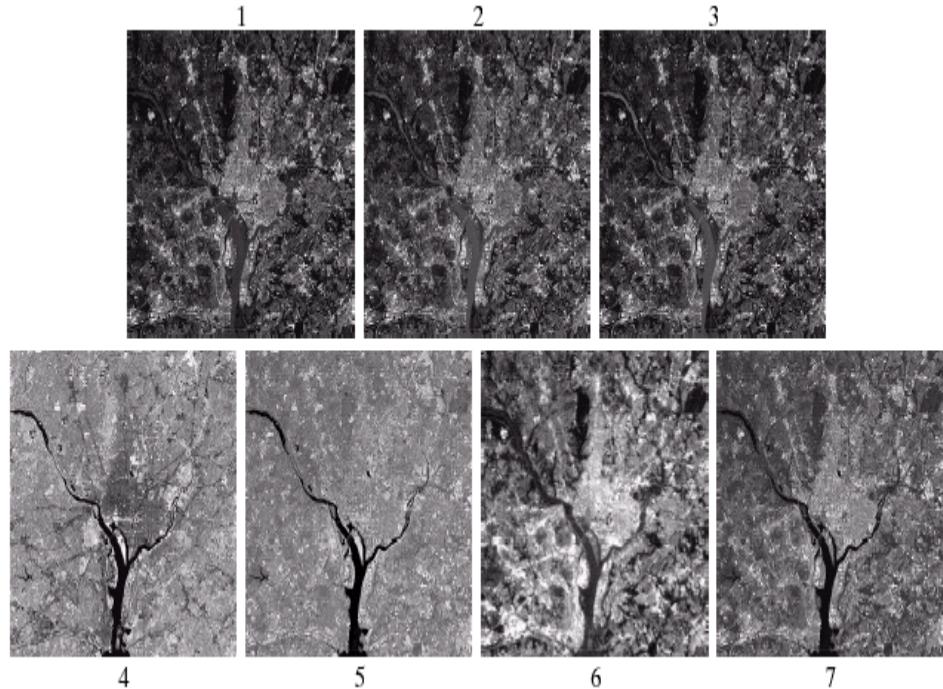
Applications of Image Processing: Law Enforcement

- Number plate recognition for speed cameras or automated toll systems
- Fingerprint recognition

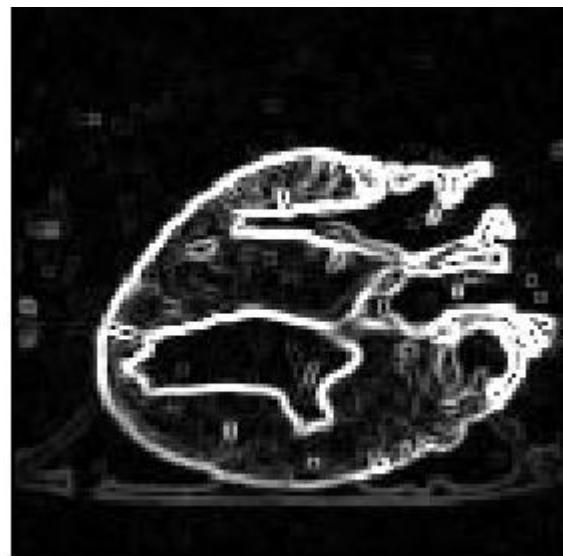
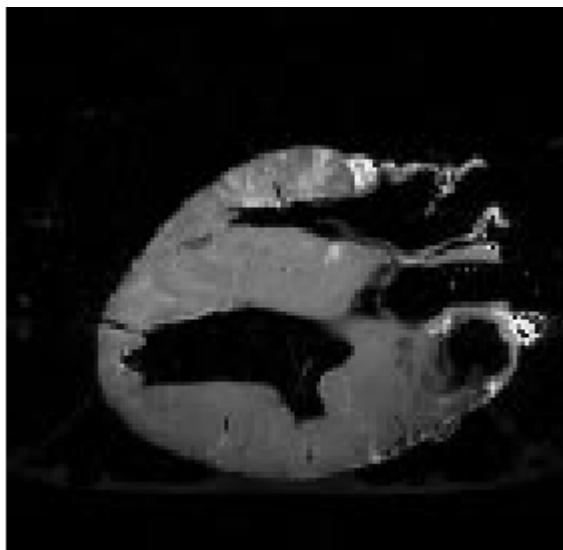


Applications of Image Processing: Geographic Information Systems (GIS)

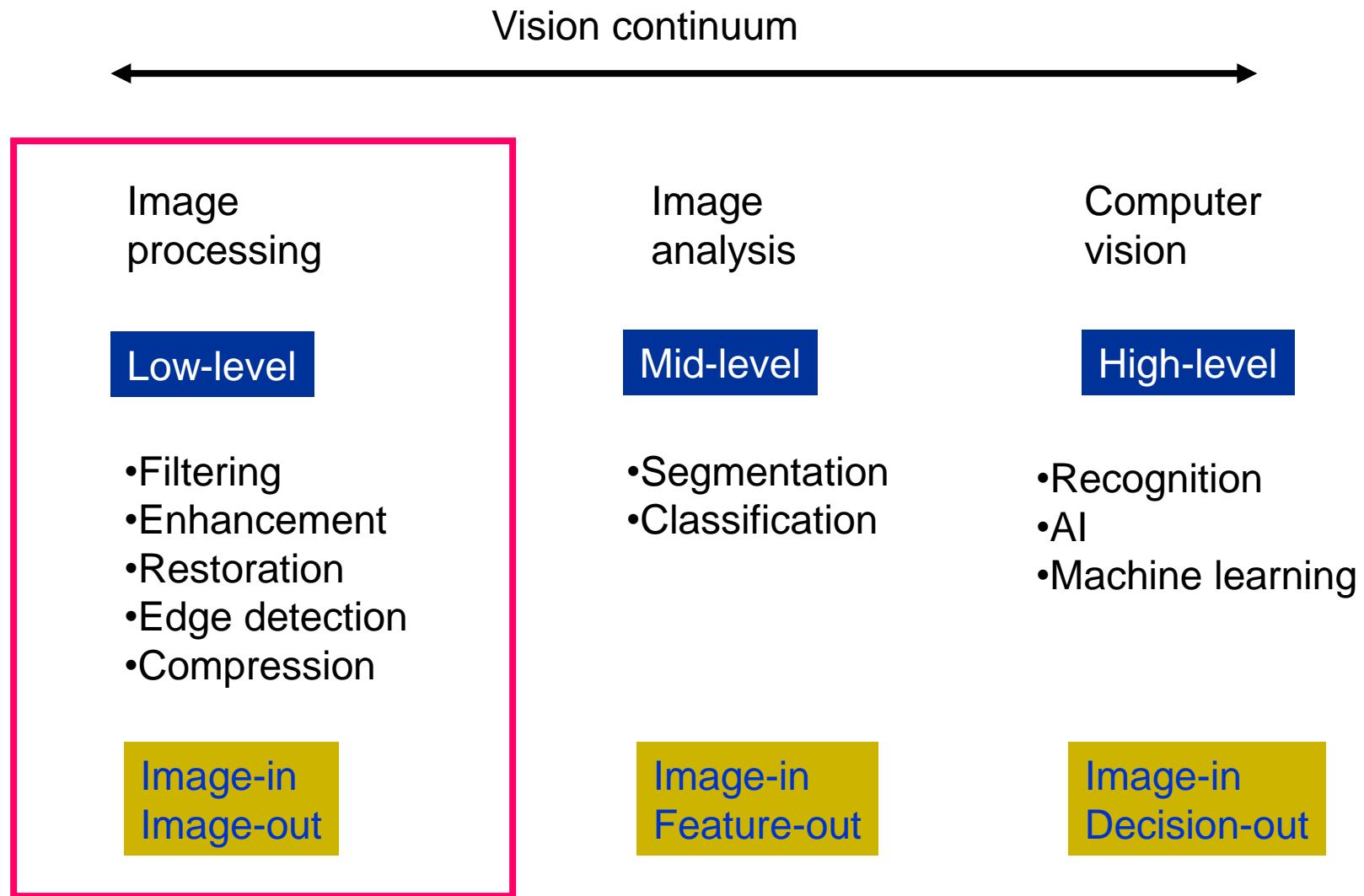
- Terrain classification
- Meteorology (weather)



Applications of Image Processing: Medicine



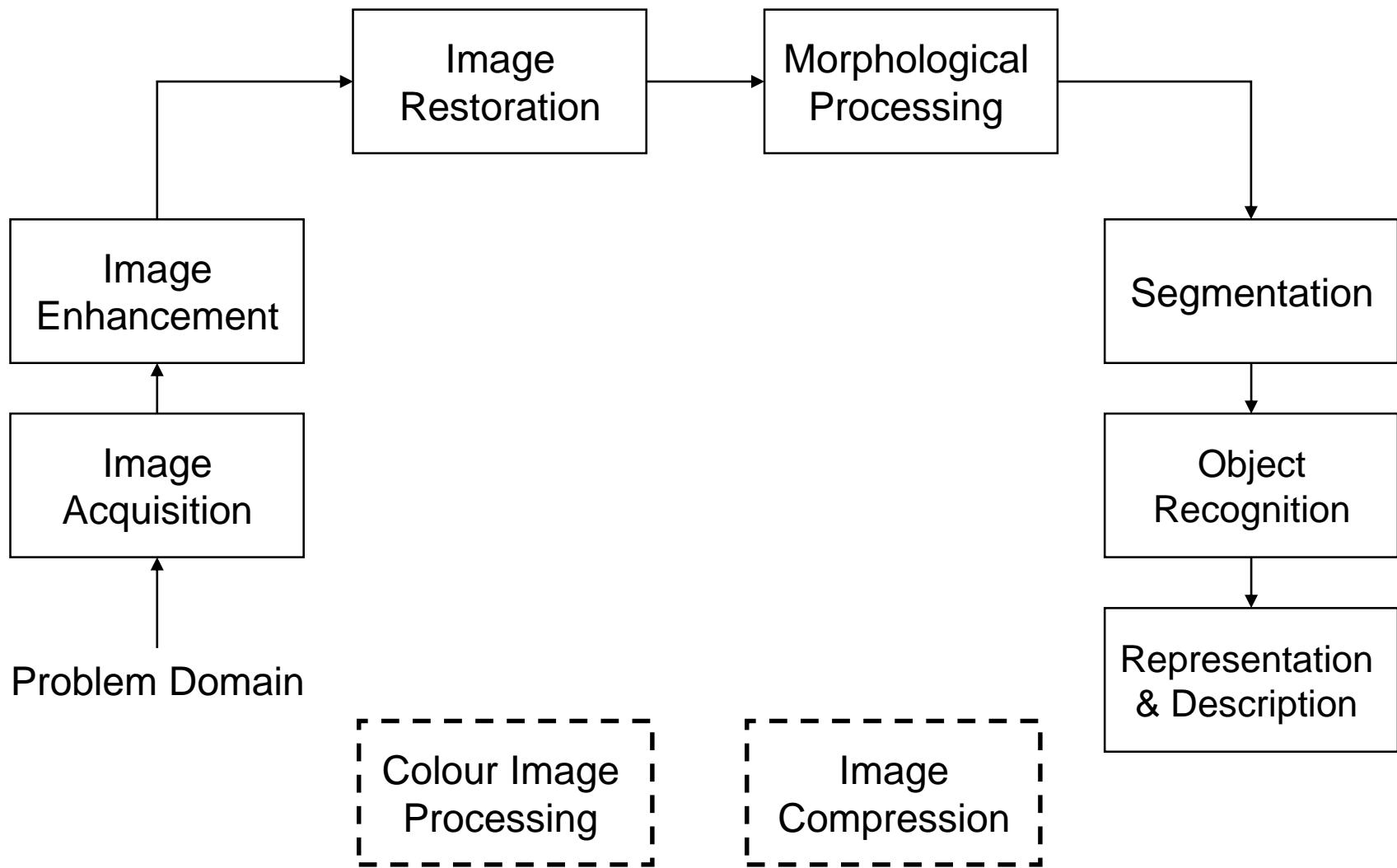
IP vs. Computer Vision



The information that can be conveyed in images has been known through out the centuries to be extraordinary-
one picture is worth a thousand words.

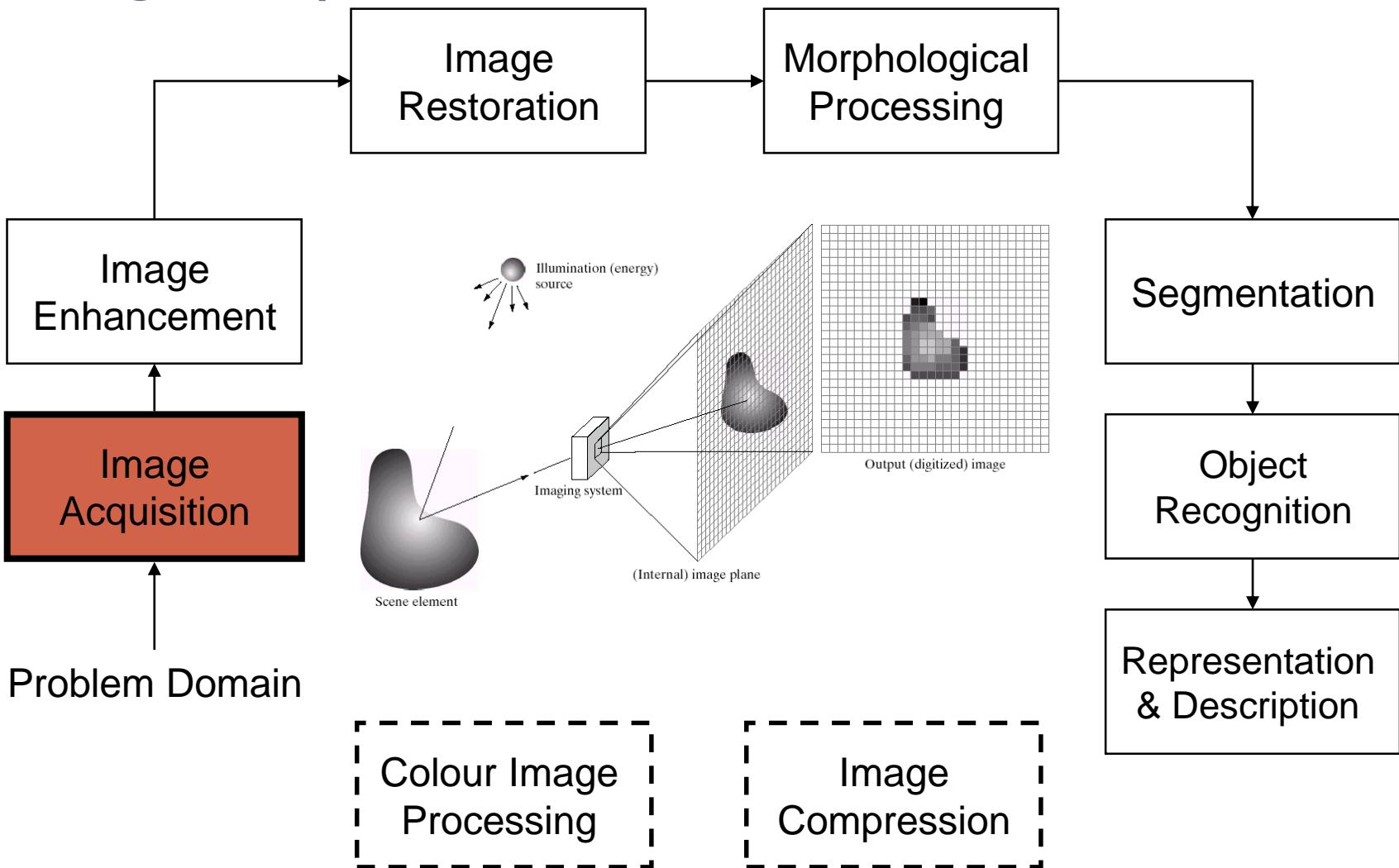


Key Stages in Digital Image Processing

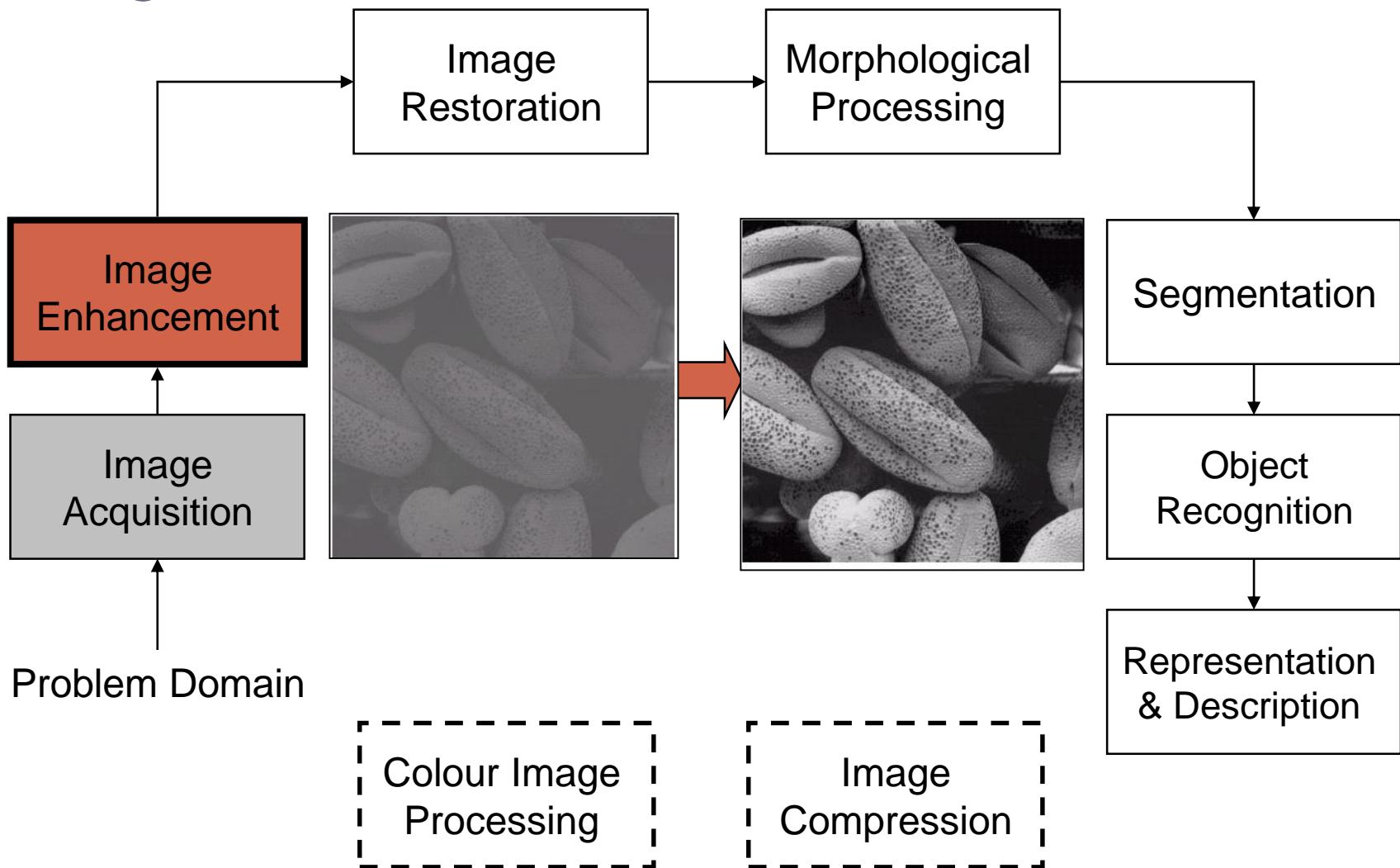


Key Stages in Digital Image Processing:

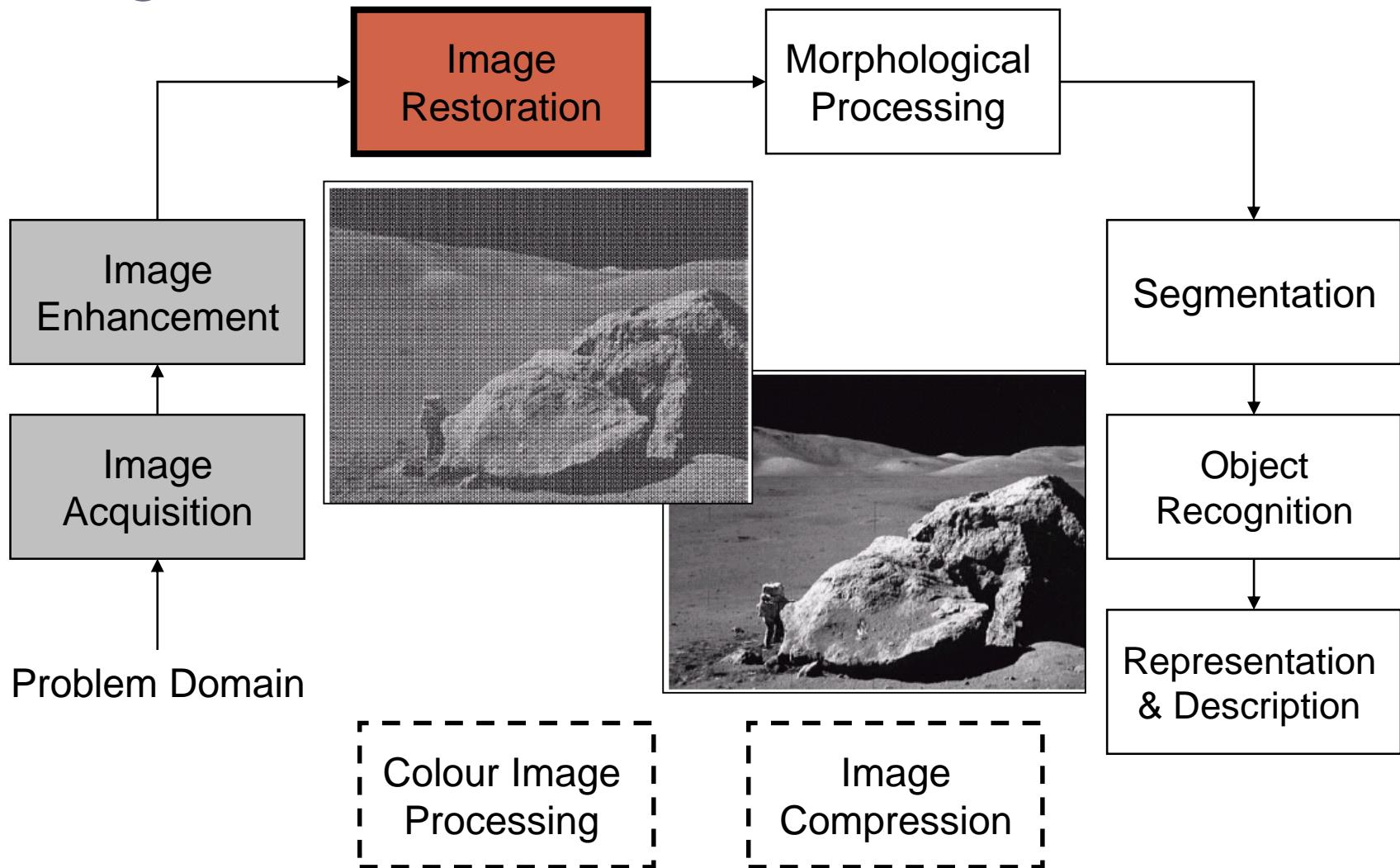
Image Acquisition



Key Stages in Digital Image Processing: Image Enhancement

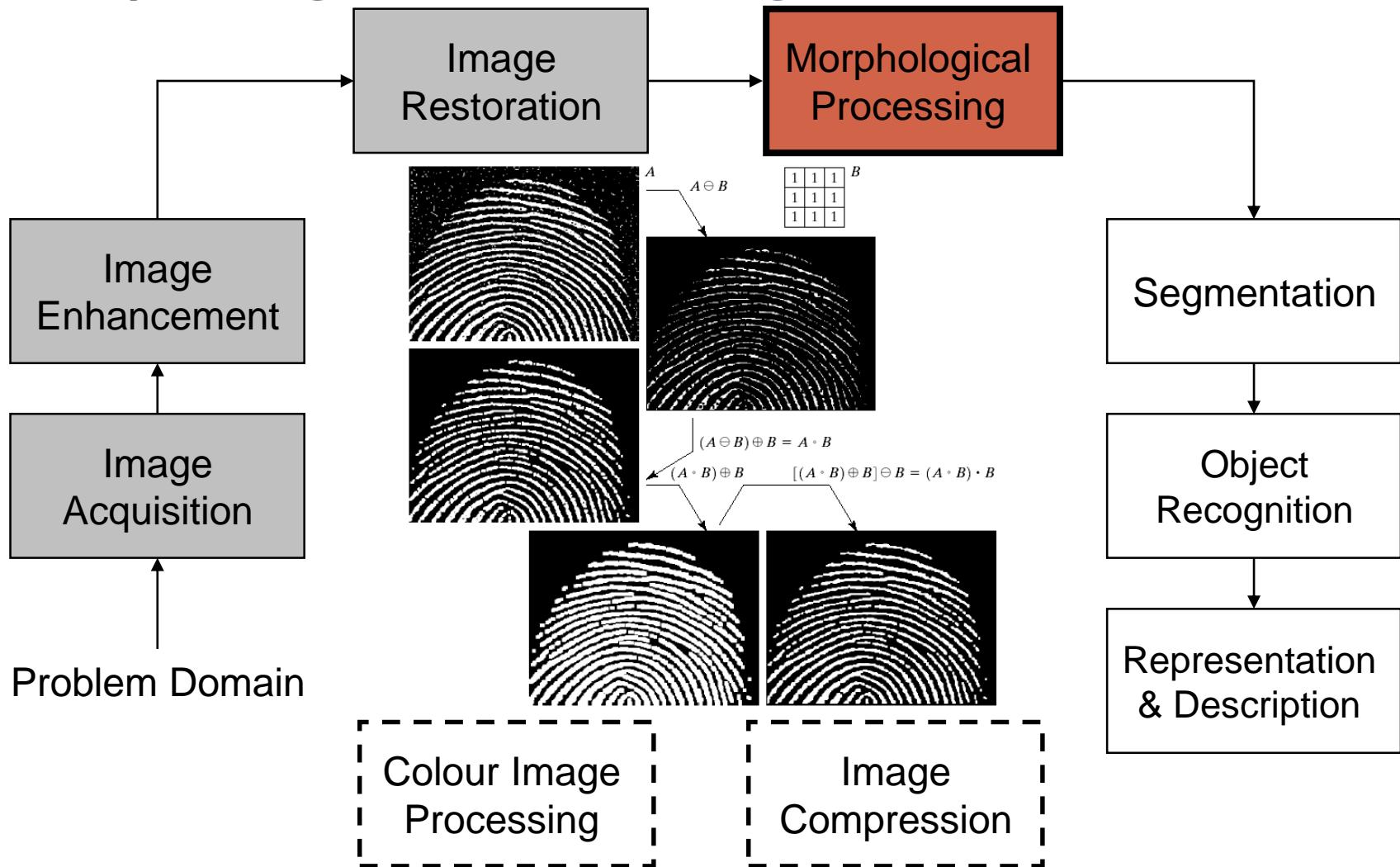


Key Stages in Digital Image Processing: Image Restoration

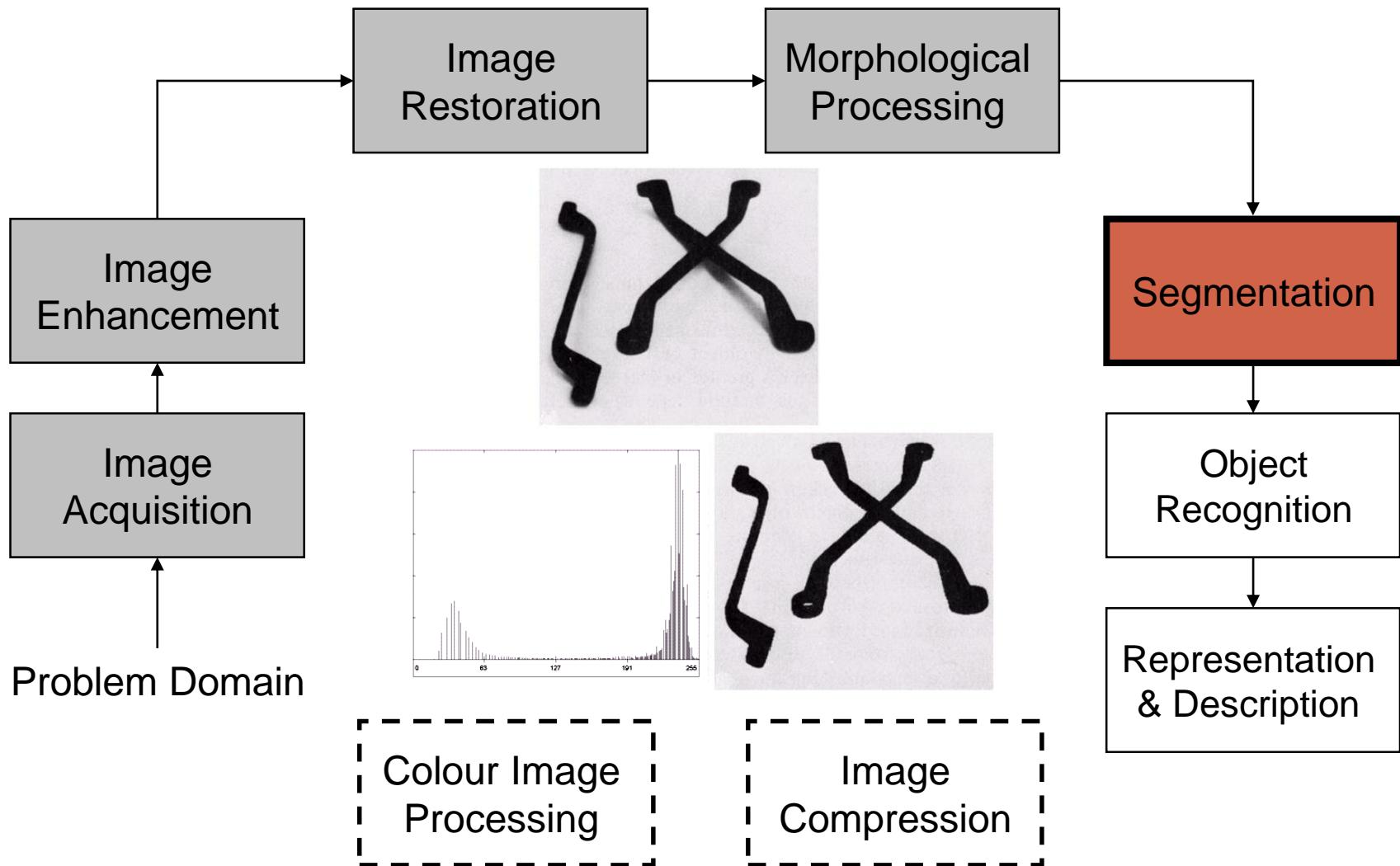


Key Stages in Digital Image Processing:

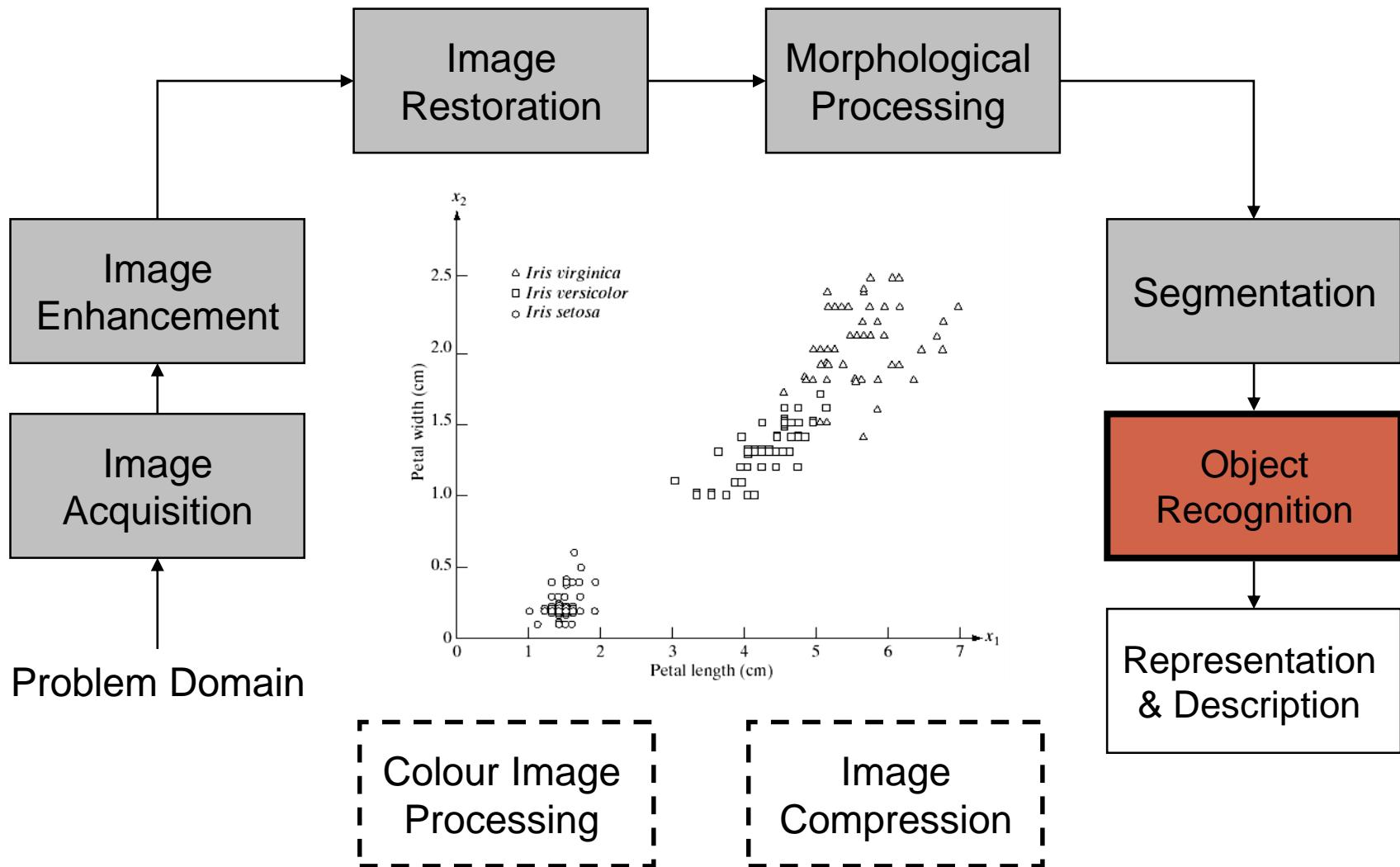
Morphological Processing



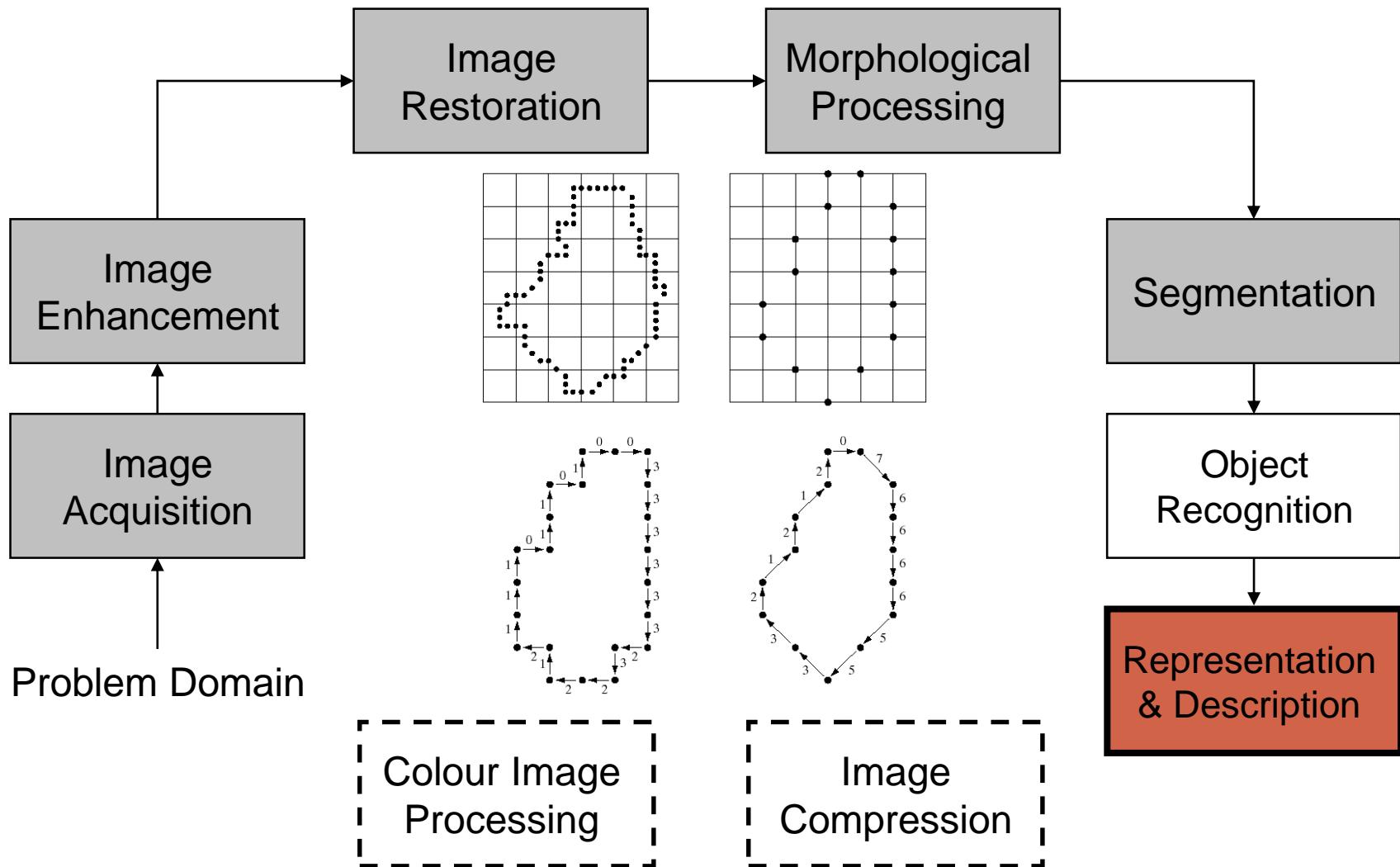
Key Stages in Digital Image Processing: Segmentation



Key Stages in Digital Image Processing: Object Recognition

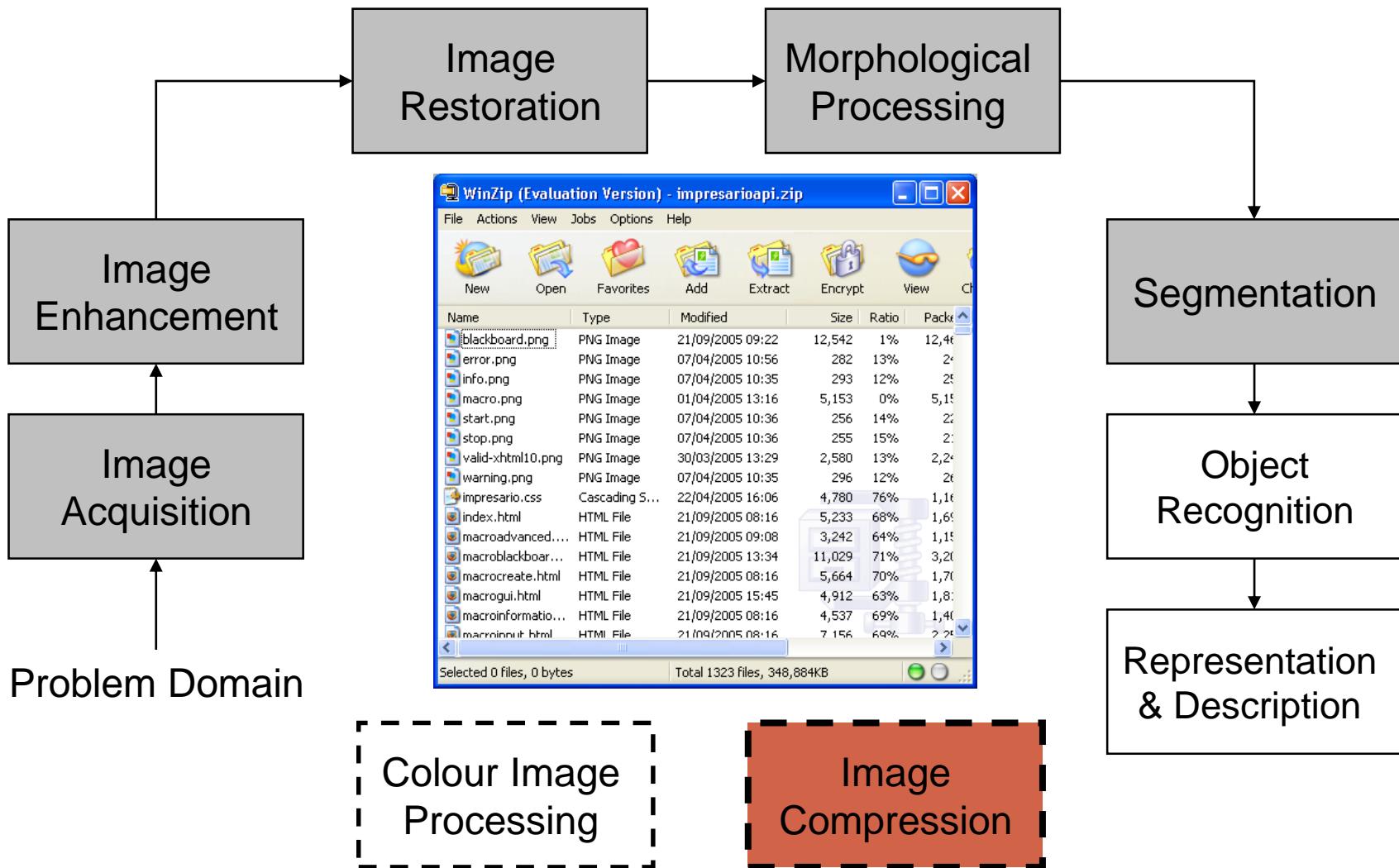


Key Stages in Digital Image Processing: Representation & Description



Key Stages in Digital Image Processing:

Image Compression



Key Stages in Digital Image Processing: Colour Image Processing

