Image Processing

Chang-Su Kim

Course Information

- Course homepage
  - http://mcl.korea.ac.kr

- Lecturer
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Course Information

- Objective
  - Study fundamentals of digital image processing
- Textbook
  - R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 2nd edition, Prentice Hall, 2002
- Reference
  - A. K. Jain, *Fundamentals of Digital Image Processing*, Prentice Hall, 1989

Course Information

- Prerequisite
  - Engineering Mathematics
  - Signals and Systems
  - Computer Language

- Assessment

Mid-tem Exam	50 %
Final Exam	50 %

Course Schedule

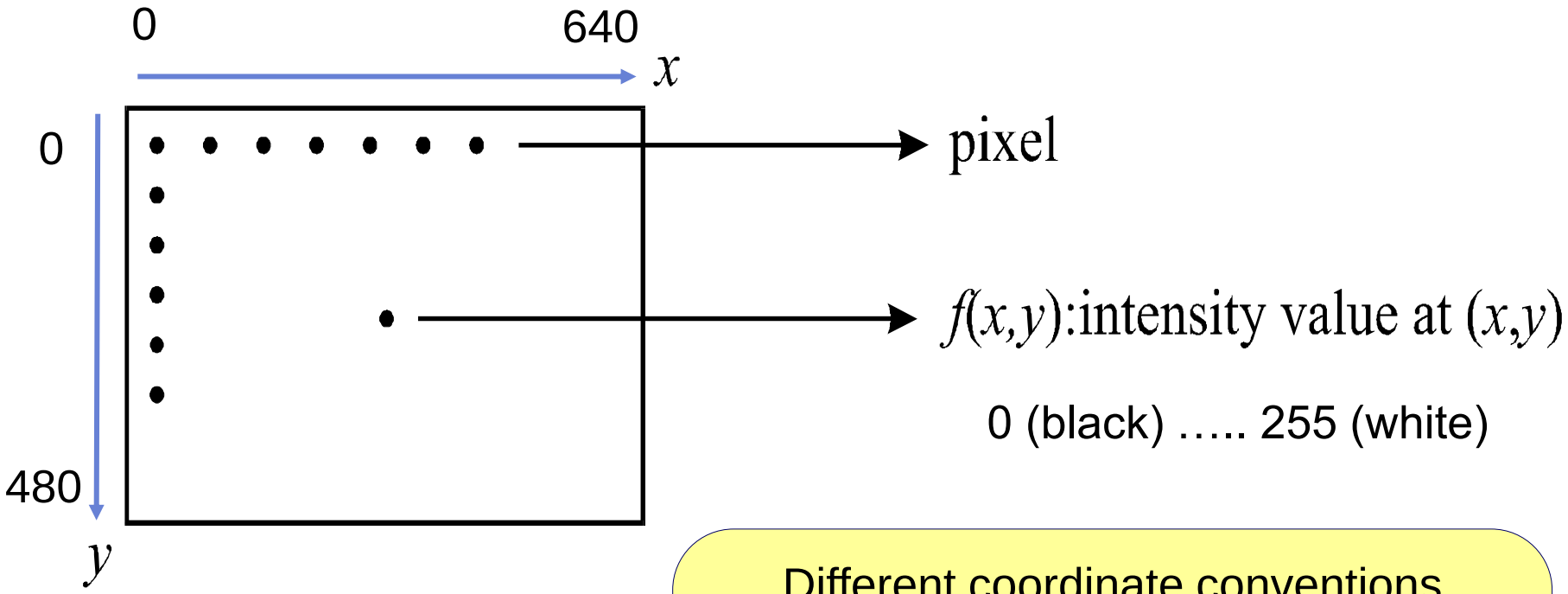
- Mid-term exam: 17 OCT 2022

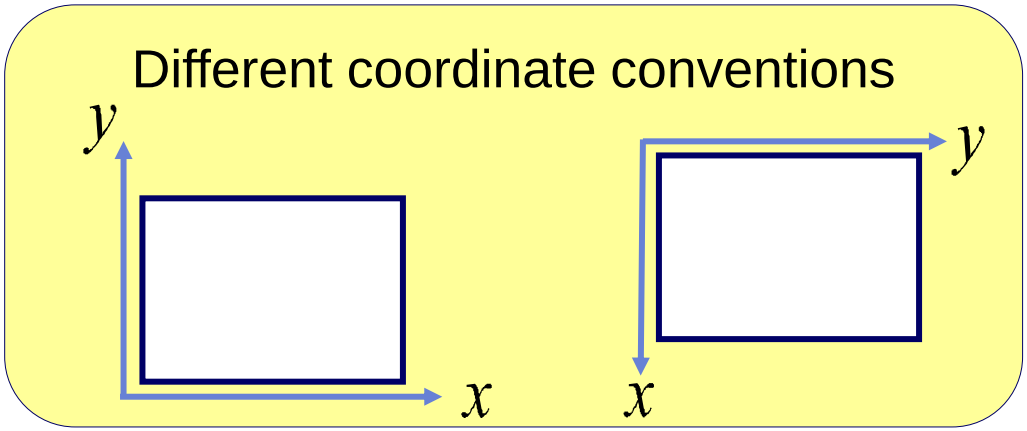
What is Digital Image Processing?

- Image
  - Two-dimensional function $f(x,y)$
    - x, y : spatial coordinates
    - Value of f : intensity or gray level

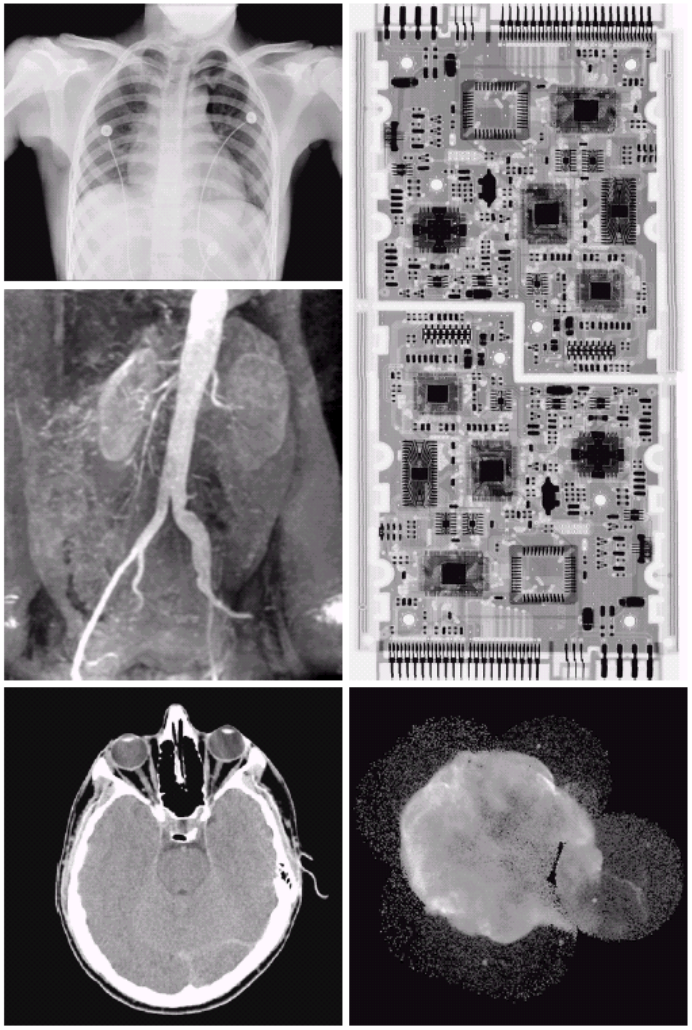
- Digital image
  - Both coordinates and value are discrete
  - A set of pixels (picture elements, pels)
  - Pixel means
    - pixel coordinate
    - pixel value
    - or both

- e.g. 640 x 480 8-bit image





Examples of Digital Images

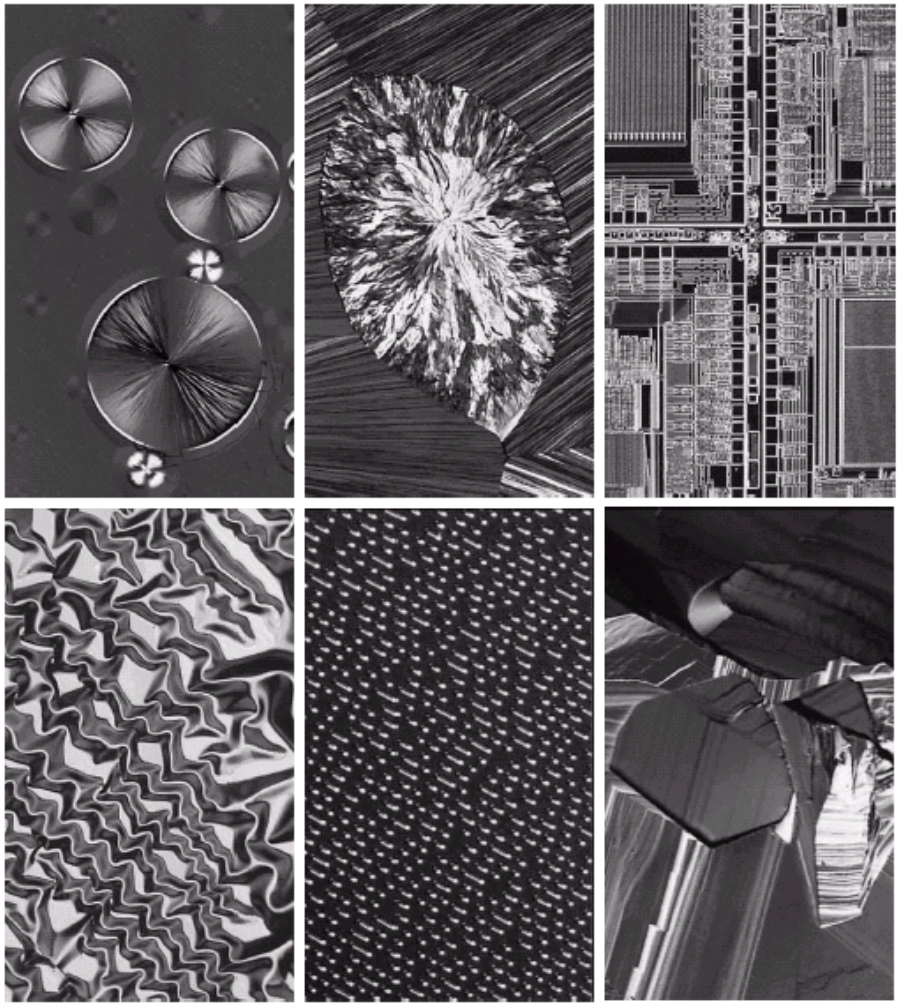


a b c d e

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.)

- X-ray
  - Chest
  - Angiogram
  - Computerized Tomography (CT)
  - Circuit board
  - Cygnus Loop

Examples of Digital Images



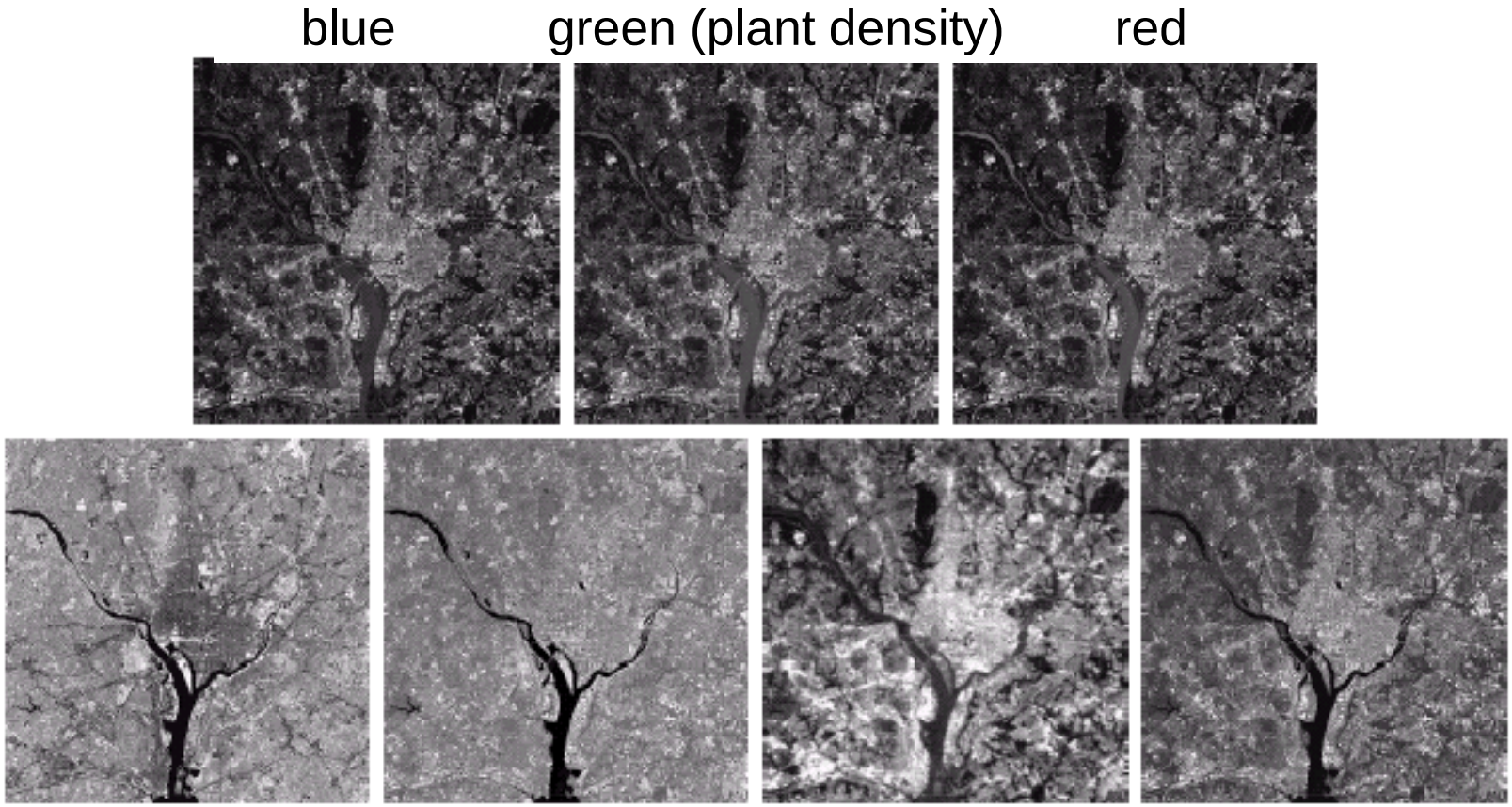
a b c
d e f

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.)

- Light microscopy
  - Anticancer medicine (250x)
  - Cholesterol (40x)
  - Microprocessor (60x)
  - Nickel oxide film (600x)
  - CD (1750x)
  - Organic superconductor(450x)

Examples of Digital Images

- Multispectral Imaging
  - Satellite images of the Washington, D.C.



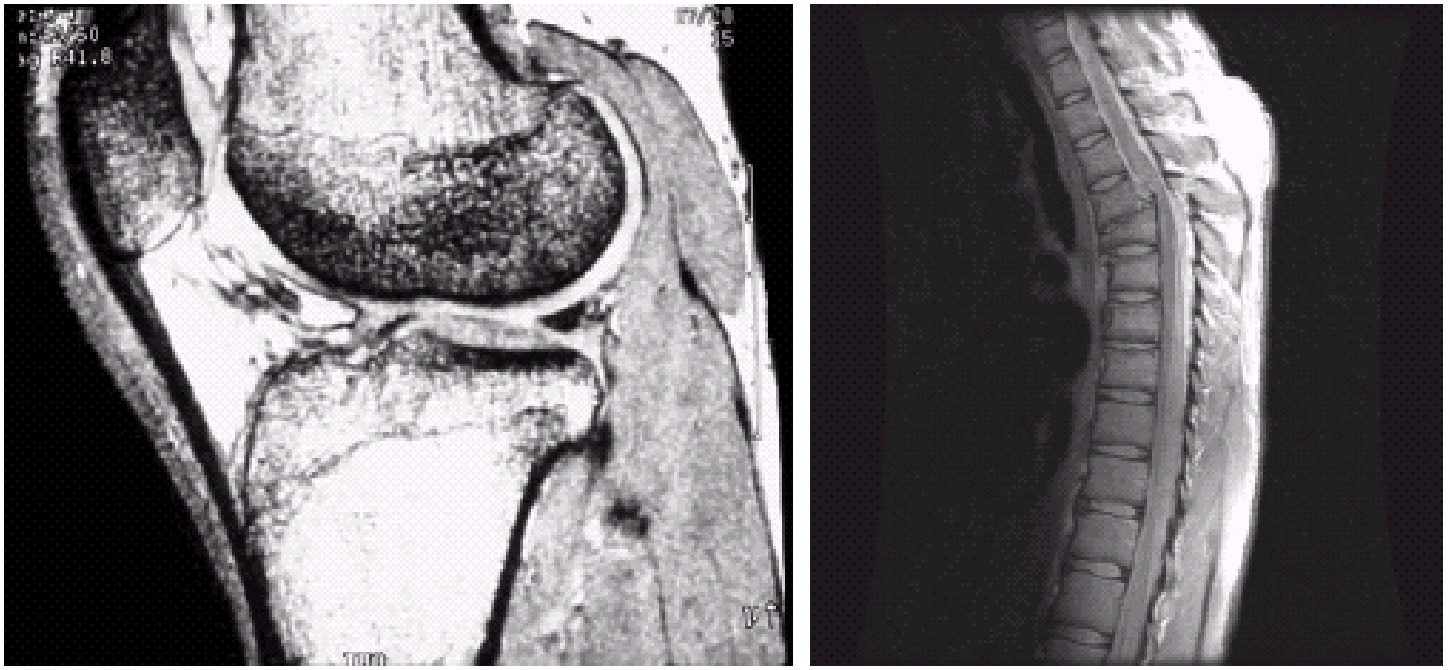
Examples of Digital Images

FIGURE 1.12 Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)

- Infrared images of the Americas
  - Nighttime lights
  - Human settlements

Examples of Digital Images

- Imaging in the radio band.



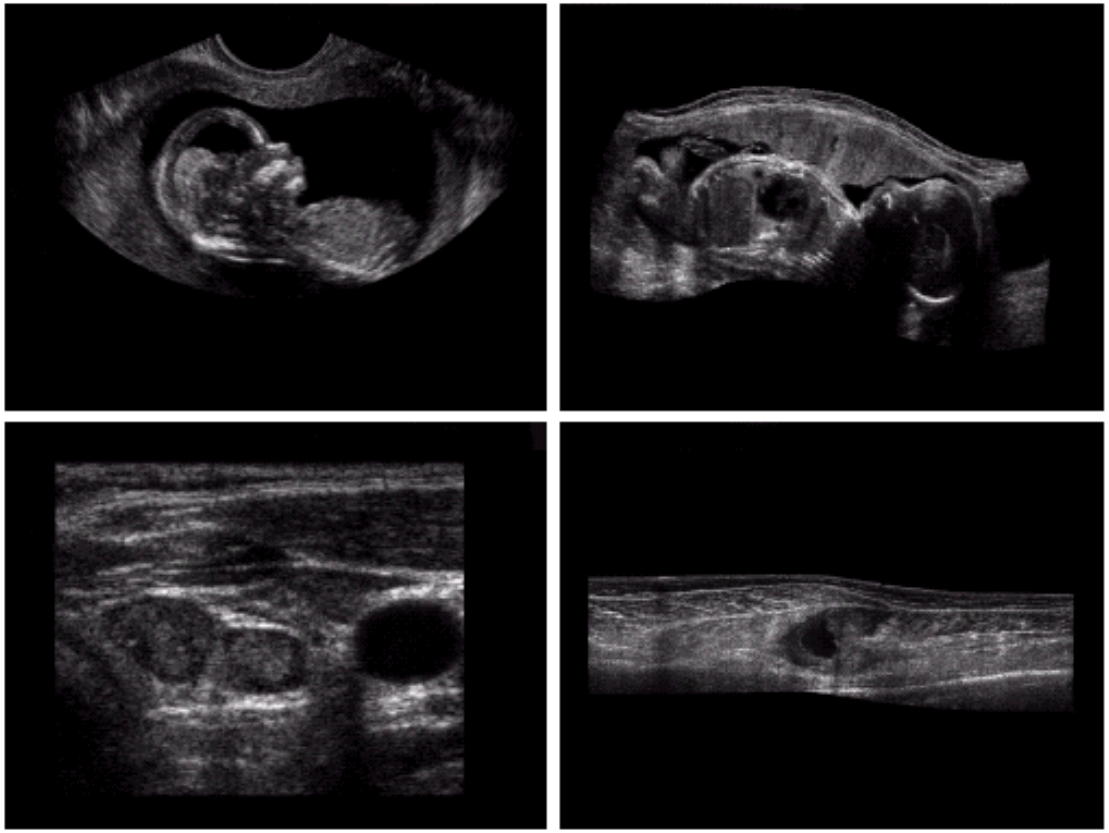
a b

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 of Digital Images

- Ultrasound images
  1. Transmit ultrasound (1 to 5MHz)
  2. Sound pulses are reflected from tissues
  3. Compute the distance using the speed
  4. Display the distances and intensities of the echoes

unborn babies



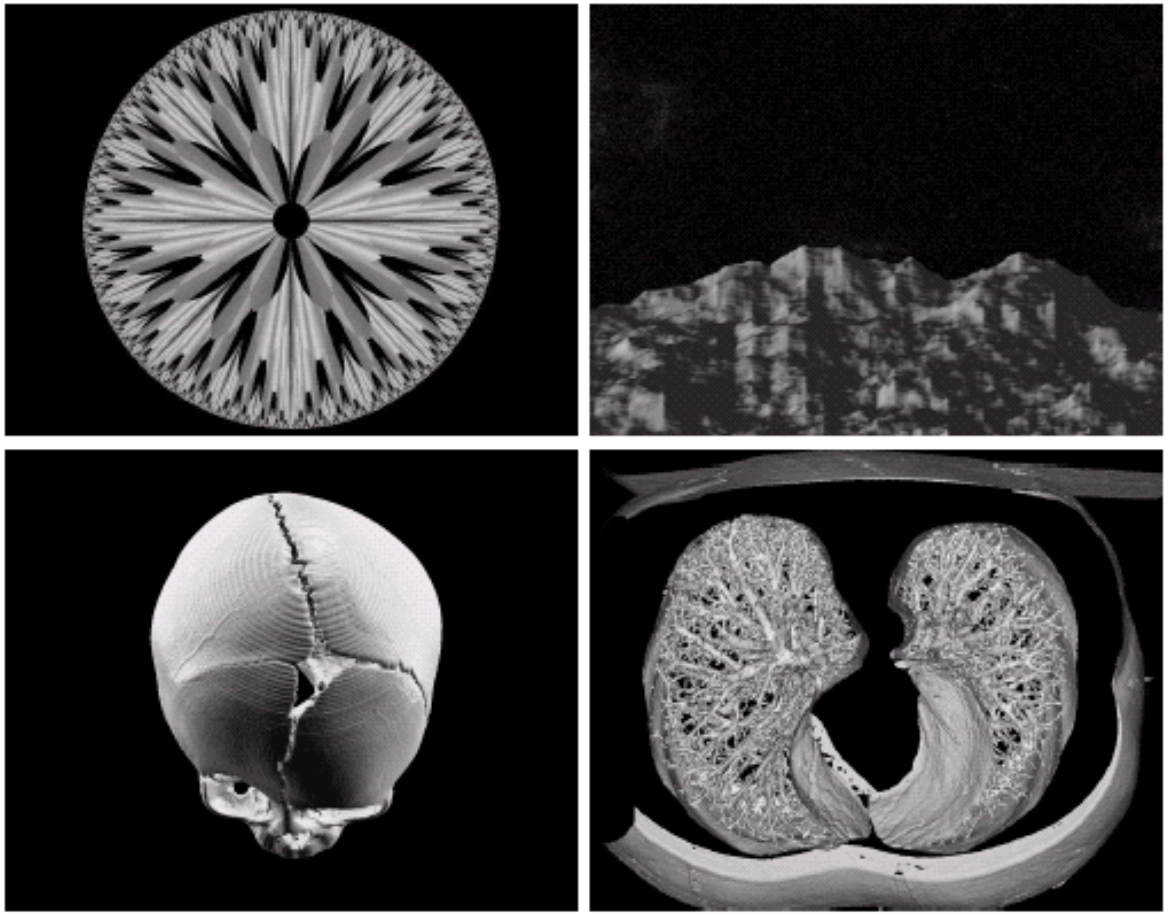
甲狀腺 [jiǎ zhuàng xiàn]

thyroids

injured muscle

Examples of Digital Images

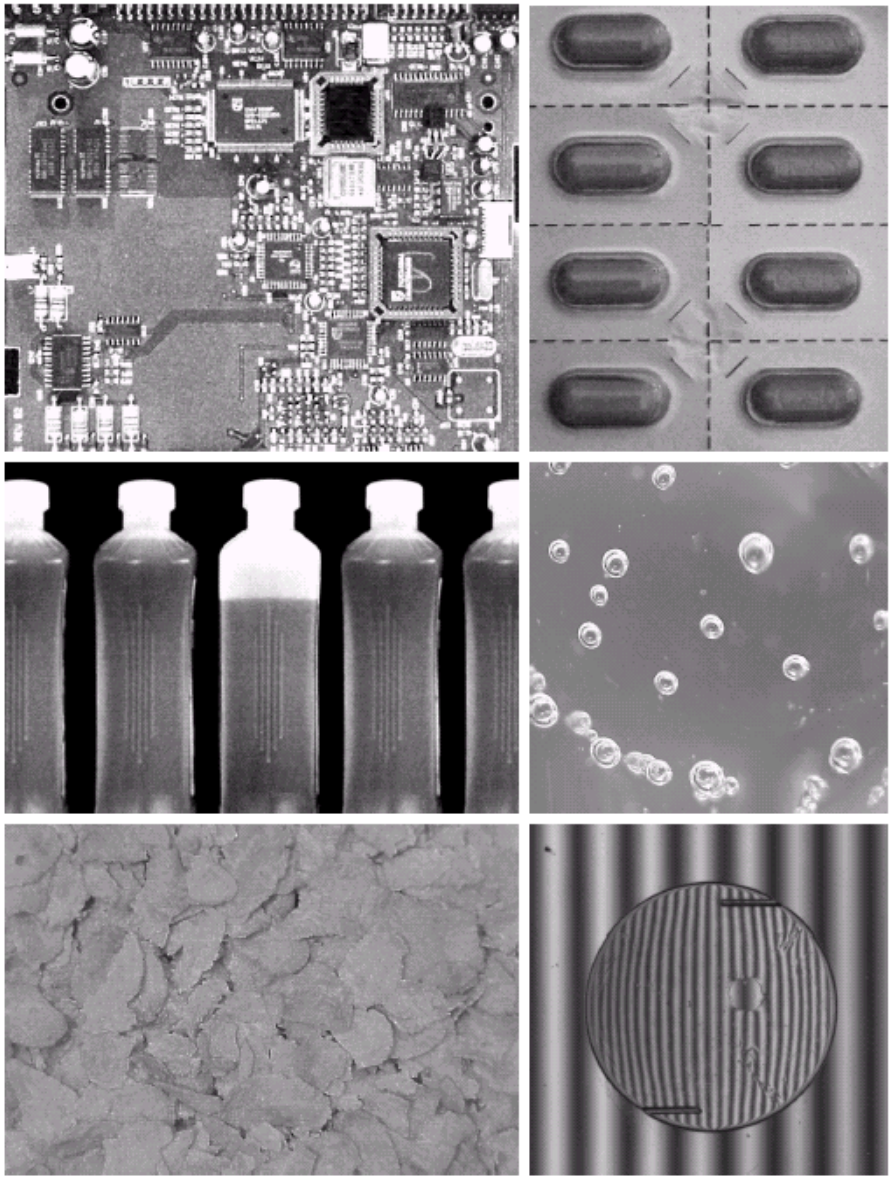
- Artificial images



a b
c d

FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

Examples of Digital Images

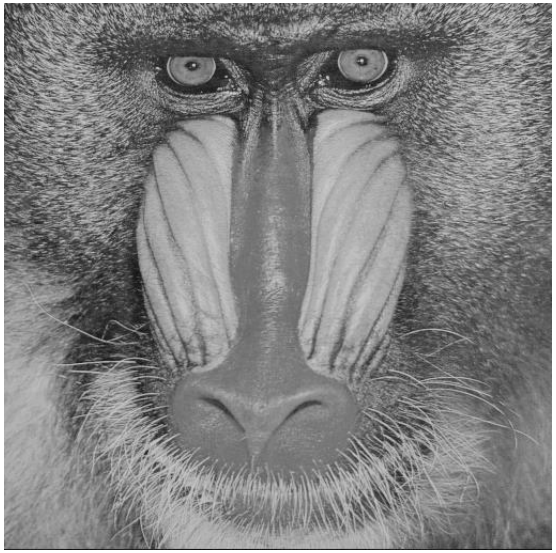


- Automated visual inspection
  - Unconnected circuit board
  - Missing pills
  - Unfilled bottles
  - Air pockets in plastic
  - Burned flakes in cereal
  - Defects in replacement lens
    - structured lighting

Examples of Digital Images

- Famous images in image processing society

Lena (512*512)



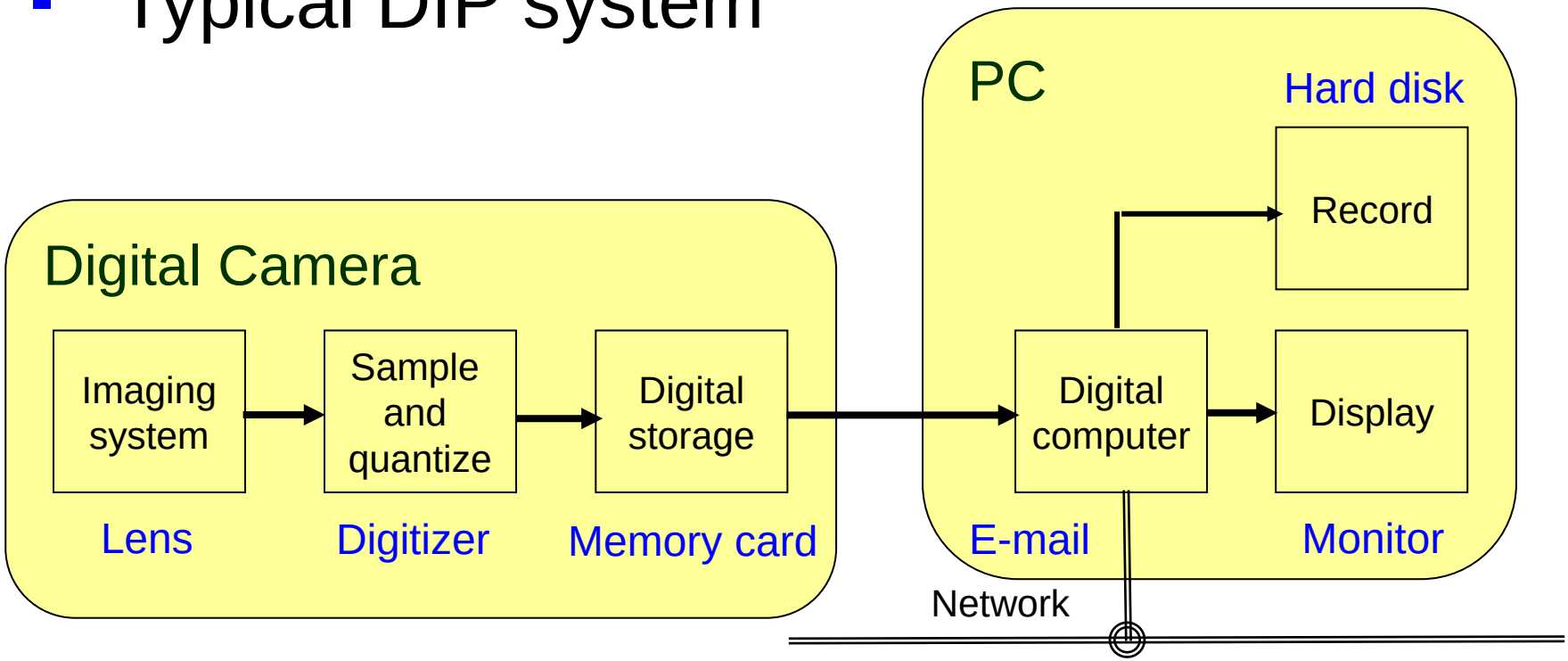
Baboon (512*512)

Boat (512*512)

What is Digital Image Processing?

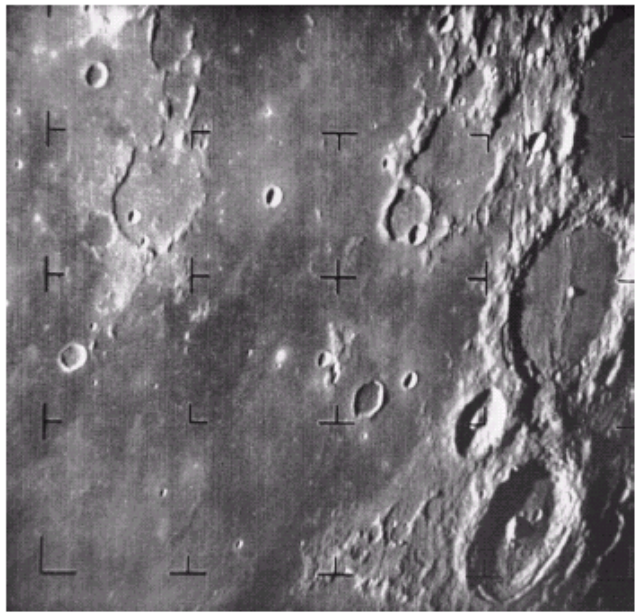
- Digital Image Processing
  - Processing of **two-dimensional data** by a digital computer

- Typical DIP system



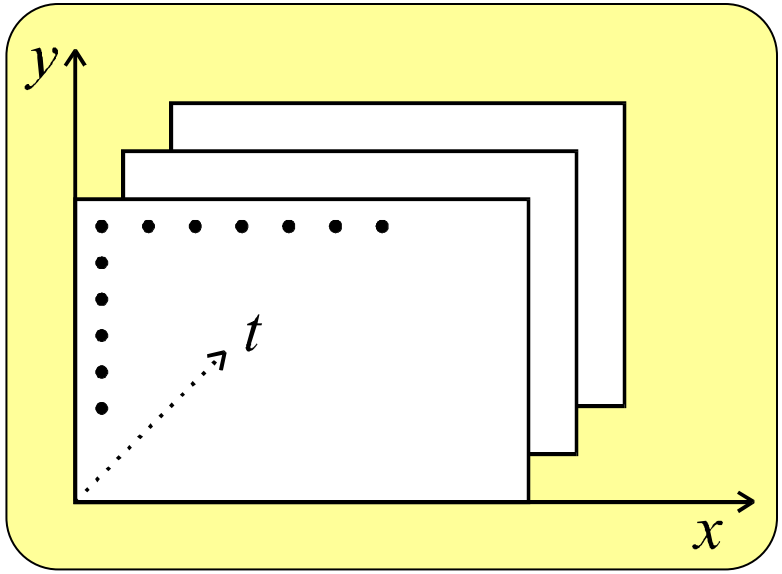
Developments of DIP

- 1920's: Analog image transmission
  - Transatlantic picture transmission
  - London – New York
- 1960's: Space program
  - Invention of digital computer hardware and software
  - Source data is very expensive
- 1970's: X-ray imaging (CT)
- Nowadays: Cheap computing
  - Lots of DIP applications



Computational Complexity of DIP

- HDTV quality video
  - Resolution : 1024 x 768
    - 786,432 pixels
  - Refresh rate : 30 pictures/s
  - Compute average gray level of each picture
    - 786,432 x 30 = about 23 million additions/s



- Digital video processing had not been possible for a long time

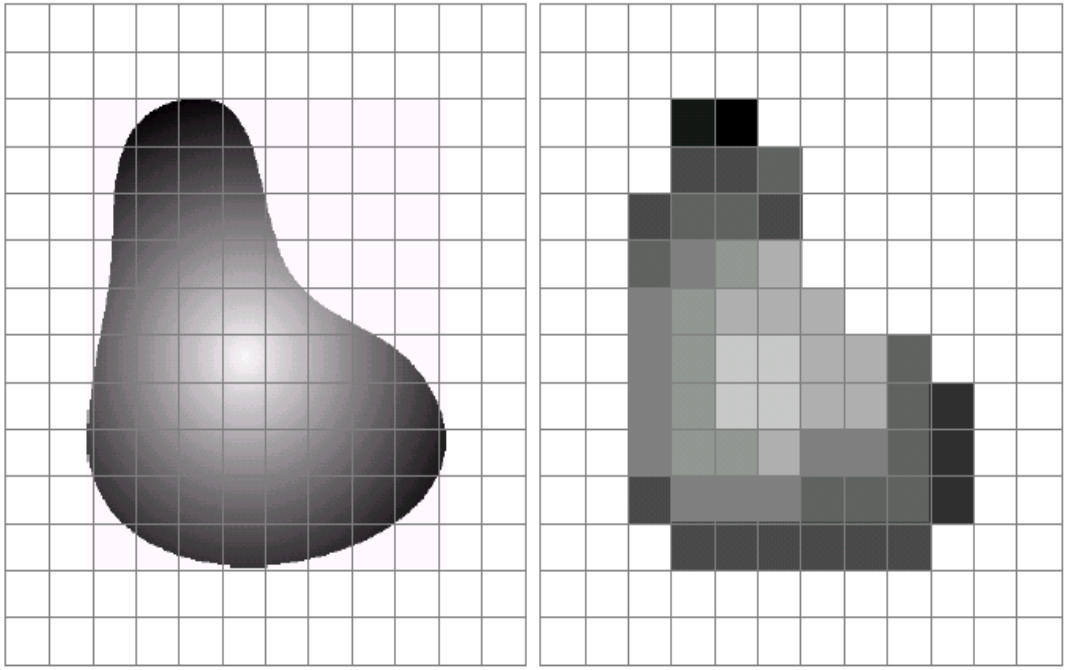
Selected Topics in DIP (Course Overview)

- Sampling and Quantization (Chap. 2)

- Image Enhancement (Chaps. 3-4)
- Image Transform and Related Maths (Chap. 4)
- Image Restoration (Chap. 5)
- Color Image Processing (Chap. 6)
- Image Compression (Chap. 8)

- Advanced Topics as time allows

Sampling and Quantization

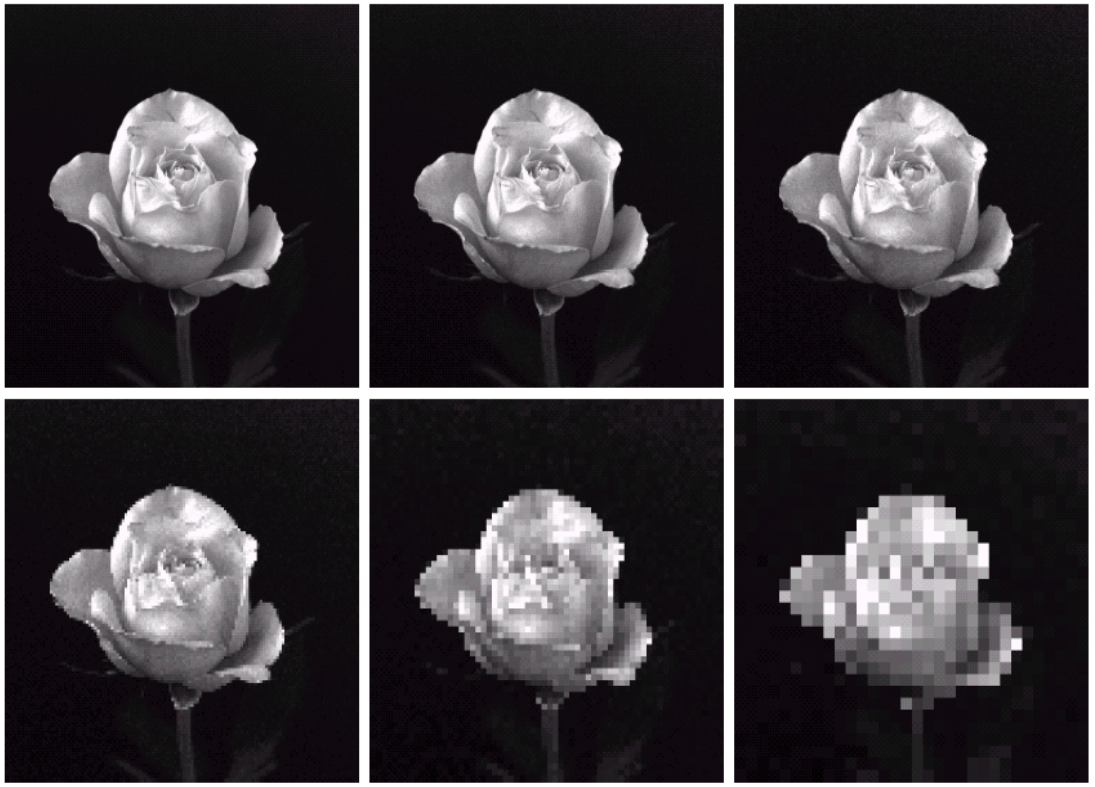


a b

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

Sampling and Quantization

- Sampling
  - Digitization in Spatial Domain



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.

Sampling and Quantization

- Quantization
  - Digitization of pixel levels

e f
g h

FIGURE 2.21 *(Continued)* (e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)

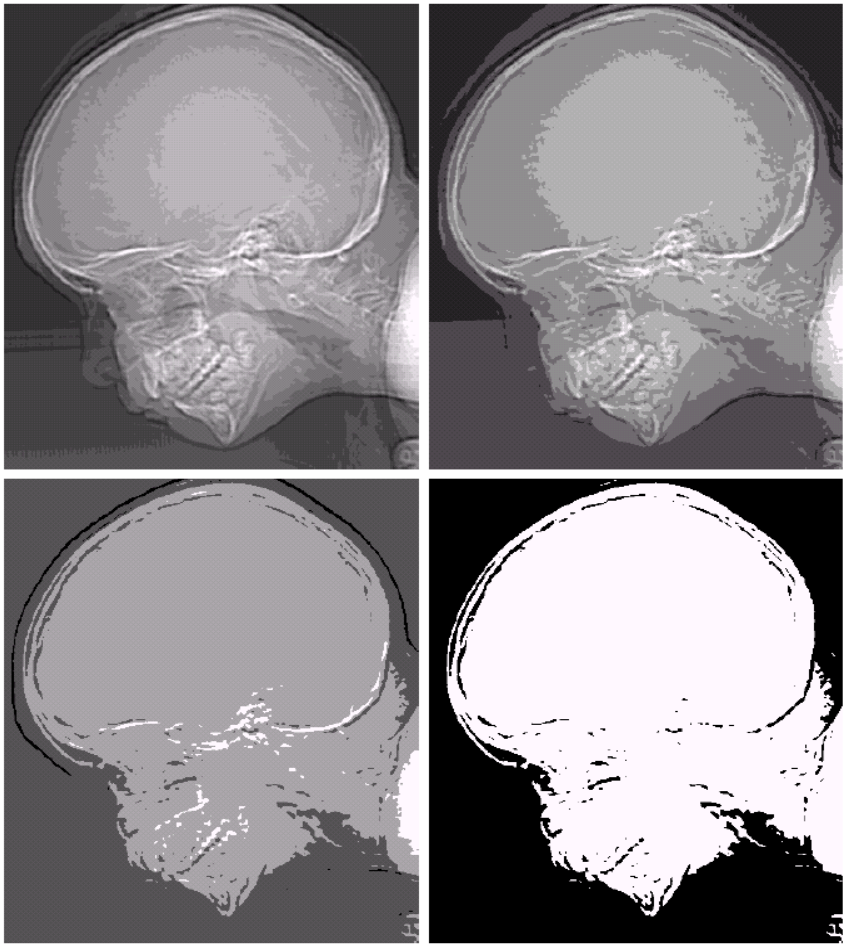
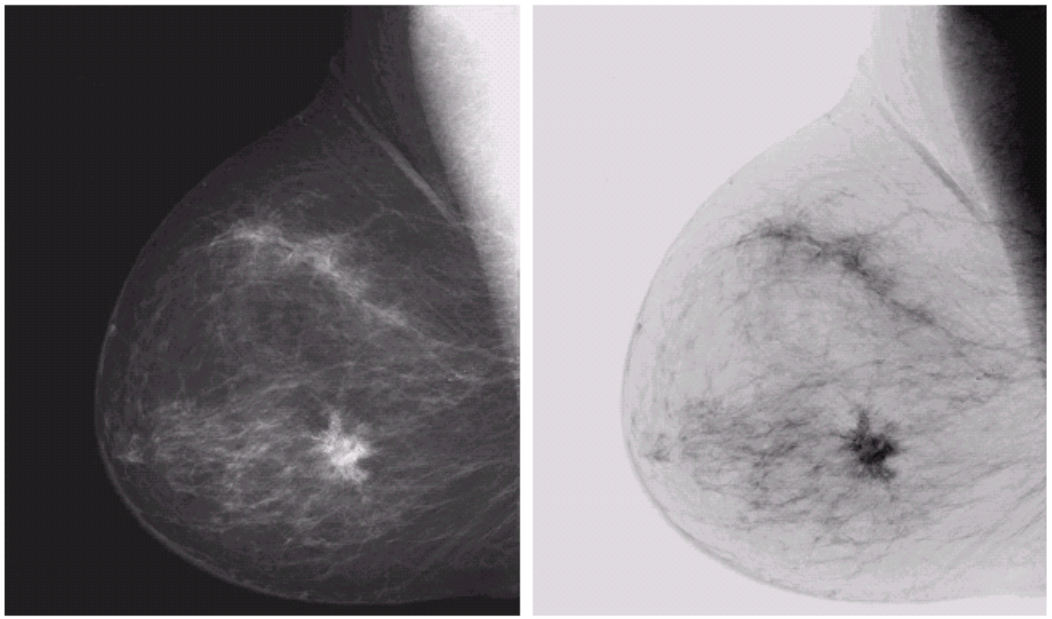


Image Enhancement

- Objective
  - to accentuate certain image features for subsequent analysis or for image display
- Subjective process

$$g(x,y) = 255 - f(x,y)$$



a b

FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

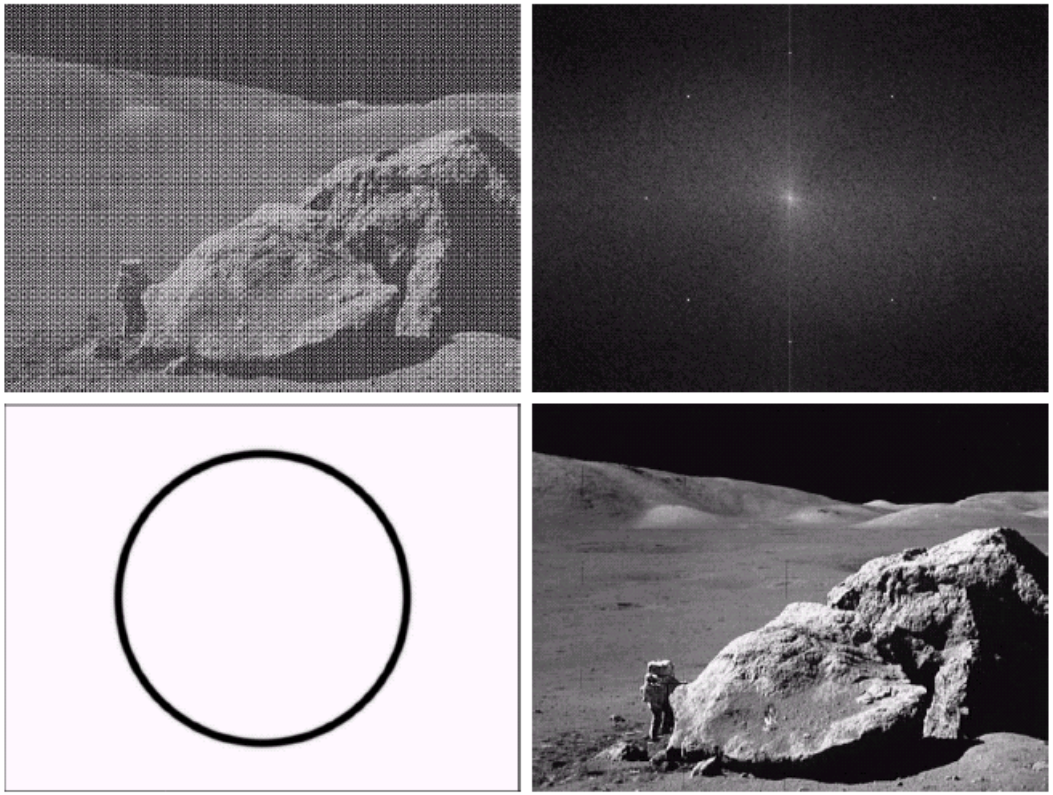
Image Enhancement

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.)

Image Restoration

- Objective
  - to remove or minimize known/unknown degradations in image
- Objective process



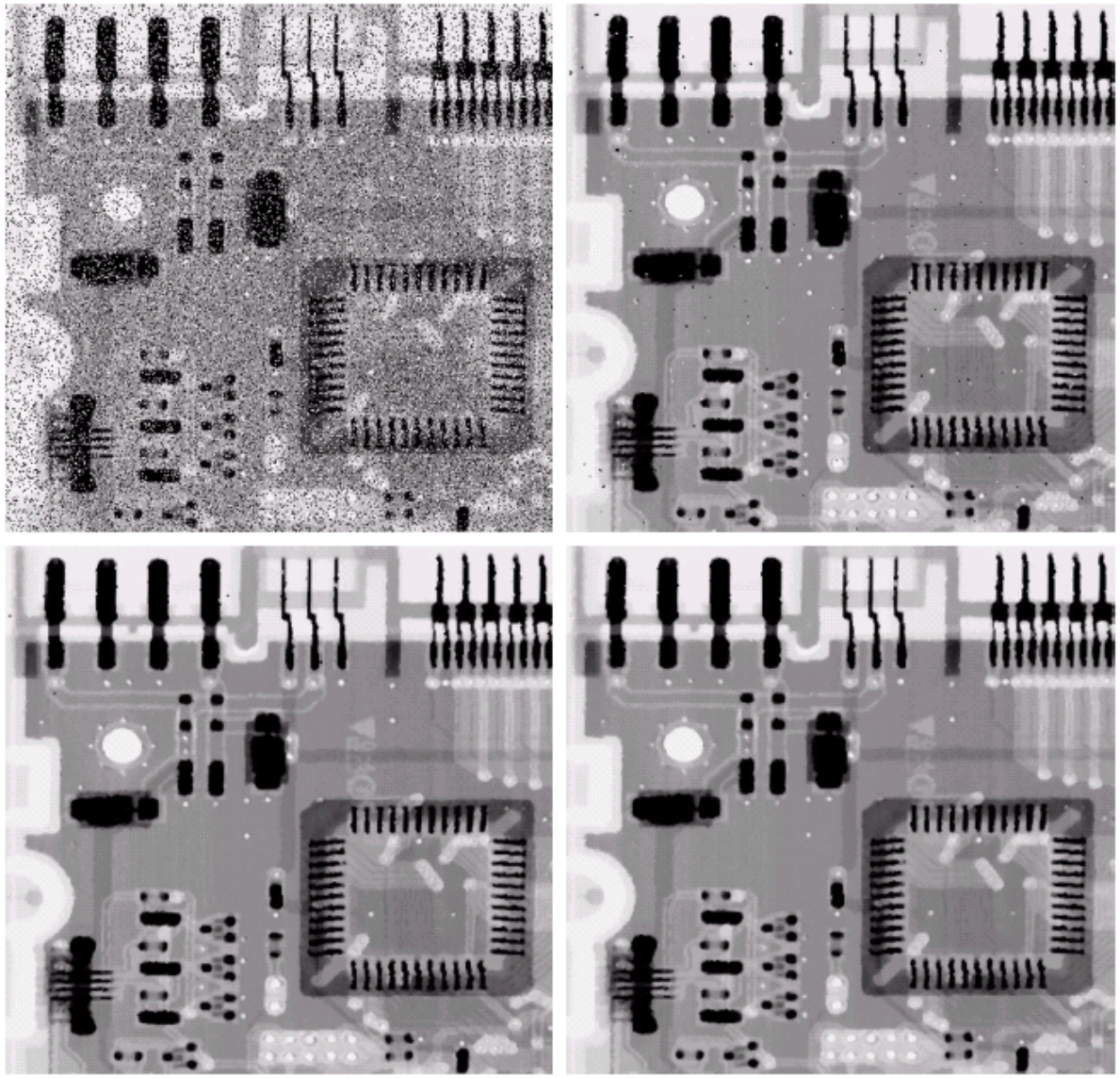
a b
c d

FIGURE 5.16
(a) Image corrupted by sinusoidal noise. (b) Spectrum of (a). (c) Butterworth bandreject filter (white represents 1). (d) Result of filtering. (Original image courtesy of NASA.)

Image Restoration

a b
c d

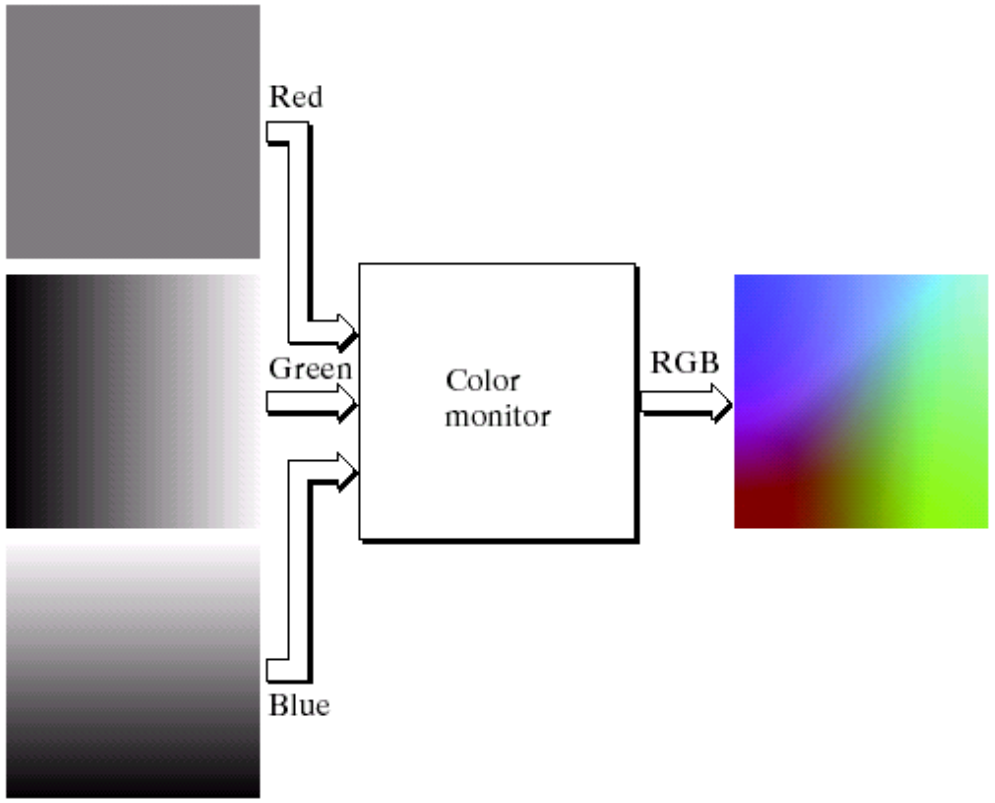
FIGURE 5.10
(a) Image corrupted by salt-and-pepper noise with probabilities $P_a = P_b = 0.1$.
(b) Result of one pass with a median filter of size 3×3.
(c) Result of processing (b) with this filter.
(d) Result of processing (c) with the same filter.



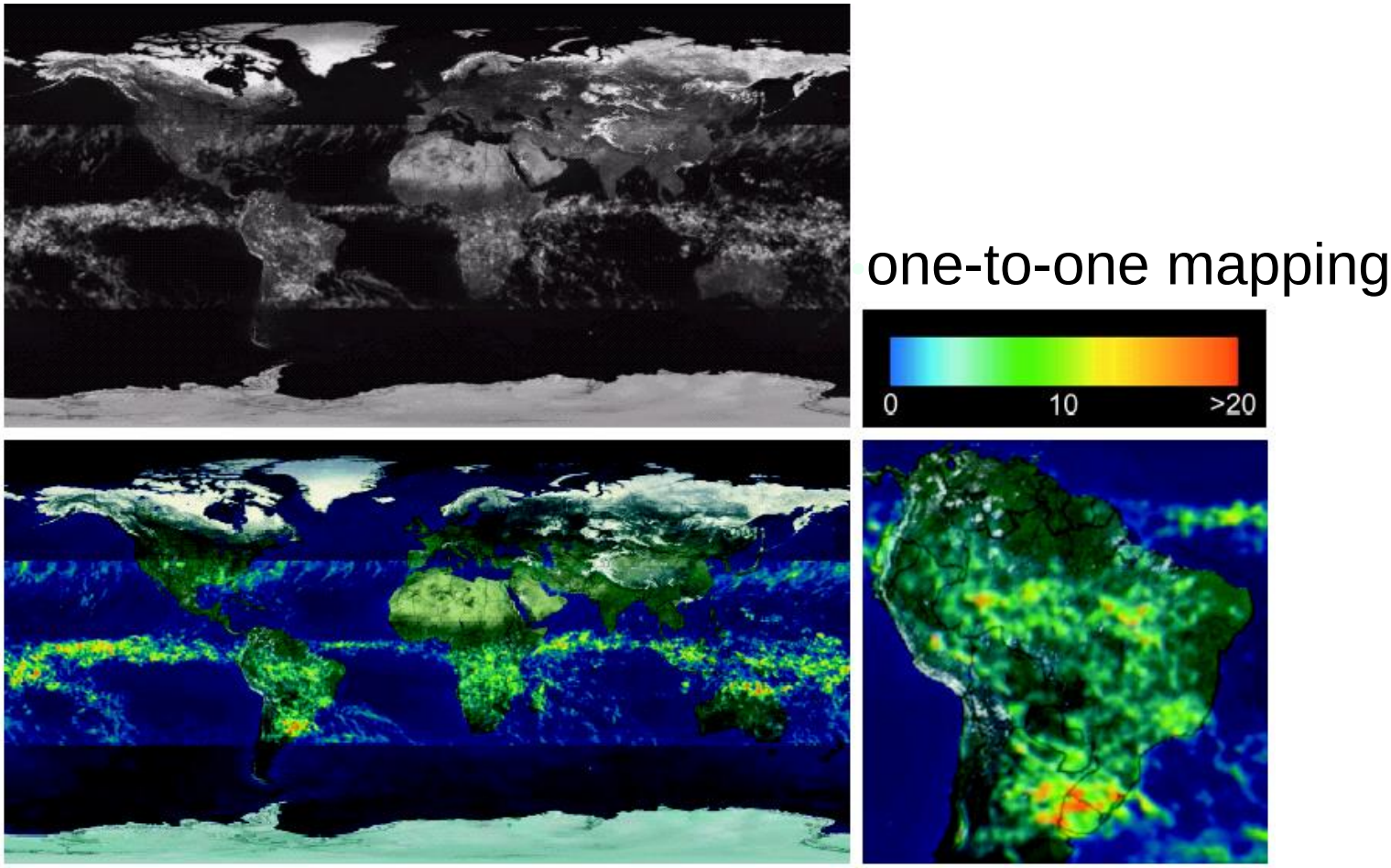
Color Image Processing

a
b

FIGURE 6.9
(a) Generating the RGB image of the cross-sectional color plane (127, *G*, *B*).
(b) The three hidden surface planes in the color cube of Fig. 6.8.



Color Image Processing



a b
c d

FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South America region. (Courtesy of NASA.)

Image Compression

- Objective
  - to reduce the amount of data to represent images

Input image (8 bits/pixel)

Output : bit-stream data

“01010010110011010100 1 . . . .”

  - From the bit stream, the approximate copy of the original image can be reproduced

Image Compression

- JPEG compression

(a) 0.125 bits/pixel

64:1

(b) 0.25 bits/pixel

32:1

(c) 0.5 bits/pixel

16:1

- 1000 x 1000 RGB picture = 3 MB
- 16 MB memory card can store only 5 pictures
- With JPEG, the same card can store more than 80 pictures

Image Compression

- Video compression
  - HDTV quality video
    - 1024 x 768 x 3 x 30 x 8 = 566 Mbits/s (Mbps)
  - Video compression standards
    - MPEG-1: Video-CD, 1-2 Mbps
    - MPEG-2: HDTV and DVD, 2-15 Mbps
    - H.263: Low bit-rate applications, 10-2048 Kbps
    - MPEG-4: similar to H.263
    - H.264/AVC : new video coding standard

Image Processing and Computer Vision

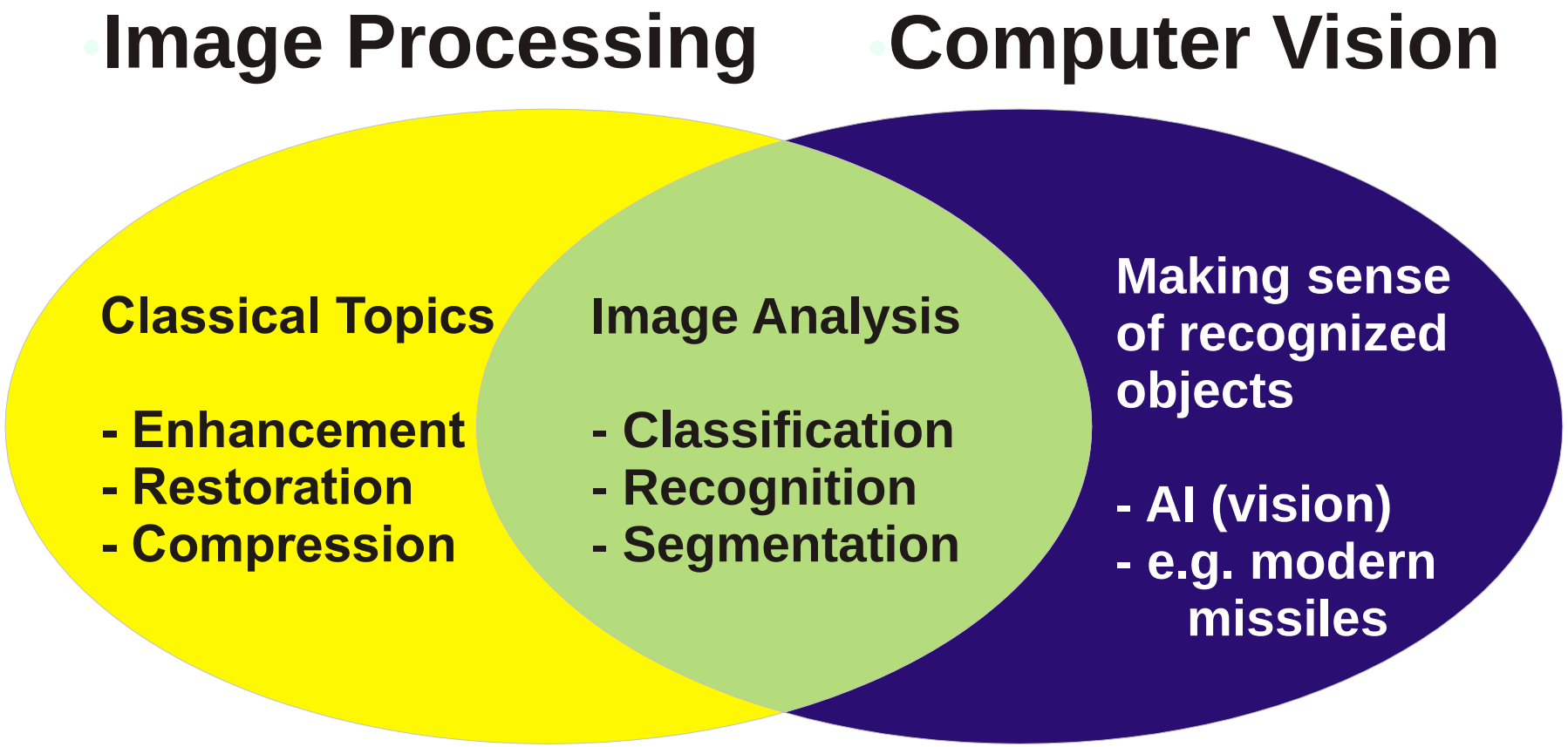


Image Segmentation

- Edge detection

Image Segmentation

(a) Aerial Image

(b) Segmented Image

Image Segmentation

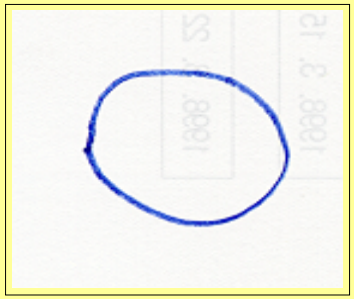
a
b

FIGURE 10.37
(a) Original image. (b) Image segmented by local thresholding. (Courtesy of IBM Corporation.)

Image Description

- Objective
  - interpret or describe the meaning contained in image
- Output is not image

Input : image **Output : description**



“KAISION”

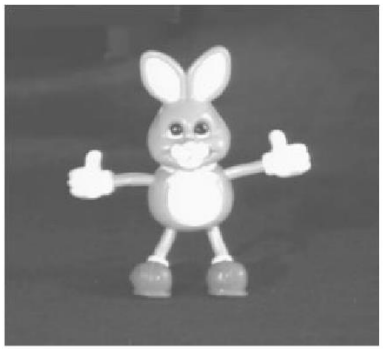
“circle”

Image Description

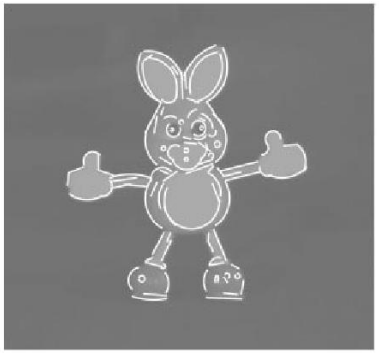
a b
c
d

FIGURE 1.15
Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d). Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

Scene Matching



Model image

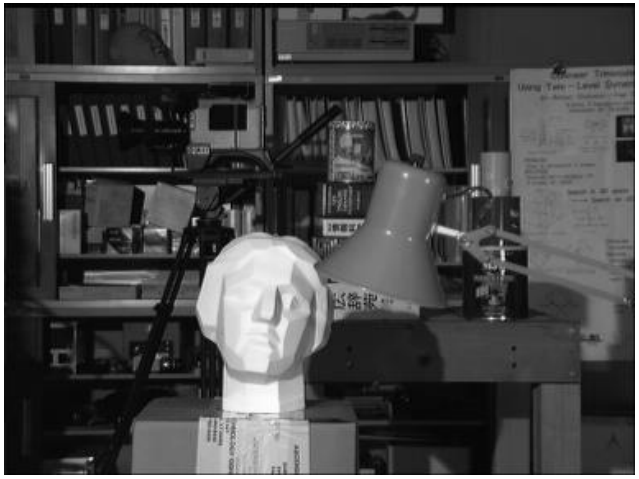


Model

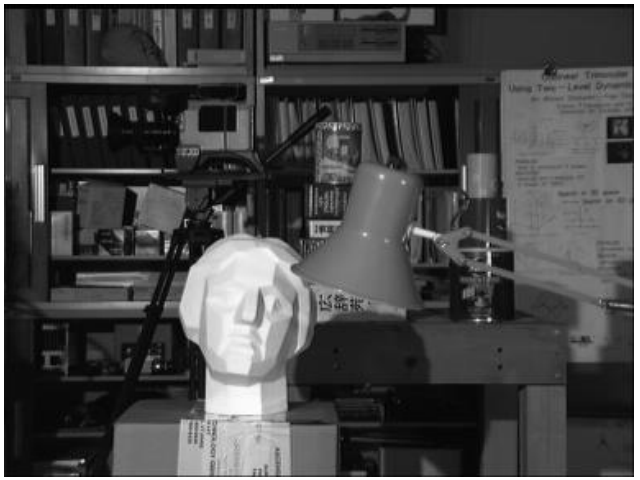
Input scene

Scene matching result

Stereo Vision

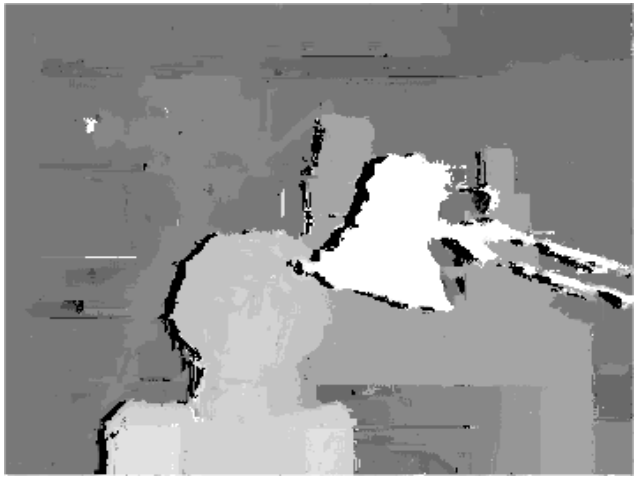


Left eye view



Right eye view

True disparity map
(red: occlusion)



Obtained disparity map

Image and Video Retrieval

- Image retrieval
  - Find similar images from image database
- Used features
  - Color
  - Texture
  - Shape

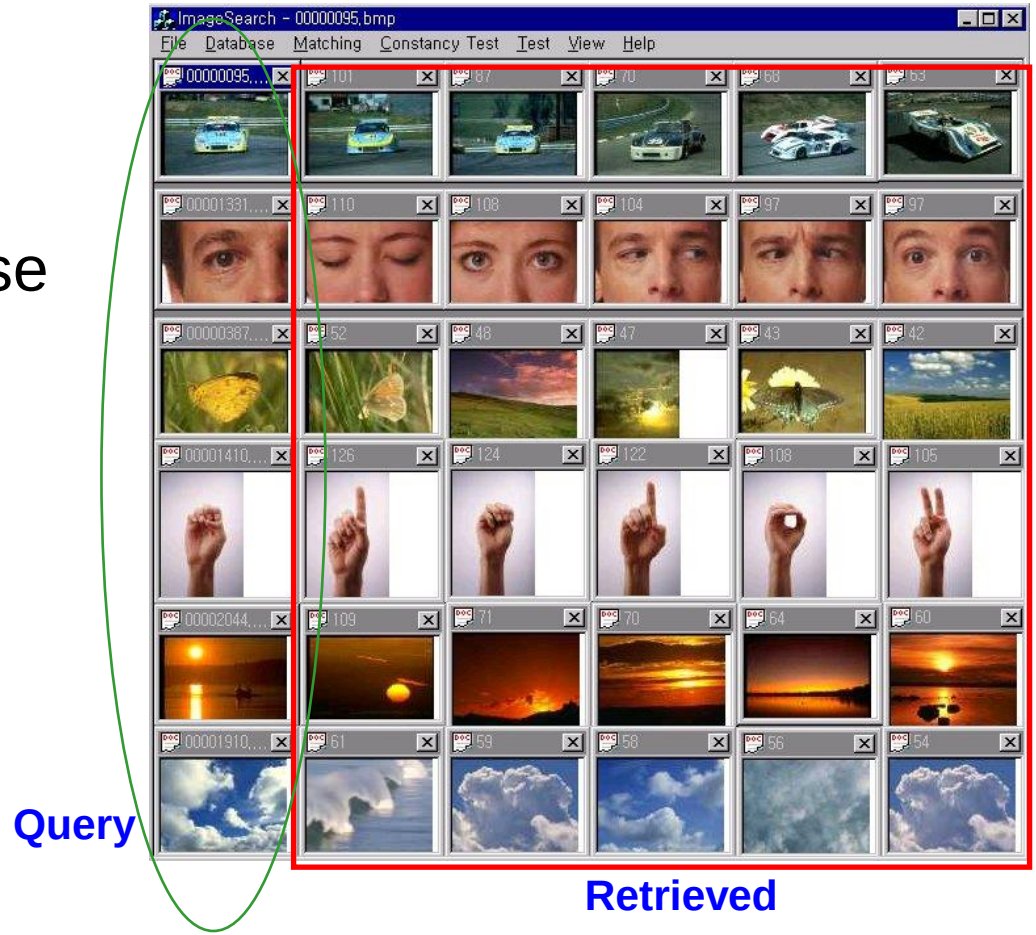


Image and Video Retrieval

- Video retrieval
  - Scene change detection and key frame extraction
  - Extract key frames from a movie clip

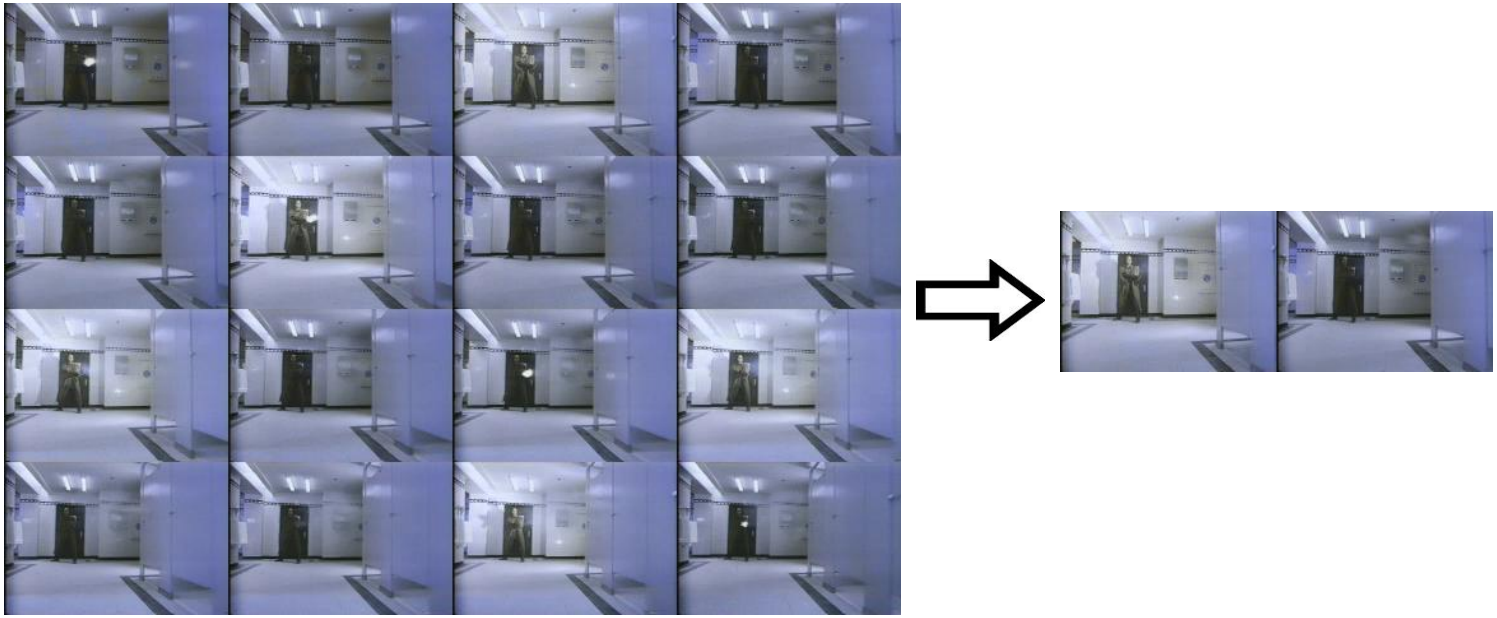
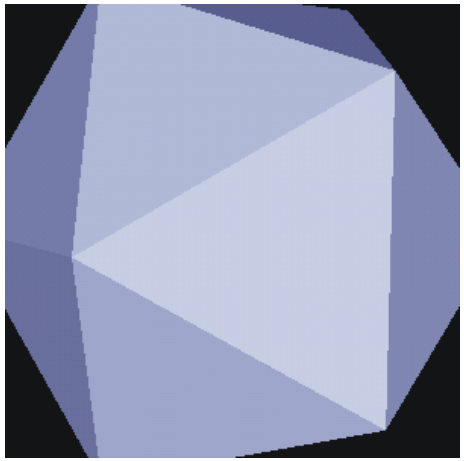
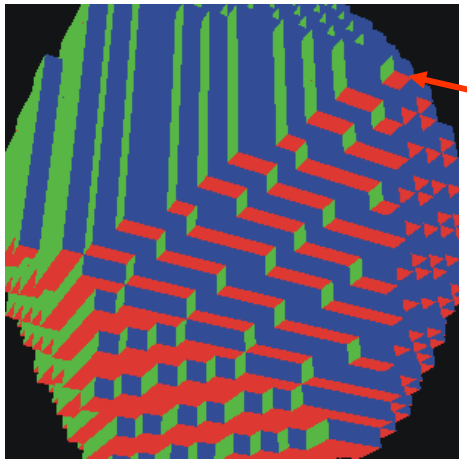


Image and Video Retrieval

- Key frame extraction example
  - Automatic indexing of a news sequence

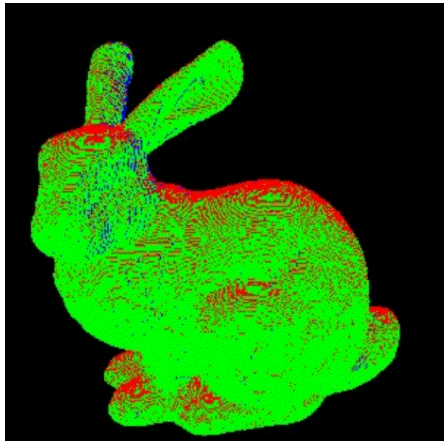
Graphic Image Processing



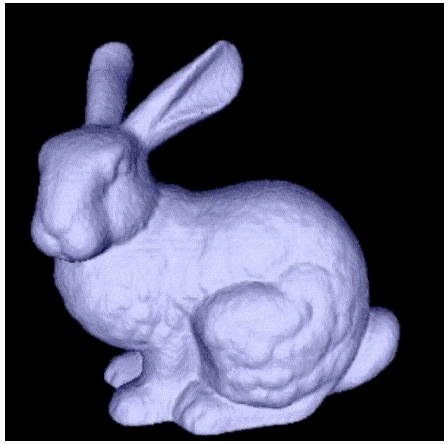


Voxel
(volume element)

(a) Original `bunny' mesh model



(b) Voxel surface of resolution 512^3



(c) Shading of (b) using normal vectors