Columbia University
in the City of New York

Digital Image Processing
ELEN E4830

Lecturers:
Shahram Ebadollahi
Lexing Xie

General Information

Mondays 4:10~6:40pm

4:10~5:20 part 1

5:20~5:30 break

5:30~6:40 part 2

Location: Mudd 1127, Room

Credits: 3.0

Offered on CVN

Course Webpage	**http://www.ee.columbia.edu/~xlx/ee4830/**

Target audience:

First year Graduate and Senior level students

Staff

- Lecturers/Staff:
  - Shahram Ebadollahi

    Research Staff Member, IBM T.J. Watson Research

    PhD from Columbia U. EE dept.

  - Lexing Xie

    Research Staff Member, IBM T.J. Watson Research

    PhD from Columbia U. EE dept.

  - TA: Graham Grindlay

    PhD student, LabROSA

How to reach us?

- Shahram Ebadollahi
  - E-mail: shahram@ee.columbia.edu
  - Office hours: Mondays 3:00~4:00pm
  - Office: 1312 Mudd (EE dept., Adjunct faculty office)
- Lexing Xie
  - E-mail: xlx@ee.columbia.edu
  - Office hours: Mondays 3:00~4:00pm
  - Office: 1312 Mudd
- Graham
  - E-mail: grindlay@ee.columbia.edu
  - Office hours:Thursdays 2-4pm
  - Office Location: 7LE4 CEPSR (LabROSA)
  - Office Phone: (212) 854-0235
  - Mailbox:TBA

Please contact the lecturer of the week for problems/question related to each lecture!

Use the discussion area in CourseWorks!

Our research

- Shahram Ebadollahi
  - Image/Video content understanding
  - Medical imaging informatics
- Lexing Xie
  - multimedia content analysis, data mining
  - statistical learning and signal processing in multimedia

Pre-requisites

- Signals & Systems
- Linear Algebra
- Probability

- If you haven't taken these courses please see us during the break TODAY!

Outline

- Part I [Shahram Ebadollahi]
  - Course protocol, policy, and all that
  - Introduction to DIP and examples of applications
  - Course outline
  - Brief review of signals and systems
- Break
- Part II [Lexing Xie]
  - Introduction to MATLAB for Image Processing
  - Brief review of linear algebra and probability

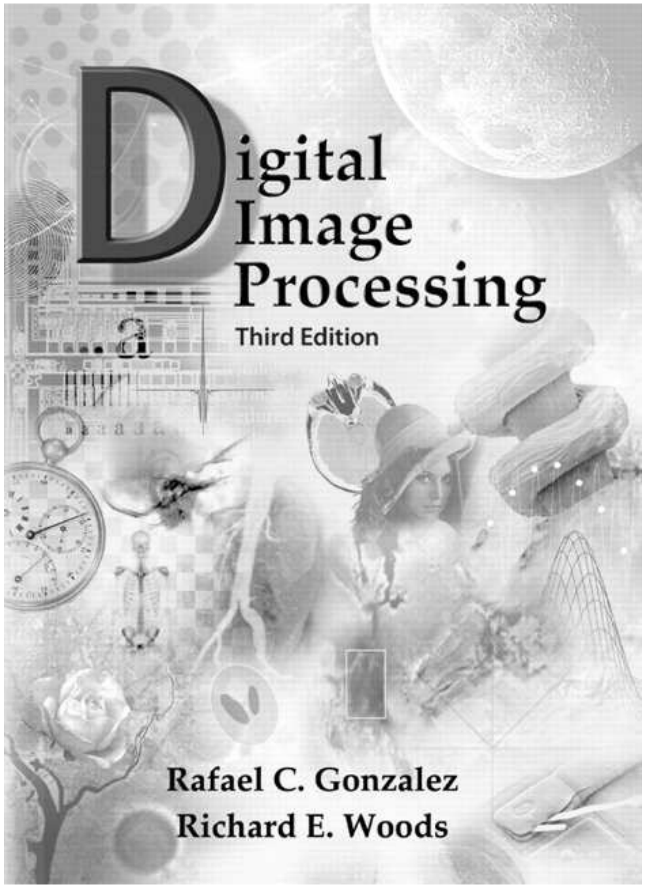
Protocol & Policies

Course textbook

- **Digital Image Processing,** 3rd Edition by Gonzalez and Woods, Prentice Hall 2008 (ISBN 9780131687288)

- Very well written book
- Broad coverage of the subject
- Accessible by wide audience

- Other references: see course web-page!



Assignments

- 6 assignments
- Due at: END OF DAY OF CLASS IN TA's MAILBOX OR EMAIL INBOX! (NO EXCEPTIONS)
- Solutions and graded homeworks will be handed out the week after you hand in your assignments.
- Types of questions in the assignment:
  - <u>Analytical</u>
  - <u>Experimental</u>

    A problem which require some programming and experimentation.

    e.g.

    1) change parameters of an image processing algorithm, observe the effect, comment on your findings

    2) how do you think this image could be enhanced? Show it! Why this approach?

    [Programming: minimum MATLAB]

2 Exams

- Midterm (03/9/2009)
  - 150 minutes
  - Open book
- Final (05/11/2009)
  - 3 hours
  - Open book

Grading Policy

- Homeworks: 30%
- Midterm: 30%
- Final: 40%
  - All material will be covered in the final exam

DIP Introduction

Eye

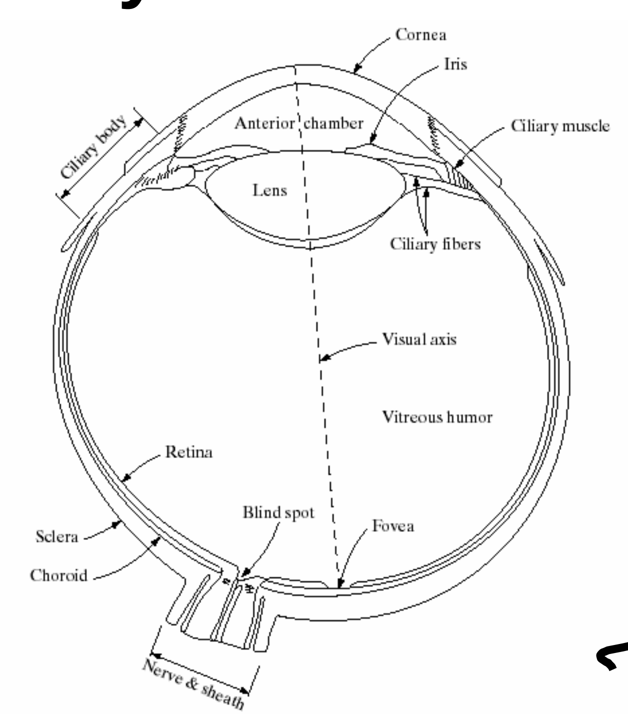
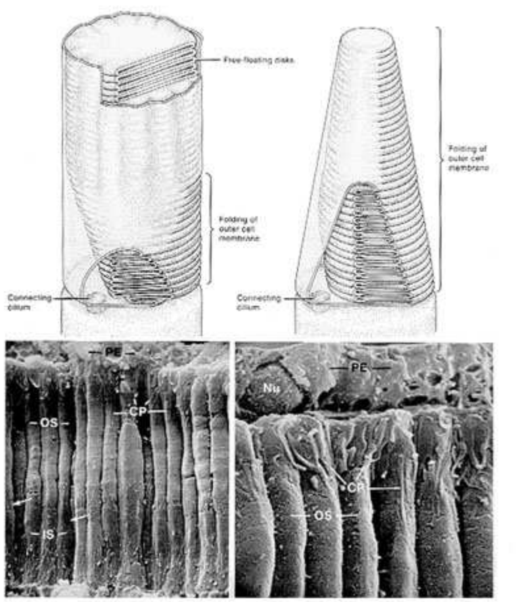


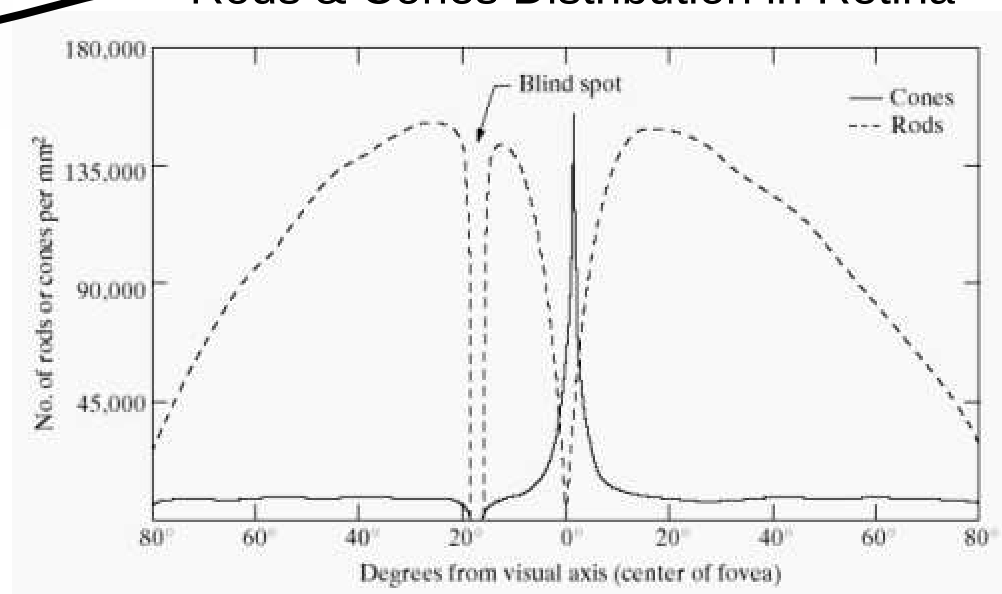
FIGURE 2.1 Simplified diagram of a cross section of the human eye.

- 75~150 Million
- Sensitive to low illumination
- Distributed over Retina
- Scotopic (dim light) vision

- 6~7 Million
- Highly sensitive to color
- Concentrated in Fovea
- Photopic (day light) vision



Rods & Cones Distribution in Retina



Brightness

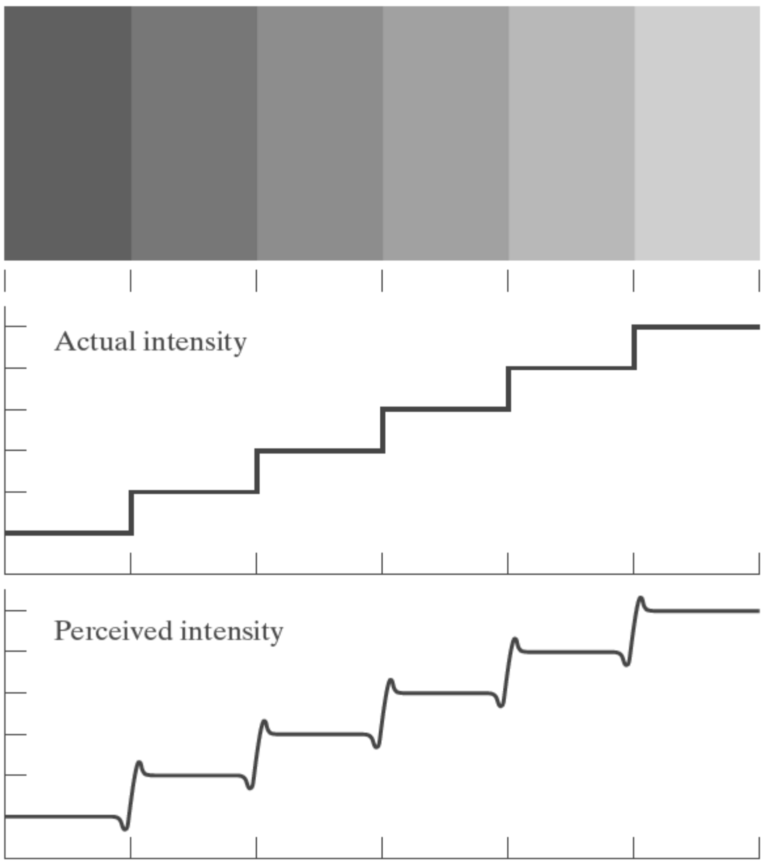
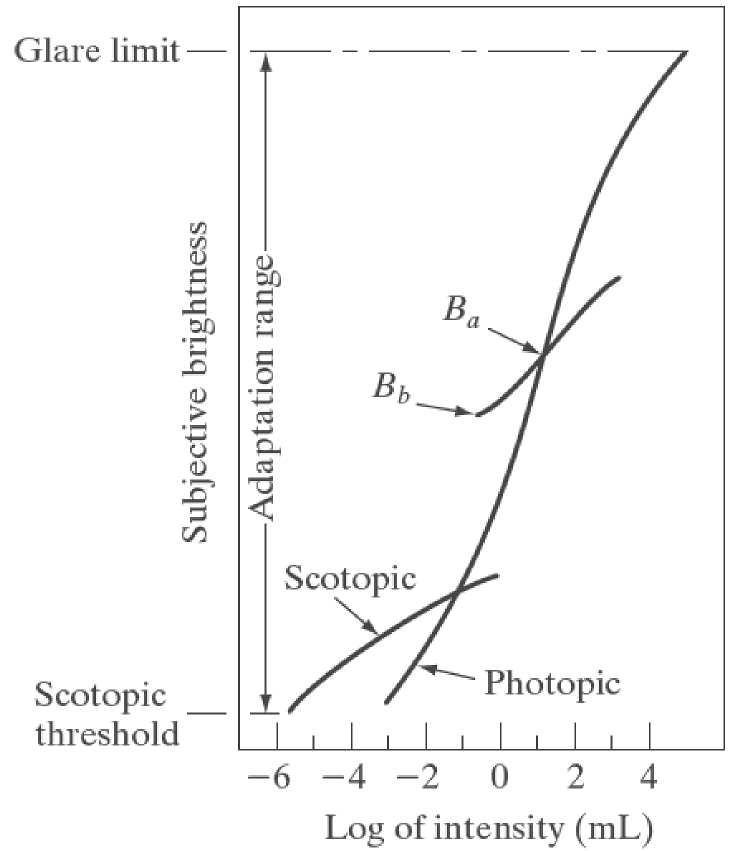


FIGURE 2.4
Range of subjective brightness sensations showing a particular adaptation level.



a
b
c

FIGURE 2.7
Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.

Electromagnetic Spectrum & more

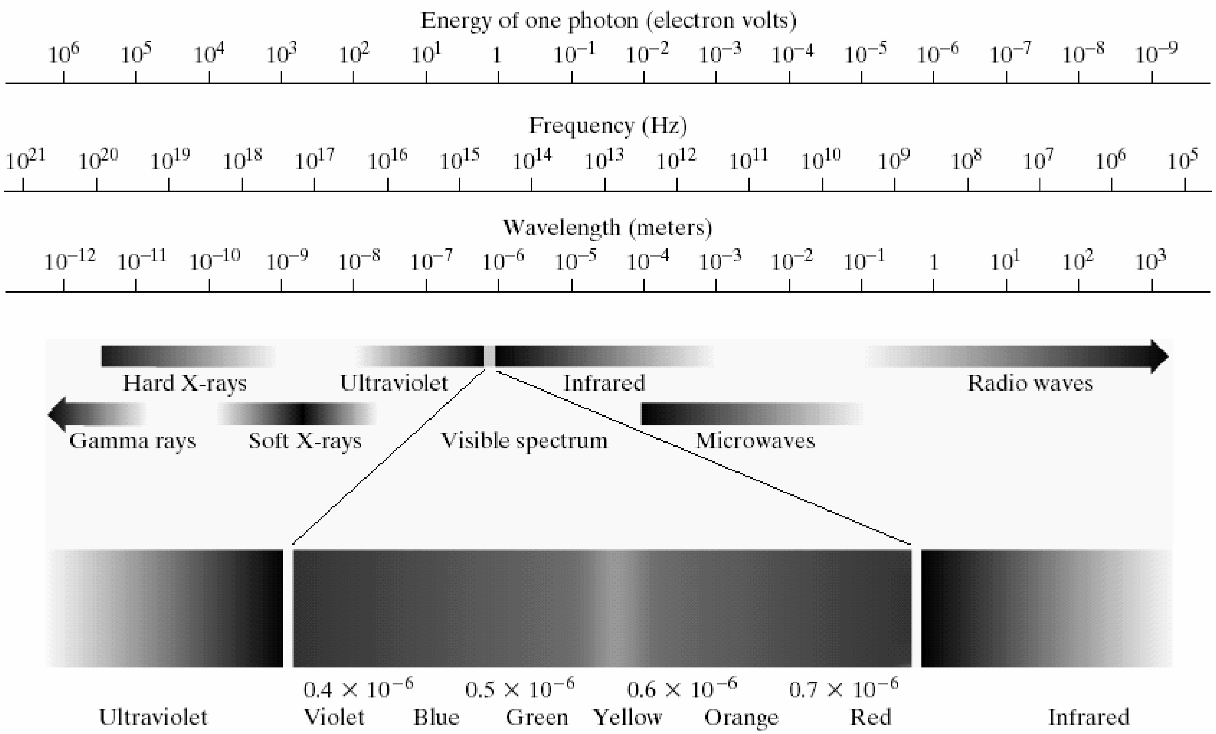
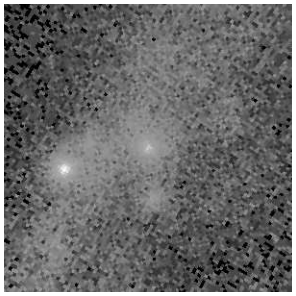
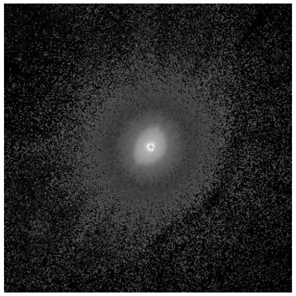


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

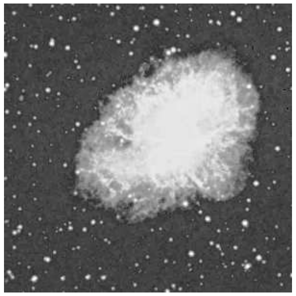
Crab Pulsar



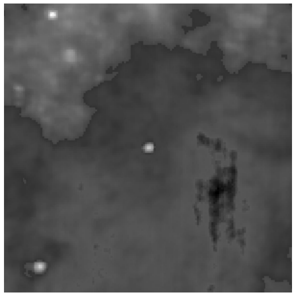
Gamma



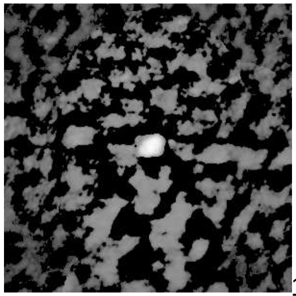
X-ray



Optical



Infrared



Radio

Image

- Image = 2d function

$$f(x, y) \in R \qquad x, y \in R$$

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

Illumination reflectance

$$0 \leq f(x, y) \leq F$$

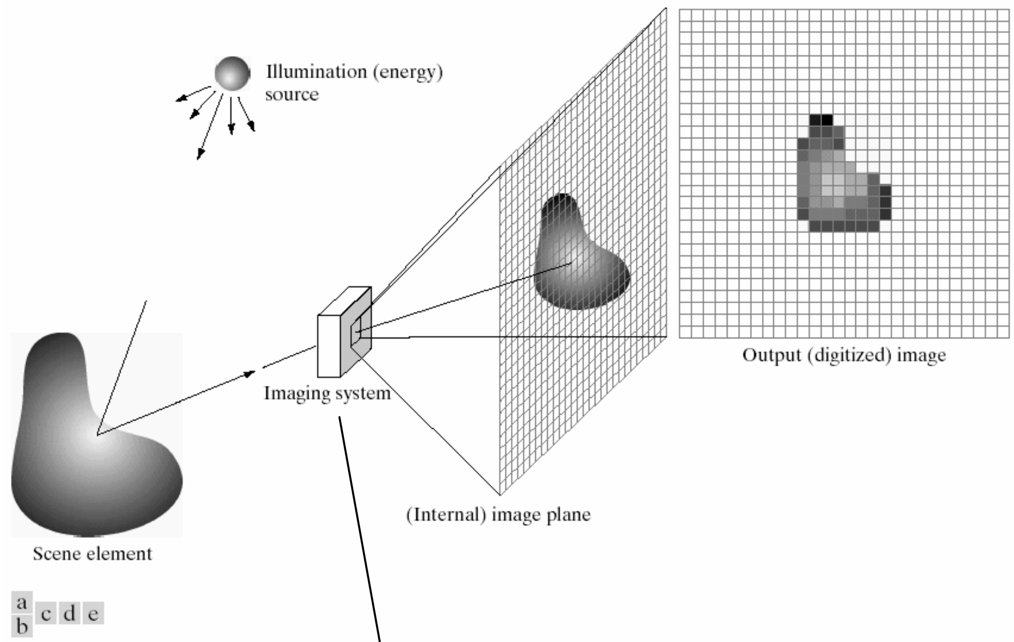


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

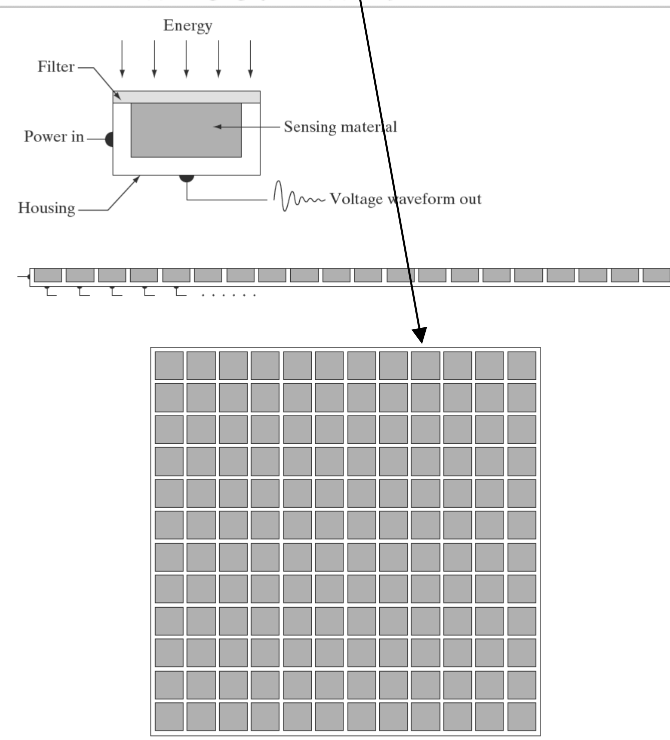
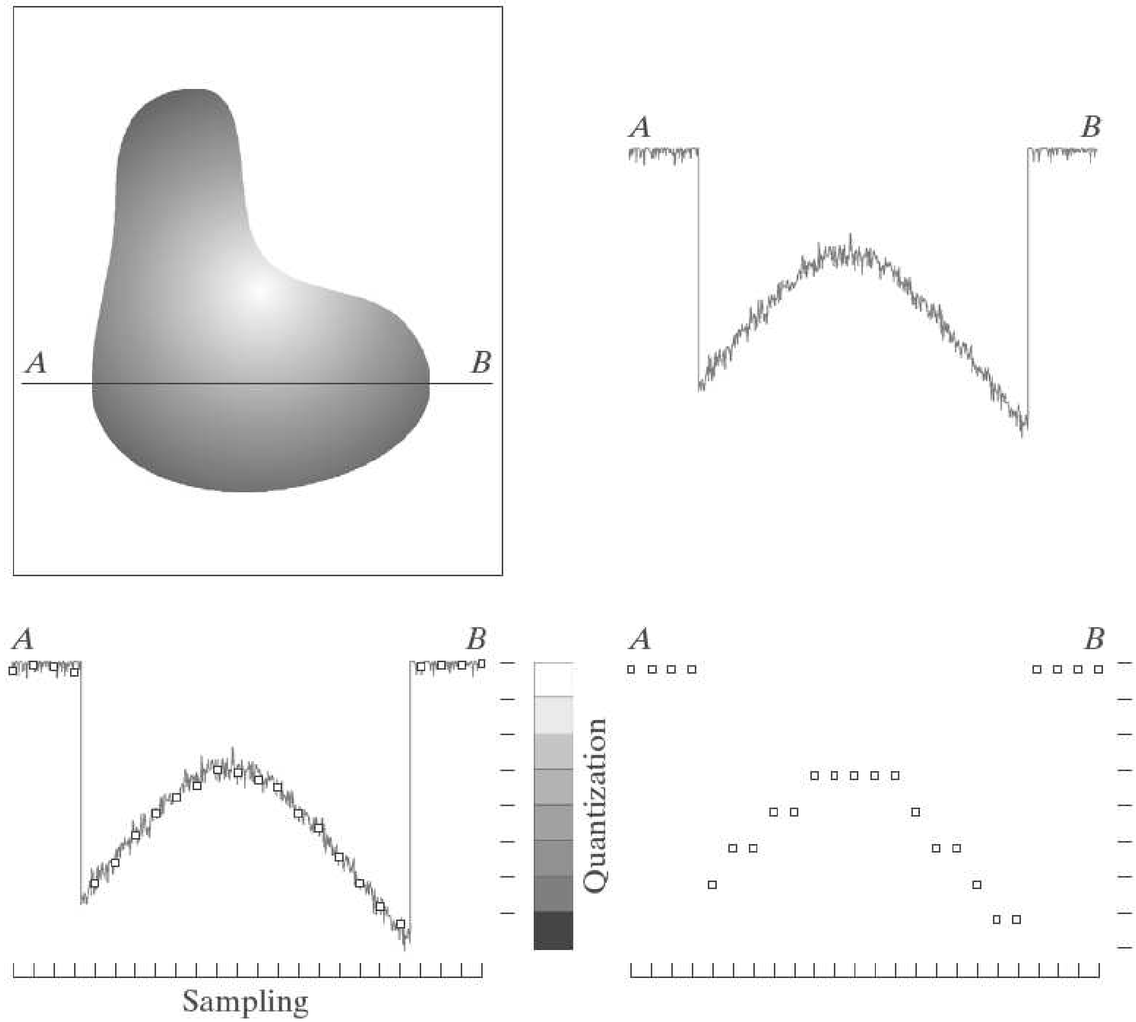


Image Digitization



Image

- Image = 2d function

$$f(x, y) \in R \qquad x, y \in R$$

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

Illumination reflectance

$$0 \leq f(x, y) \leq F$$

$$0 \leq x \leq X$$

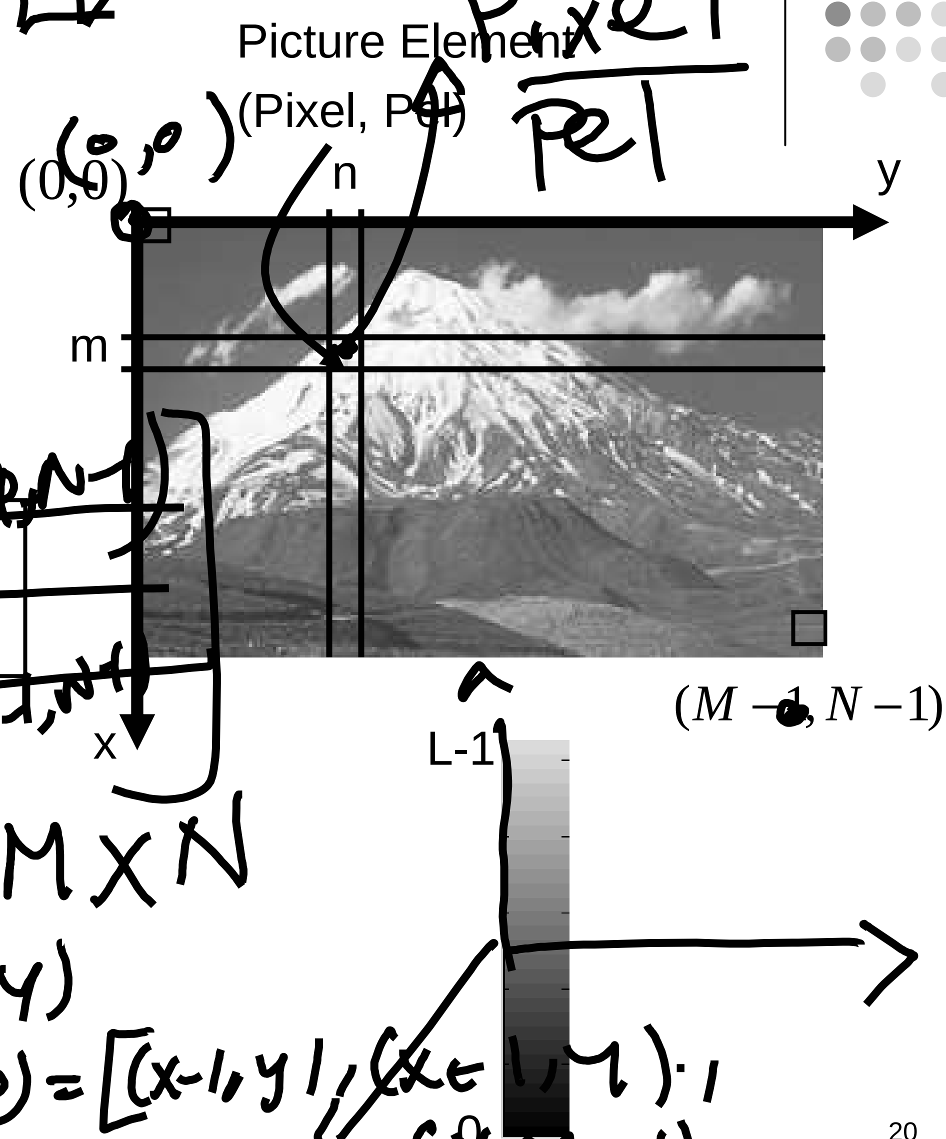
$$0 \leq y \leq Y$$

Digital Image

- Discretization
  - Spatial sampling
  - Quantization

$f(m,n) \in Z \qquad m,n \in Z$

$0 \le f(m,n) \le L-1$	$0 \le m \le M-1$ $0 \le n \le N-1$



Spatial Resolution

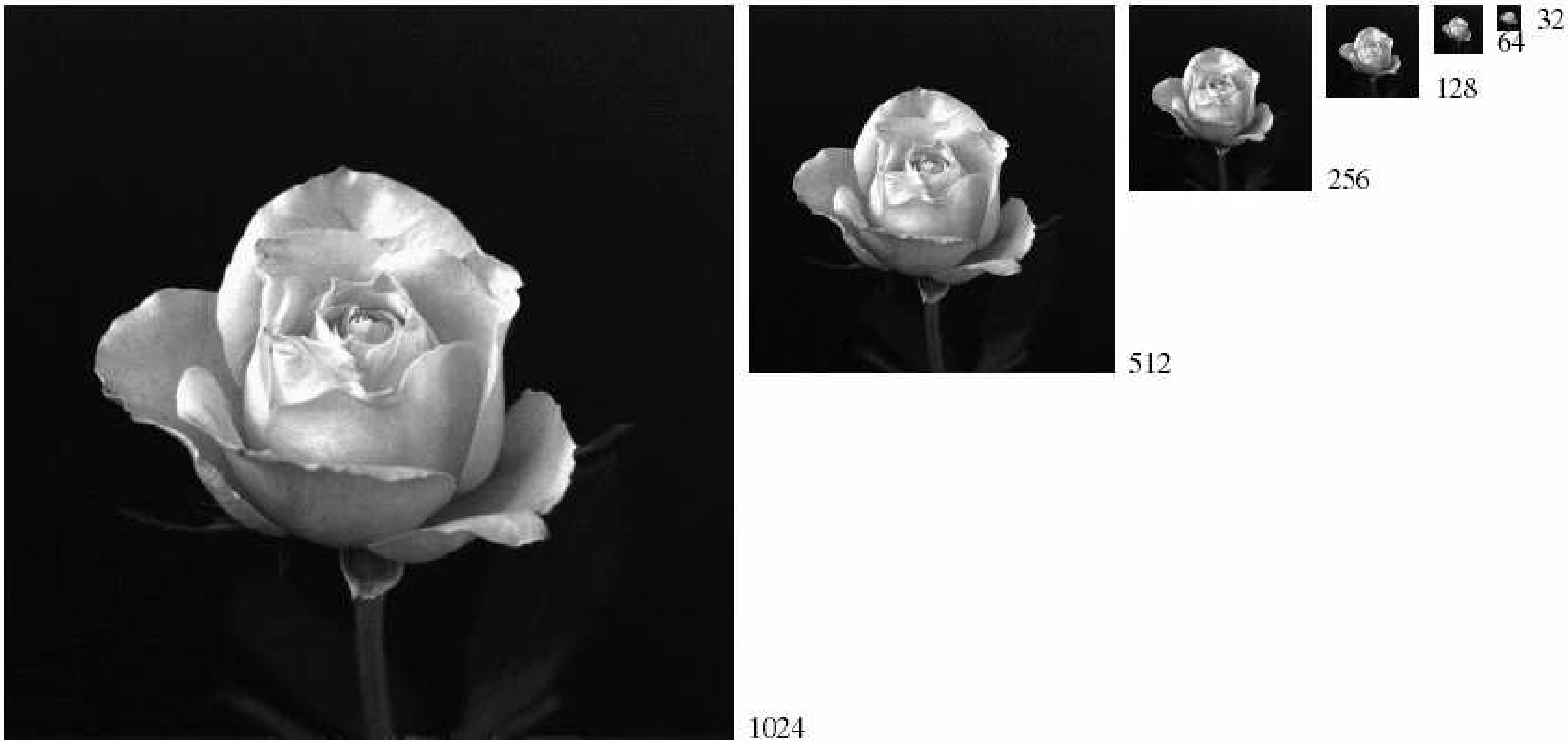
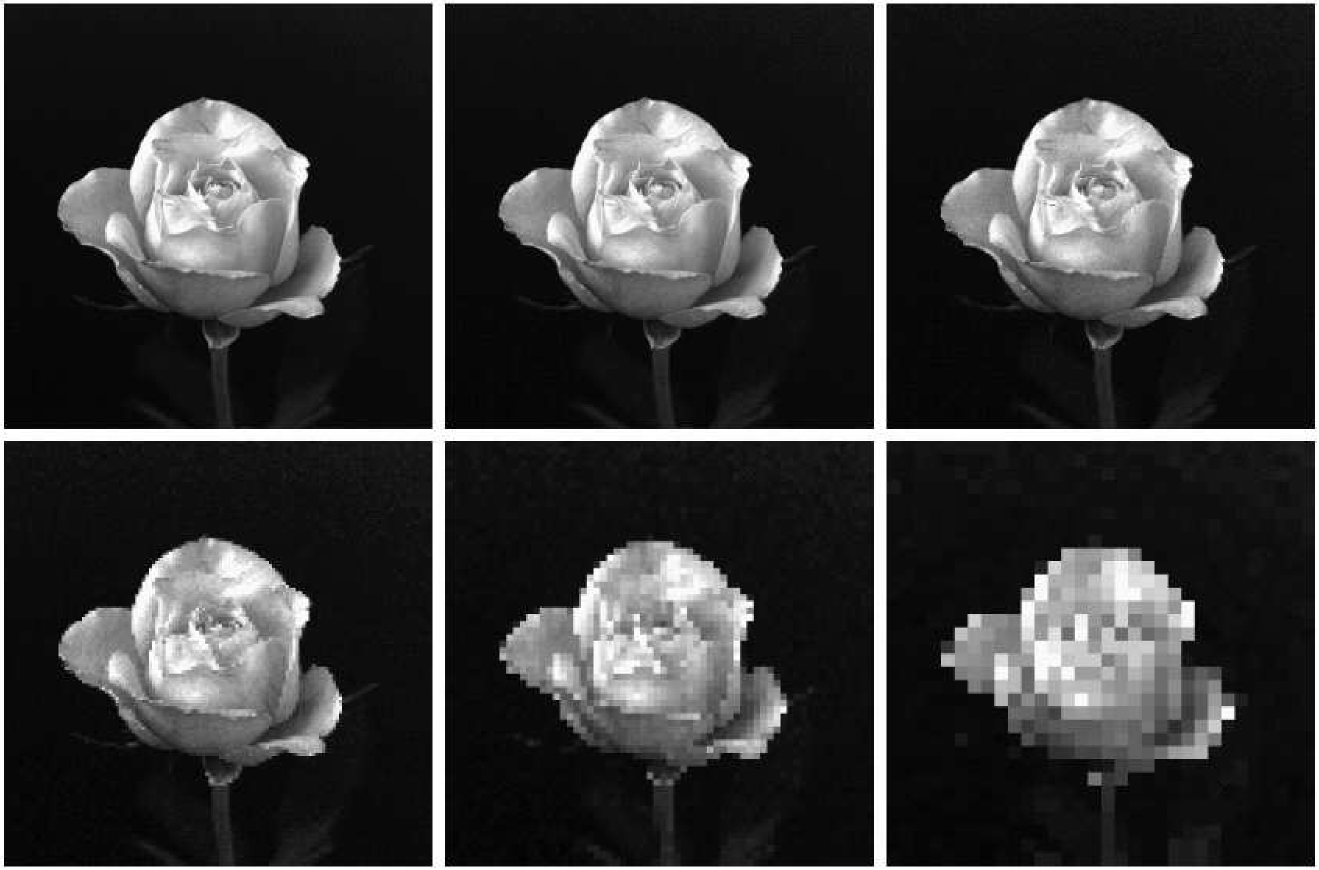


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

Spatial Resolution



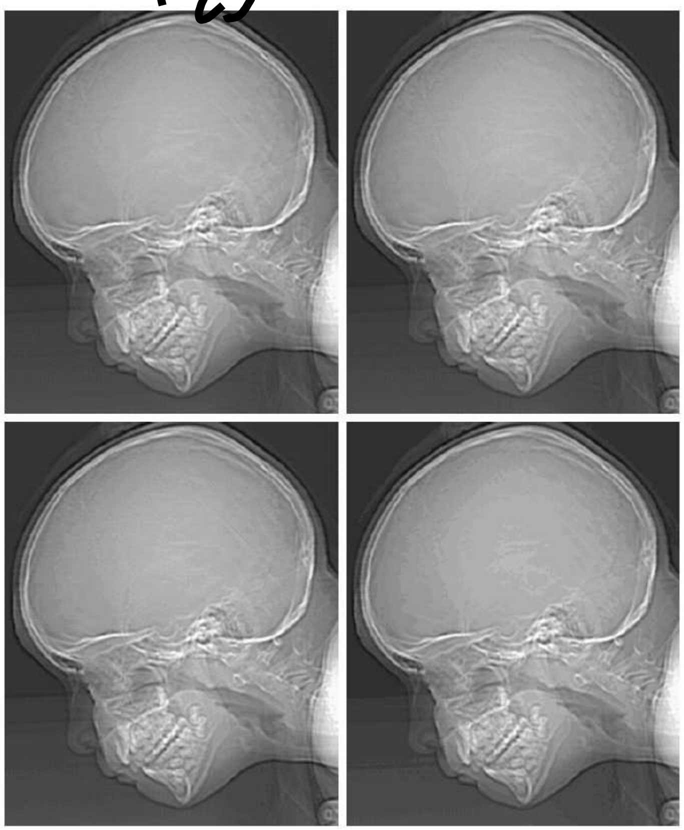
a b c
d e f

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.

Gray-level Resolution

$L = 2^{k=8}$ = 256 $b = M \times N \times k$

$1024 \times 1024 \times 8$

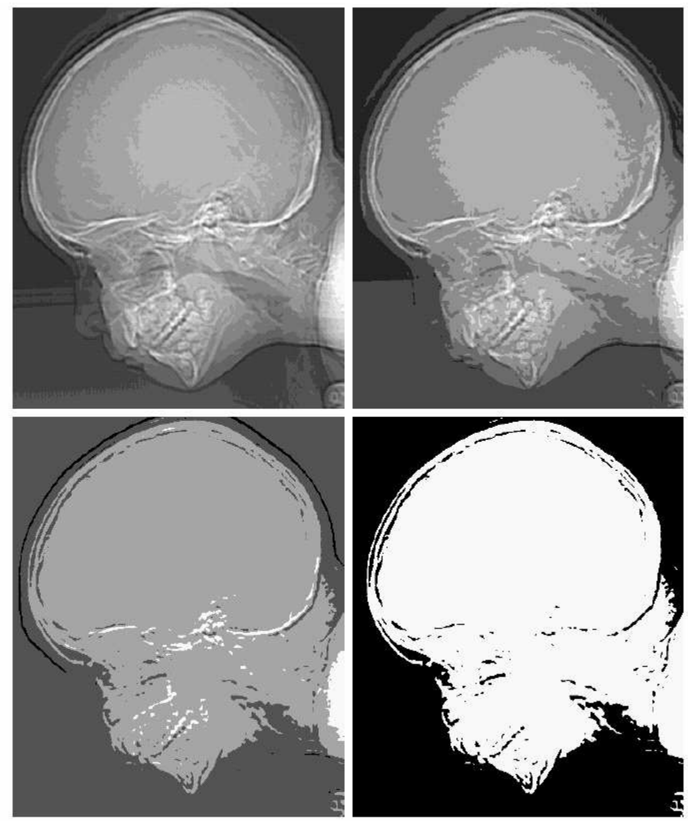


a b
c d

FIGURE 2.21 (a) 452 × 374, 256-level image. (b)–(d) Image displayed in 128, 64, and 32 gray levels, while keeping the spatial resolution constant.

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.)

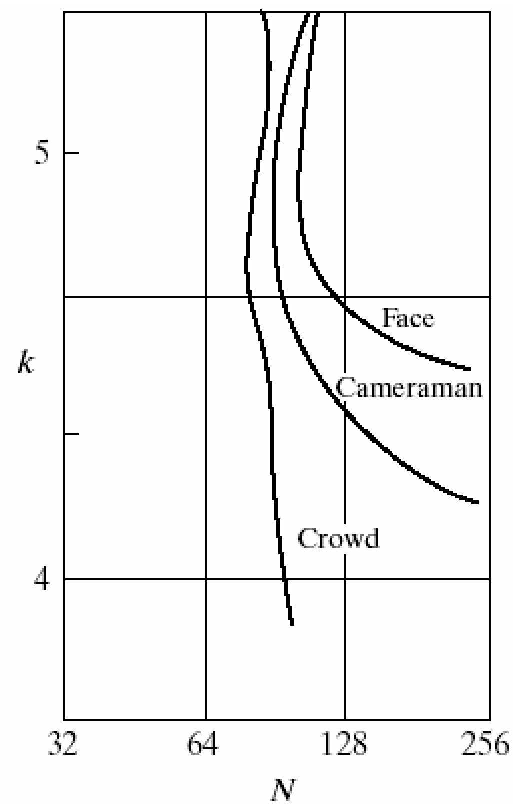


Spatial and Gray-level Resolution

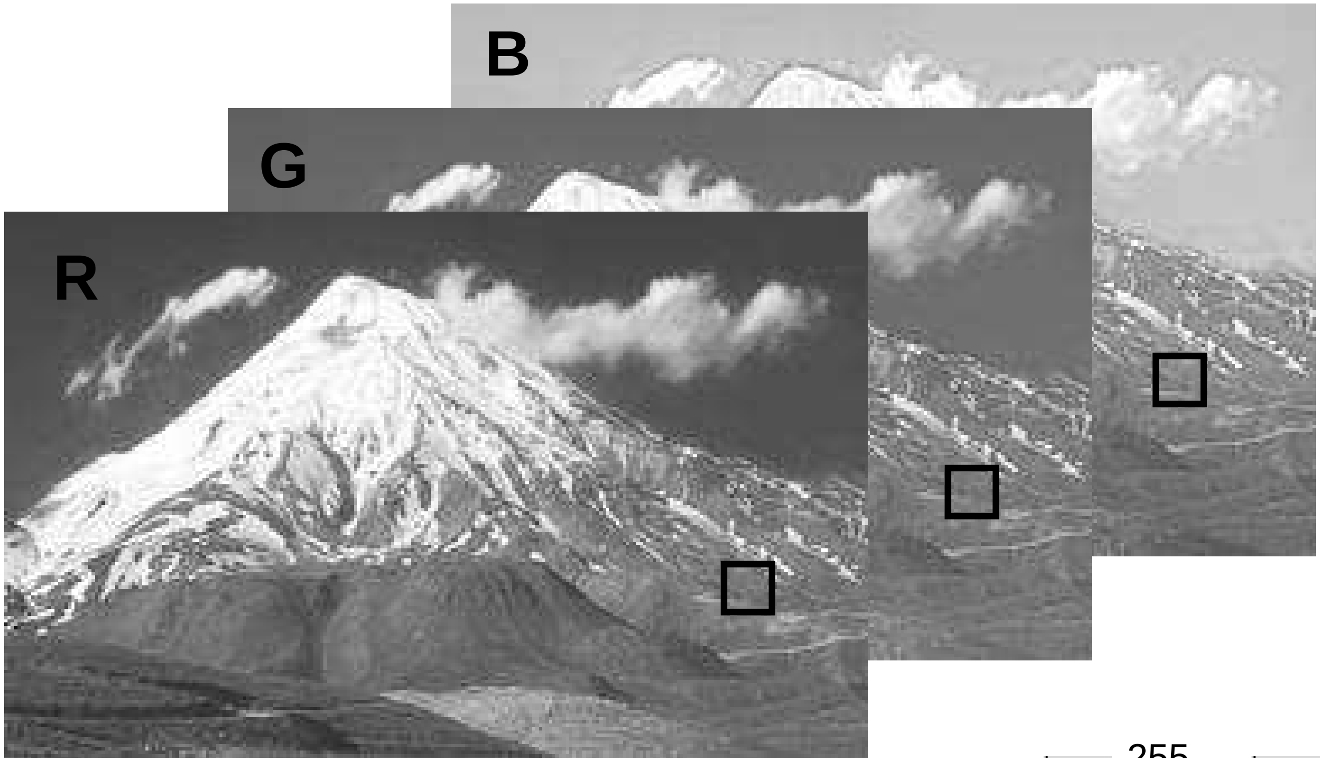
a b c

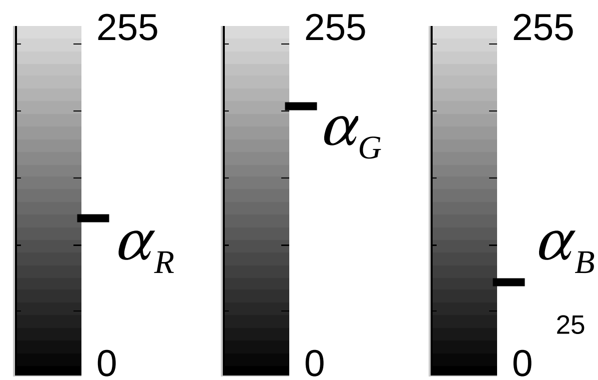
FIGURE 2.22 (a) Image with a low level of detail. (b) Image with a medium level of detail. (c) Image with a relatively large amount of detail. (Image (b) courtesy of the Massachusetts Institute of Technology.)

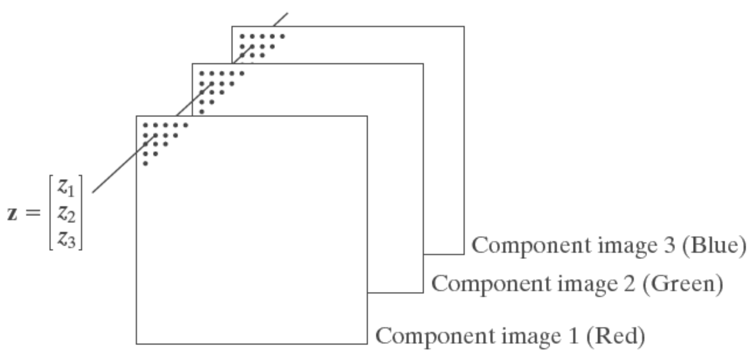
FIGURE 2.23 Representative isopreference curves for the three types of images in Fig. 2.22.



Color Image







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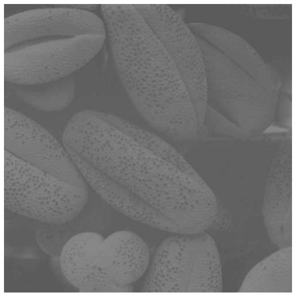
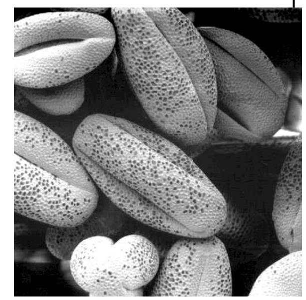
Digital Image Processing



Low level



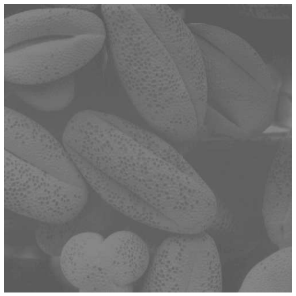
Mid level

$$\bar{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_P \end{bmatrix}$$

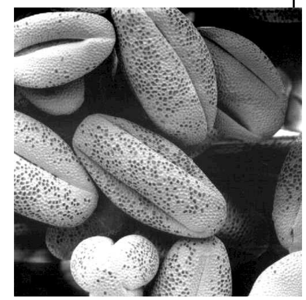
High level

IN THE CITY OF NEW YORK

Digital Image Processing



Low level



Mid level

$$\bar{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_P \end{bmatrix}$$

High level

Communication & Storage

What are we going to study?

Lecture No.	Date	Lecturer	Subject
1	1.26	SE/LX	Course Mechanics, Introduction to Image Processing, Introduction to MATLAB
2	2.2	SE	Digital Image Fundamentals (ch2): Sensing, Sampling, and Quantization
3	2.9	SE	Gray-level, Color and Multi-band Images (ch3 & 6), Video
4	2.16	LX	Image Enhancement in Spatial Domain (ch3& 6)
5	2.23	LX	Image Enhancement in Frequency Domain (ch4)
6	3.2	LX	More Image Transform, Wavelets (ch7)
Mid-term	3.9		
7	3.23	LX	Image Restoration (ch5)
8	3.30	SE	Morphological Image Processing (ch9)
9	4.6	SE	Image Segmentation (ch10)
10	4.13	SE	Image Description (ch11)
11	4.20	SE	Object Recognition (ch12)
12	4.27	LX	Image Compression (ch8)
13	5.4	LX	Applications: medical, cbir, ...

Why study DIP?

- Image & video is a major communication media
  - "An image is worth 1000 words!"
- In all application domains, image and video is becoming indispensable
- WWW, faster computation, more storage, proliferation of image capture and consumption devices → Need for more, better, faster, and more intelligent image and video analysis
- It's fun!

Application Domains

- Consumer domain
  - Storage, tagging, searching,…
- Remote sensing
  - Agriculture, Urban growth monitoring, …
- Medical
  - CAD, quantification, organization, assisted surgery, …
- Space explorations
  - Image mosaic, image matching, …
- Art
  - Working methods of painters, material used, …
- Security
  - Surveillance, monitoring, …
- Military
- … and many more!

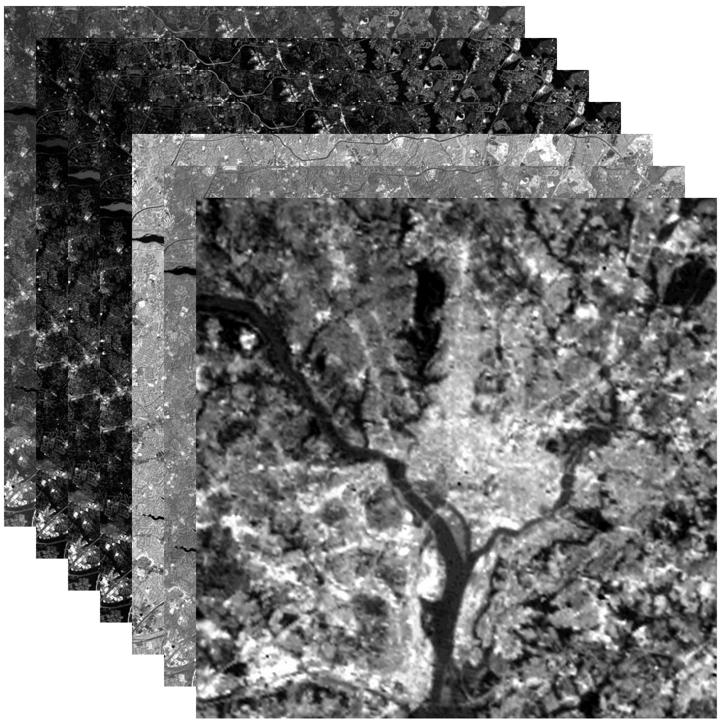
Application Domains

- Consumer domain
  - Storage, tagging, searching,…

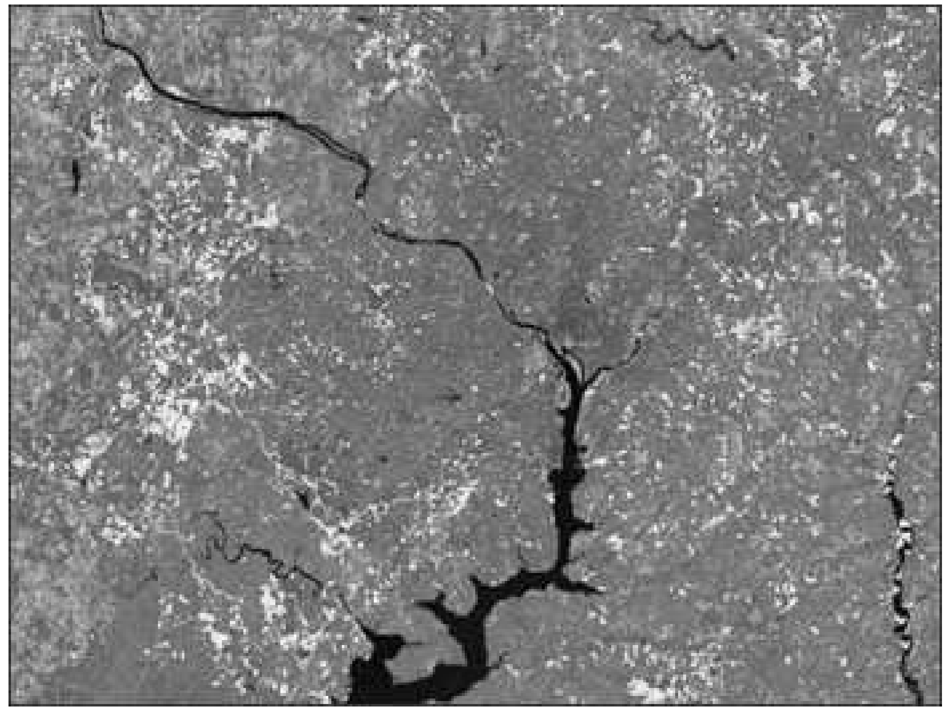
mountain, snow, buildings, sky

Application Domains

- Remote sensing
  - Agriculture, Urban growth monitoring, …



Multi-spectral imaging

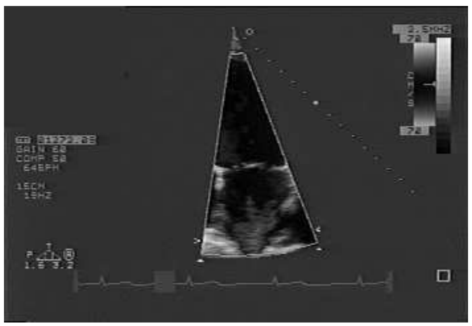


Urban growth in Washington D.C. between 1973 and 1985

[Image courtesy of NASA/LANDSAT]

Application Domains

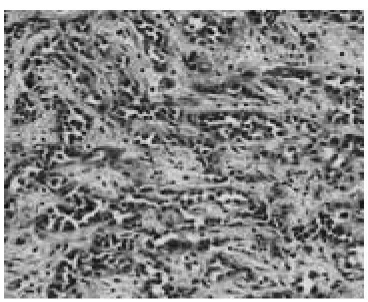
- Medical
  - CAD, quantification, organization, assisted surgery, …



Color doppler Echocardiogram

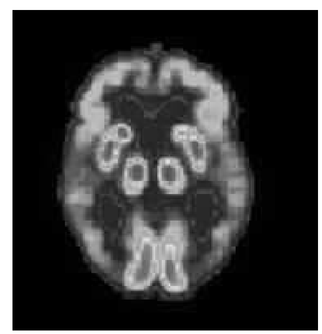
Brain MRI

Cardiac CT



Tissue Microscopy

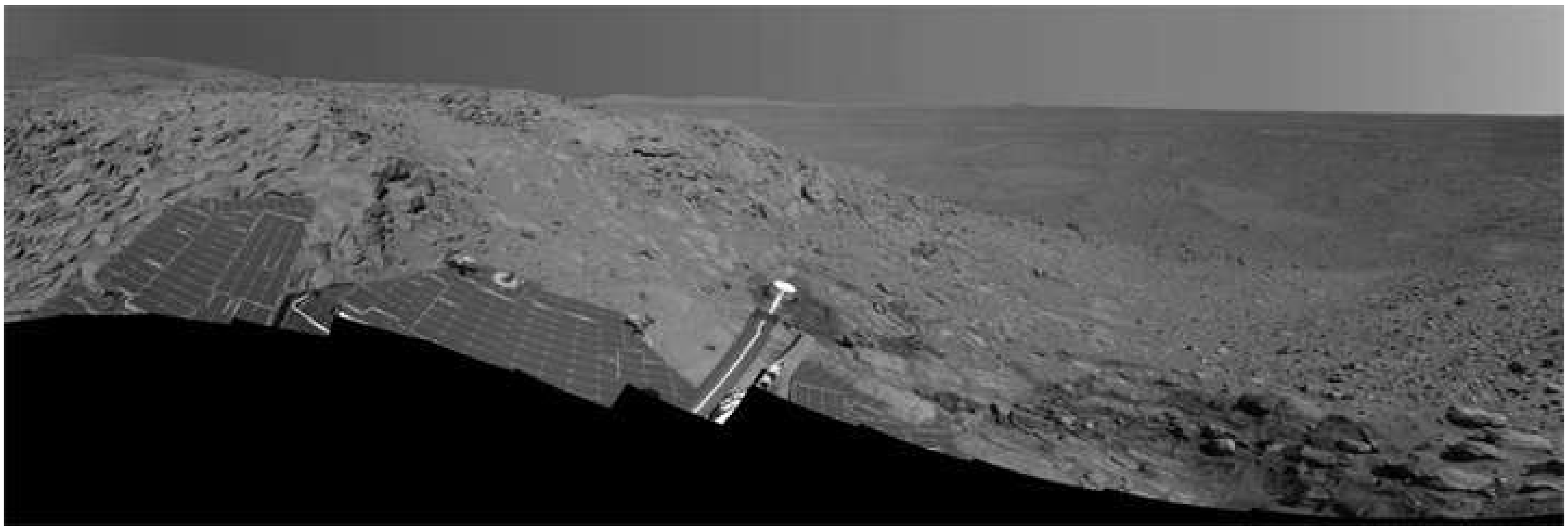
Spine X-ray



Brain PET (Alzheimers)

Application Domains

- Space explorations
  - Image mosaic, image matching, …



Panoramic image built from images taken from mars rover Spirit

[image courtesy of NASA/JPL/Cornell]

Review of Signals & Systems