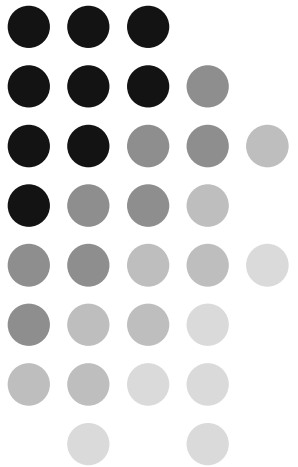
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

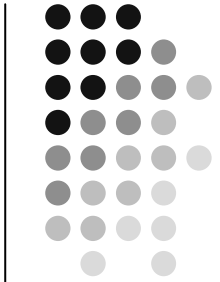
Digital Image Processing

ELEN E4830

Professors:
Shahram Ebadollahi
Lexing Xie



General Information



Spring 2008
Mondays 4:10~6:40pm
Location: Eng. Mudd 1127
Credits: 3.0
Offered on CVN

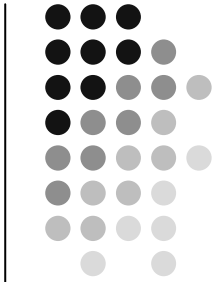
4:10~5:20 part 1
5:20~5:30 break
5:30~6:40 part 2

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.

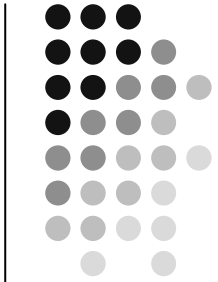
  - Lexing Xie

    Research Staff Member, IBM T.J. Watson Research

    PhD from Columbia U. EE dept.

  - TA: Wei Liu

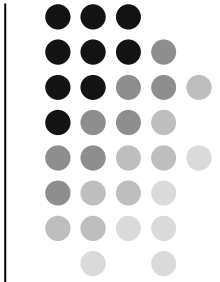
How to reach us?



- Shahram Ebadollahi
  - E-mail: shahram@ee.columbia.edu
  - Office hours: Mondays 3:00~4:00pm
  - Office: 1312 Mudd
- Lexing Xie
  - E-mail: xlx@ee.columbia.edu
  - Office hours: Mondays 3:00~4:00pm
  - Office: 1312 Mudd
- Wei Liu
  - E-mail: wl2223@columbia.edu
  - Office hours:TBD
  - Office: 711 CEPSR
  - Mailbox:TBD

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

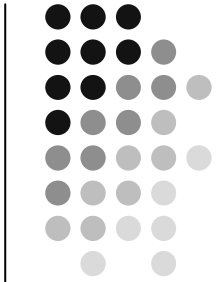
Our research



- Shahram Ebadollahi
  - Image/Video content understanding
  - Medical imaging informatics

- Lexing Xie
  - multimedia content analysis, data mining
  - statistical learning and signal processing in multimedia

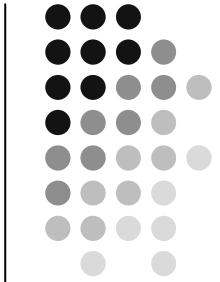
Pre-requisites



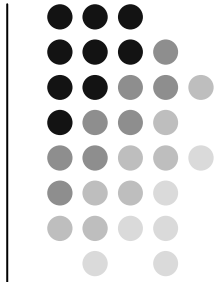
- Signals & Systems
- Linear Algebra
- Probability

- If you haven't taken these courses please see us after the class 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



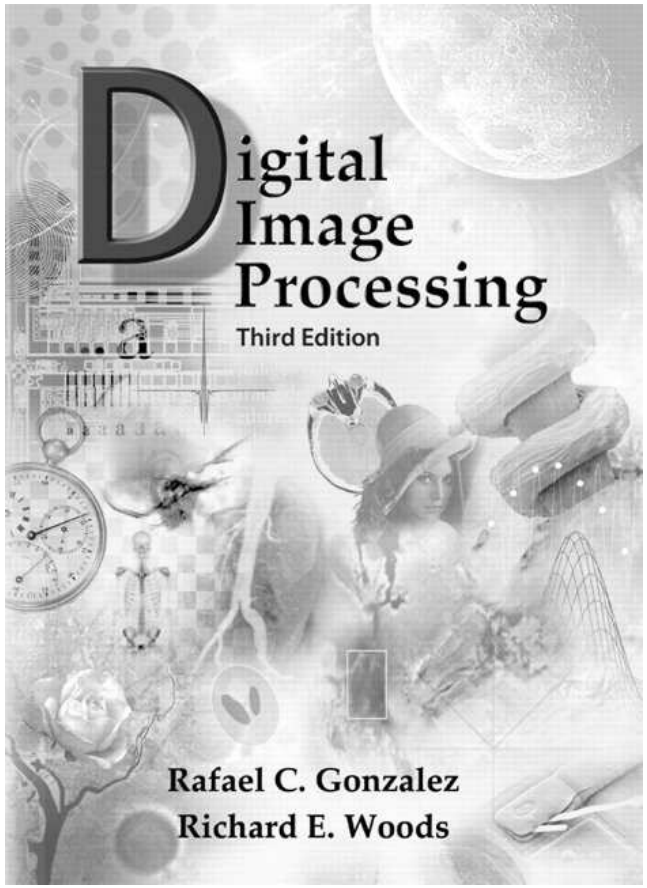
Course Protocols & Policies

Course textbook

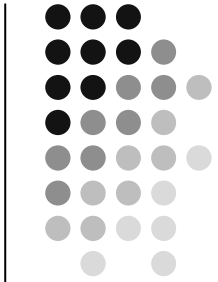
- **Digital Image Processing,** 3rd Edition by Gonzalez and Woods, Prentice Hall 2008 (ISBN 9780131687288)

- 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:
  - Analytical
  - Experimental

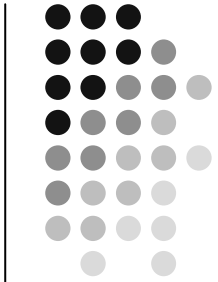
    A problem which require some programming and experimentation.

    e.g.

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

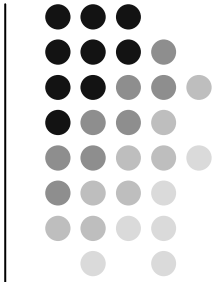
    2) how do you think this image could be enhanced? Show it! Why this approach?

2 Exams

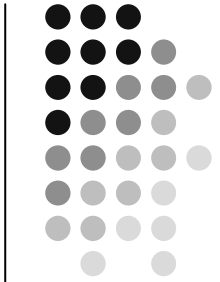


- Midterm (03/10/2008)
  - 150 minutes
  - Open book
- Final
  - 3 hours
  - Open book

Grading Policy



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



DIP Introduction

Eye Physiology

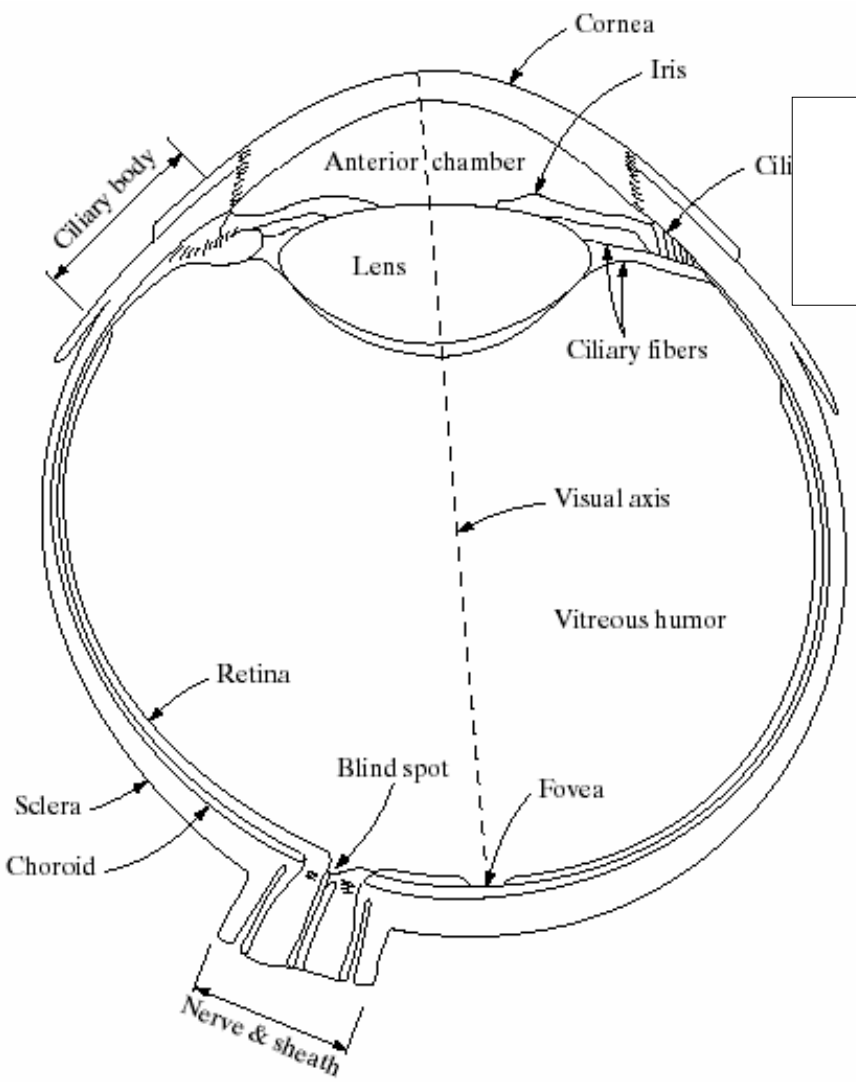
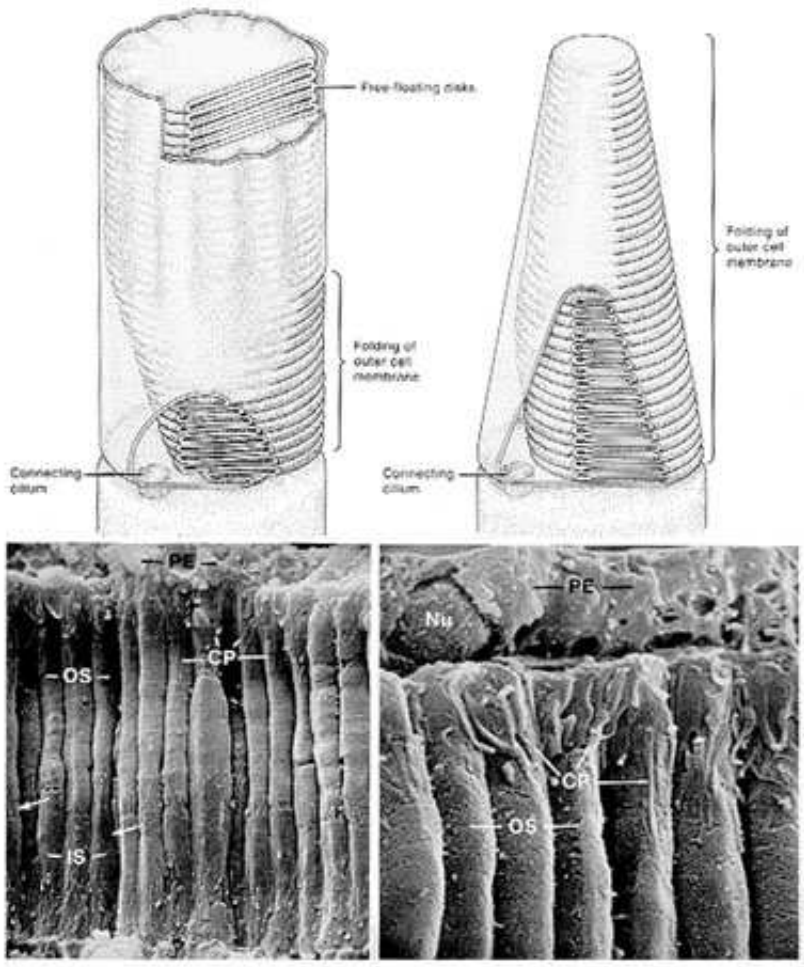


FIGURE 2.1
Simplified diagram of a cross
the
e.

Eye Physiology & Visual Perception

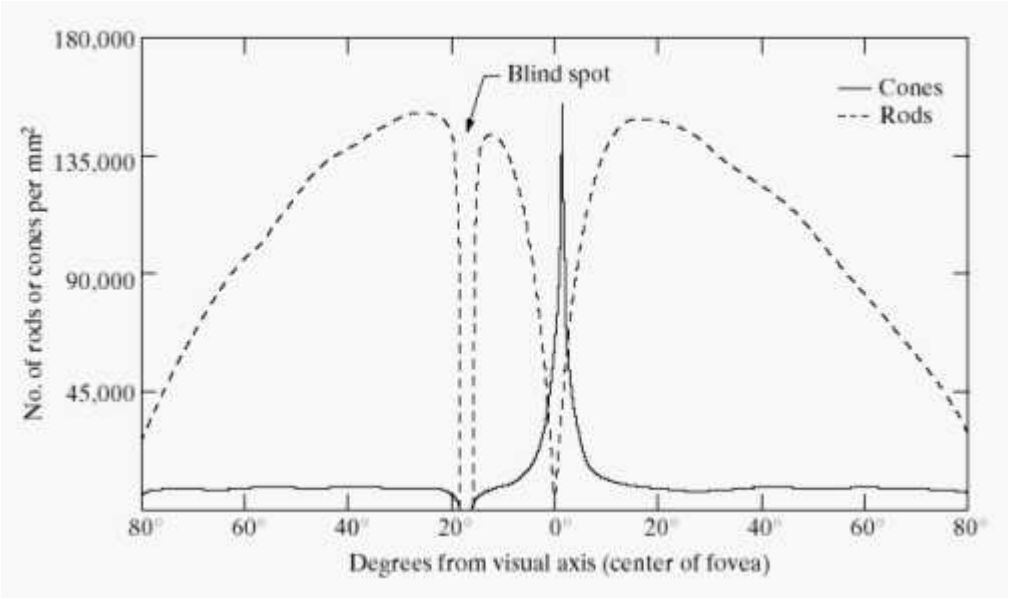


Photoreceptor Cells

- 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



Electromagnetic Spectrum & more

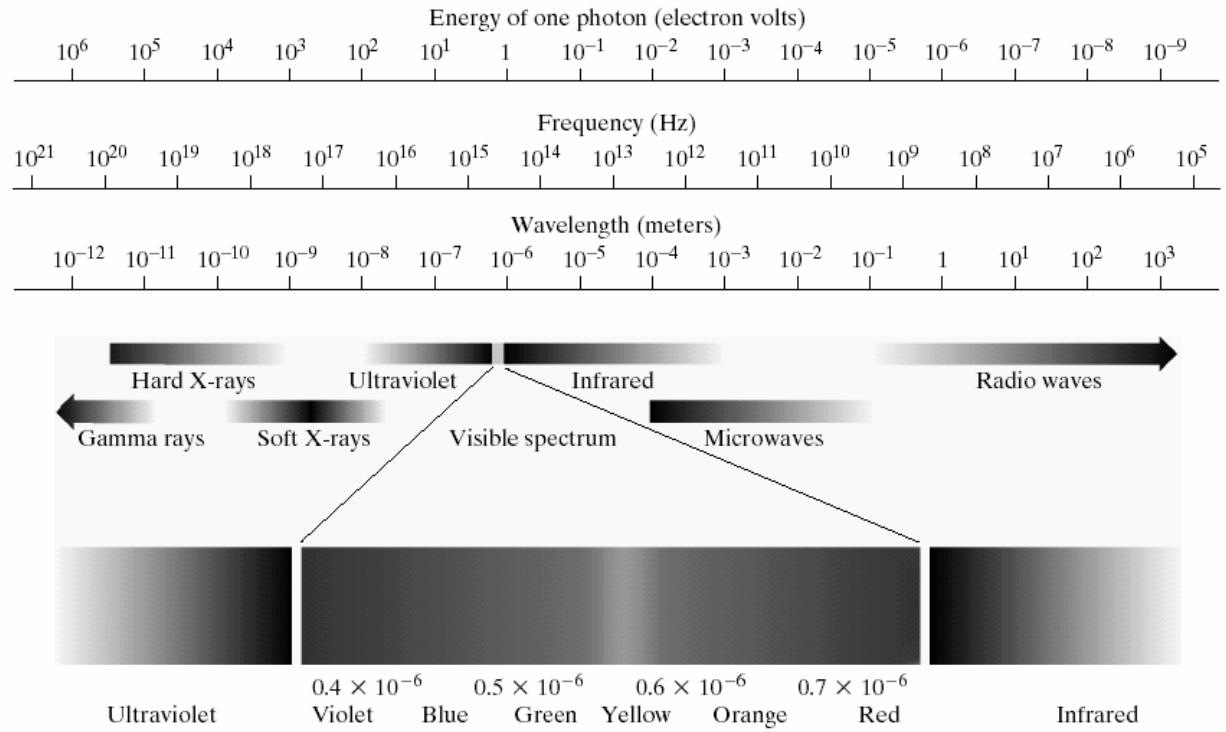
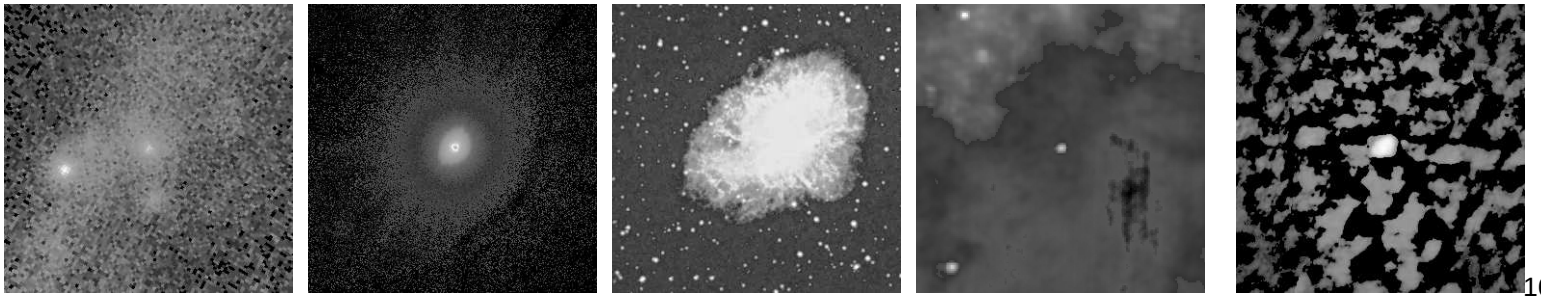


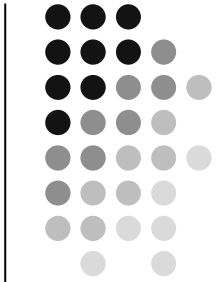
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Crab Pulsar



Gamma X-ray Optical Infrared Radio

Image



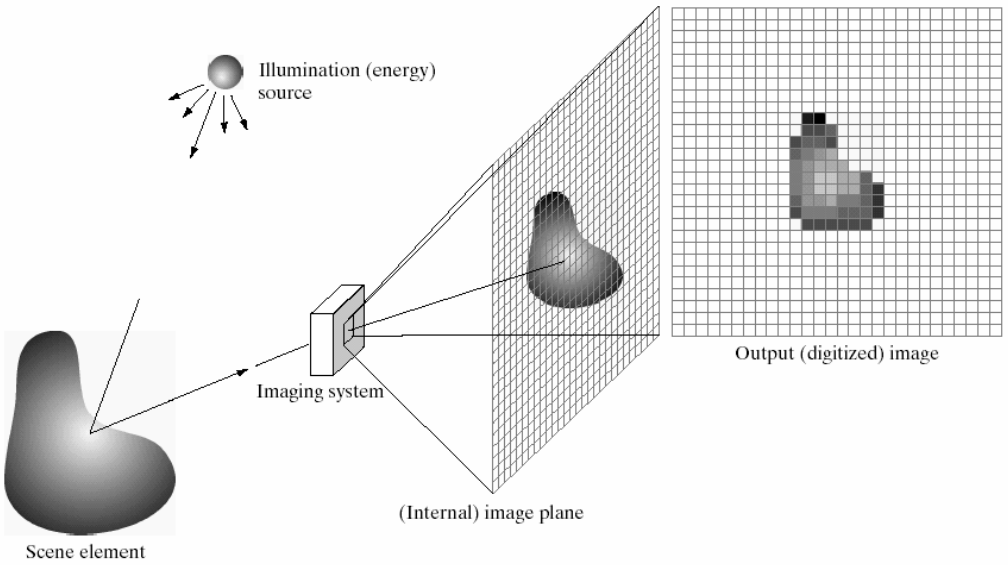
- Image = 2d function

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

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

Illumination reflectance

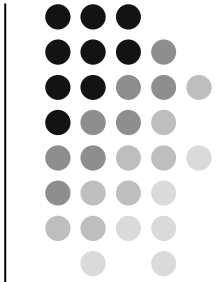
$$0 \le f(x,y) \le F$$



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



- Image = 2d function

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

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

Illumination reflectance

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

$$0 \le x \le X$$

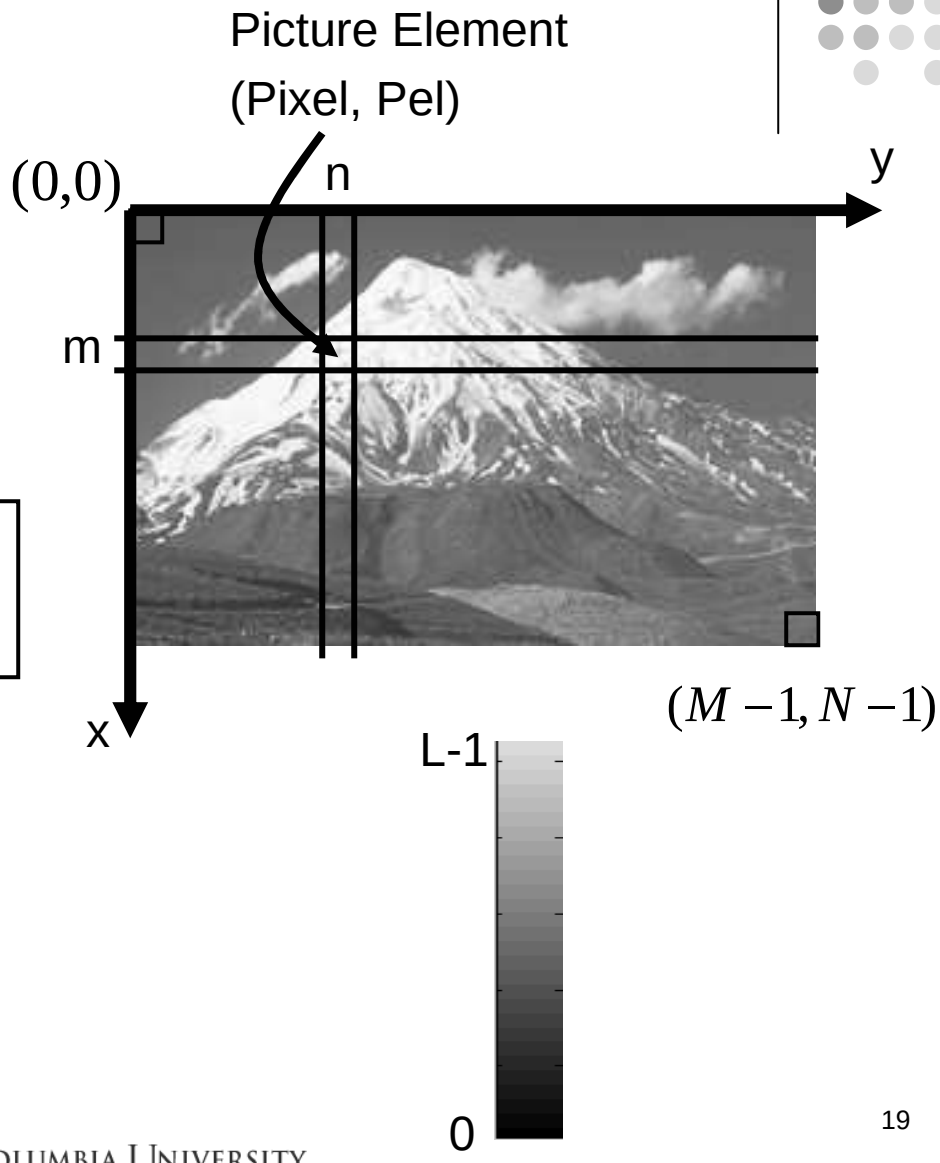
$$0 \le y \le Y$$

Digital Image

- Discretization
  - Spatial sampling
  - Quantization

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

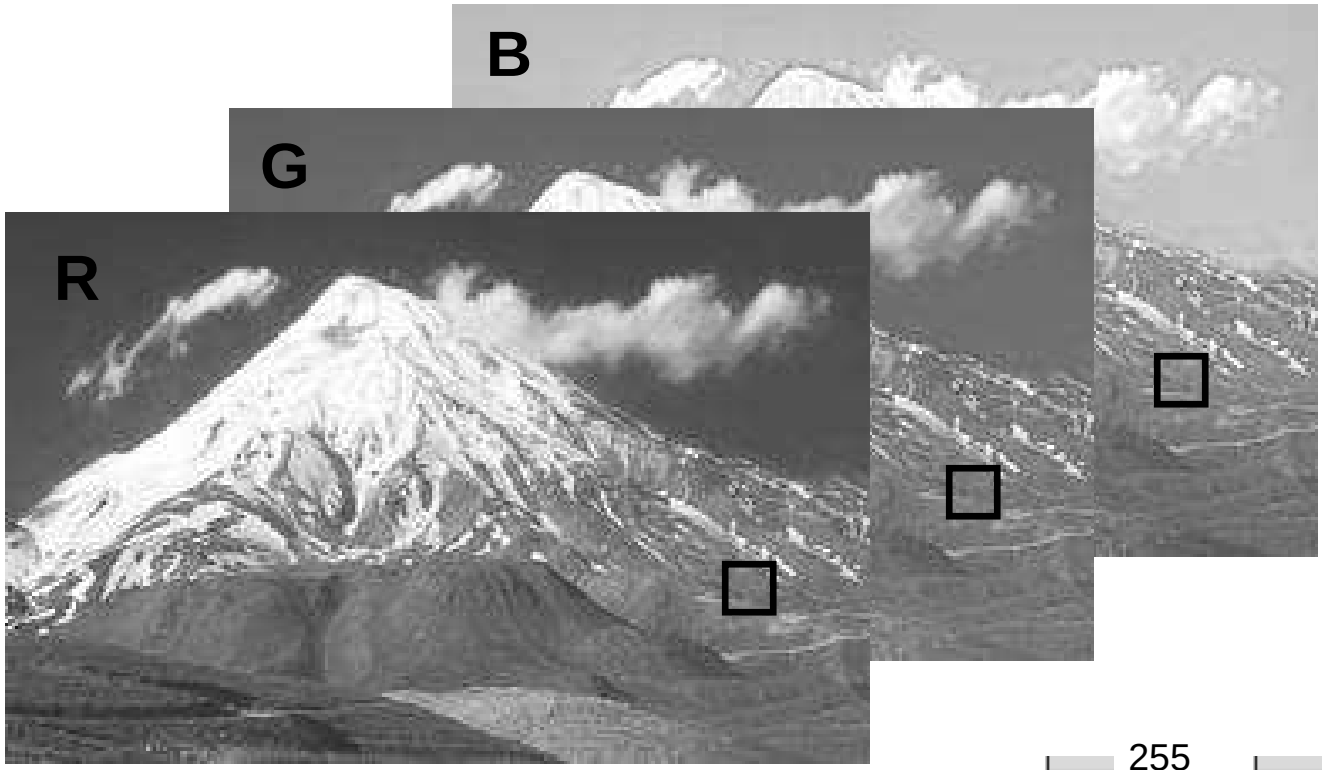
$$0 \le f(m,n) \le L-1 \qquad \begin{matrix} 0 \le m \le M-1 \\ 0 \le n \le N-1 \end{matrix}$$

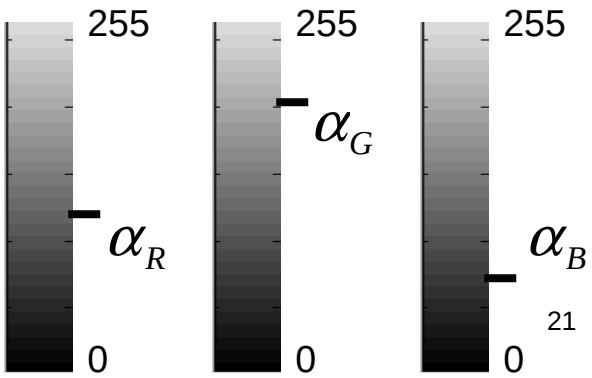


Digital Image

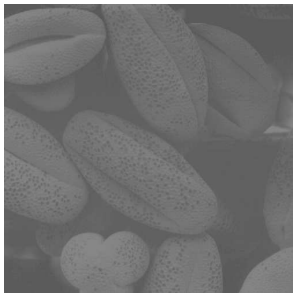
$$f = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & \vdots & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

Color Image





Digital Image Processing



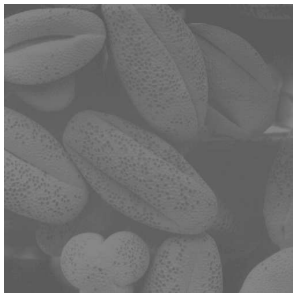
Low level

Mid level

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

High level

Digital Image Processing



Low level

Mid level

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

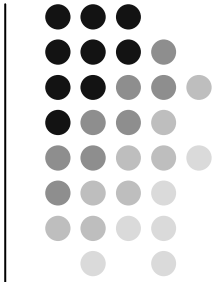
High level

Communication & Storage

What are we going to study?

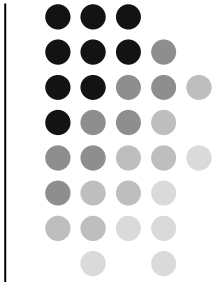
Lecture No.	Date	Lecturer	Subject
1	1.28	SE/LX	Course Mechanics, Introduction to Image Processing, Introduction to MATLAB
2	2.4	SE	Digital Image Fundamentals (ch2): Sensing, Sampling, and Quantization
3	2.11	SE	Gray-level, Color and Multi-band Images (ch3 & 6), Video
4	2.18	LX	Image Enhancement in Spatial Domain (ch3& 6)
5	2.25	LX	Image Enhancement in Frequency Domain (ch4)
6	3.3	LX	More Image Transform, Wavelets (ch7)
Mid-term	3.10		
7	3.24	LX	Image Restoration (ch5)
8	3.31	SE	Morphological Image Processing (ch9)
9	4.7	SE	Image Segmentation (ch10)
10	4.14	SE	Image Description (ch11)
11	4.21	LX	Object Recognition (ch12)
12	4.28	LX	Image Compression (ch8)
13	5.5	SE	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
- Military
- … and many more!

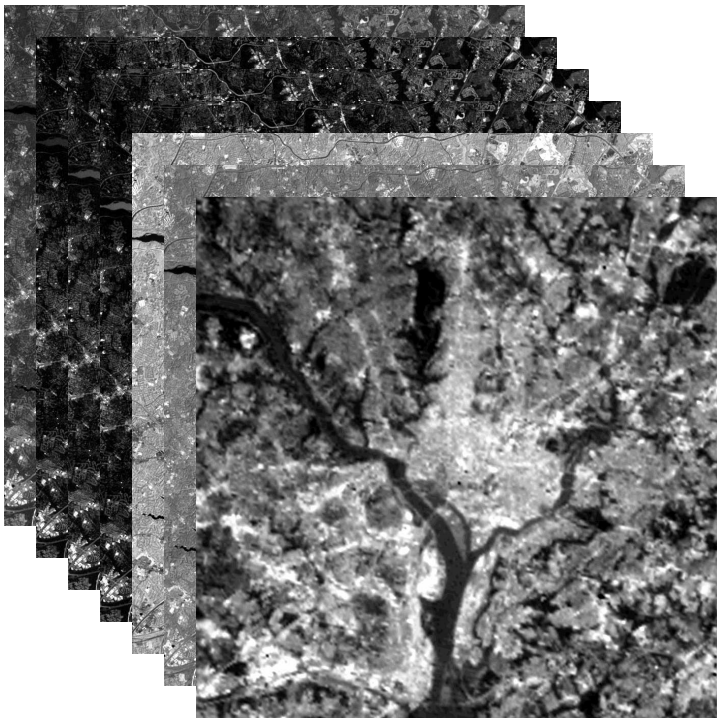
Application Domains

- Consumer domain
  - Storage, tagging, searching,…

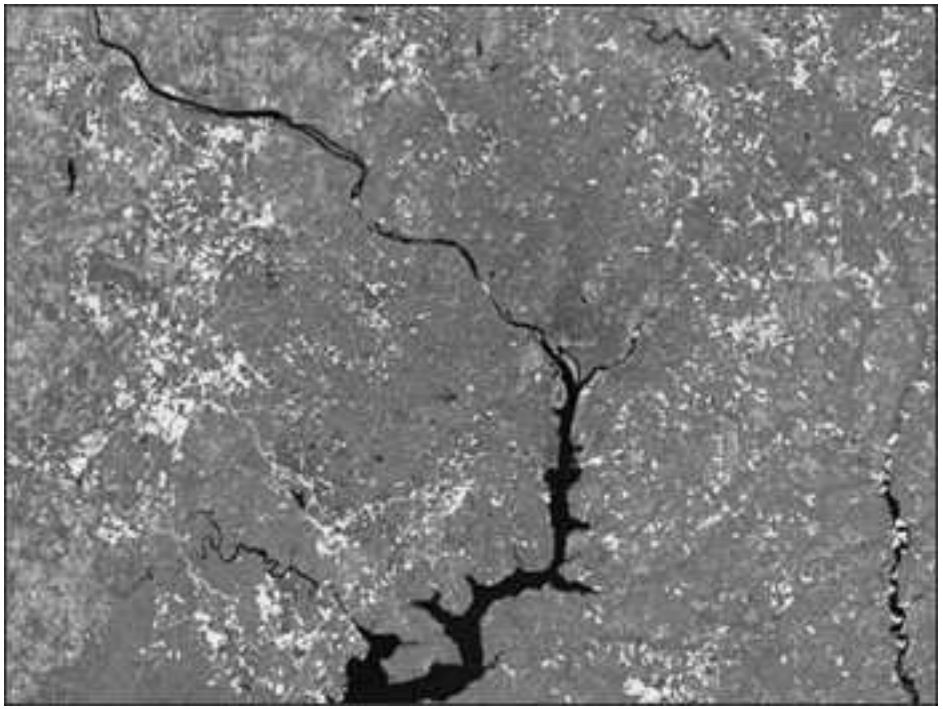
mountain, snow, buildings, sky

Application Domains

- Remote sensing
  - Agriculture, Urban growth monitoring, …



Multi-spectral imaging

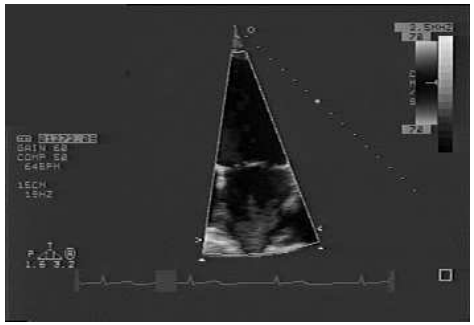


Urban growth in Washington D.C. between 1973 and 1985

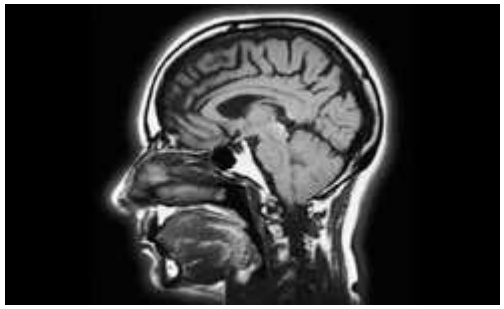
[Image courtesy of NASA/LANDSAT]

Application Domains

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

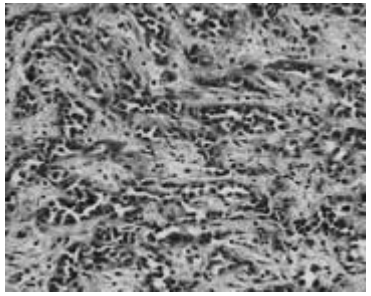


Color doppler Echocardiogram

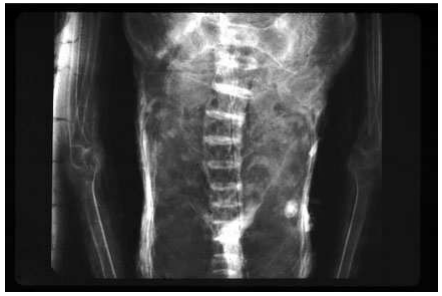


Brain MRI

Cardiac CT



Tissue Microscopy

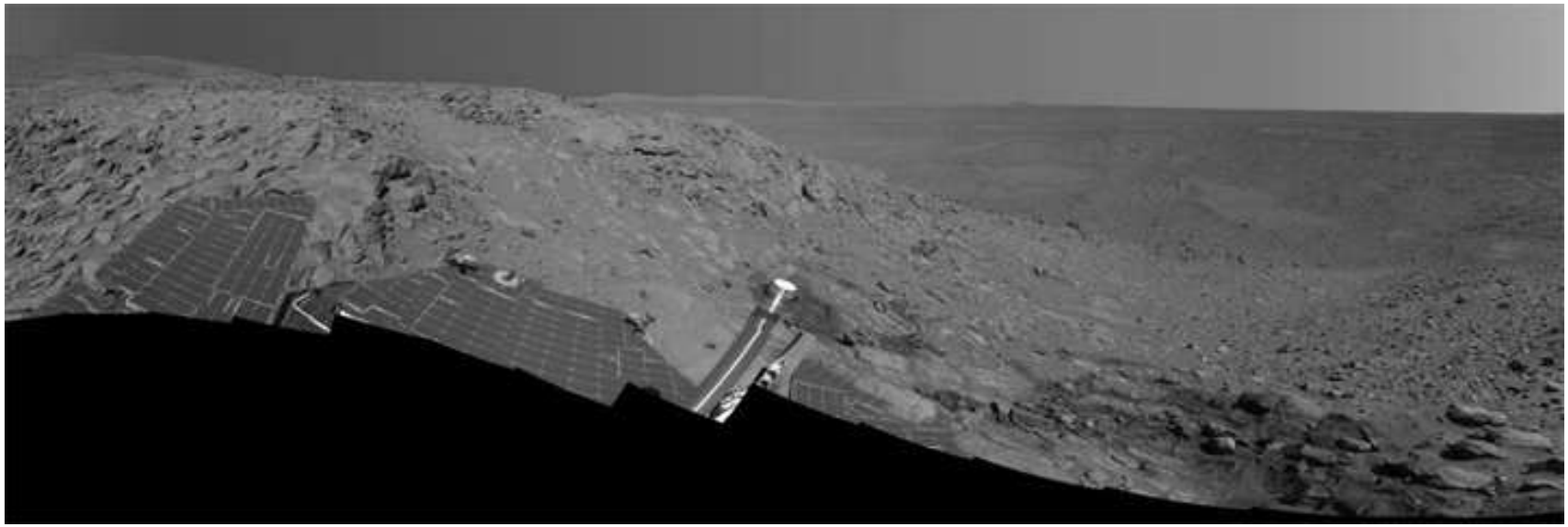


Spine X-ray

Brain PET (Alzheimers)

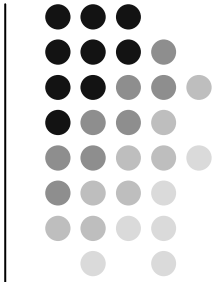
Application Domains

- 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