Lecture 1: Introduction

Digital Image Processing

Prof. Shih-Fu Chang

Digital Video and Multimedia Lab
Columbia University

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Digital Image Processing

- Processing of digital images on computers
- Digital images
  - Digital photos, image sequences, multi-sensor data like satellite images, medical images etc.

Most images are downloaded from the web site of the textbook

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Some images from Mars Rover “Spirit”

- Image feature registration is used to align the landing trajectory of the rover.

Color mosaic image
Of Mars surface

taken by Rover’s
descent imaging motion
estimation (DIME)
system

taken by
Mars Global Surveyor

Images downloaded from the NASA/JPL web site

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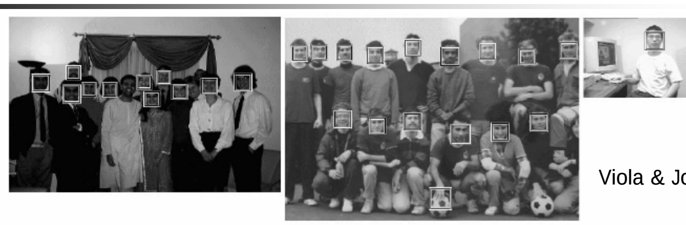
Face Detection



Viola & Jones 2001

Schneiderman & Kanade 98

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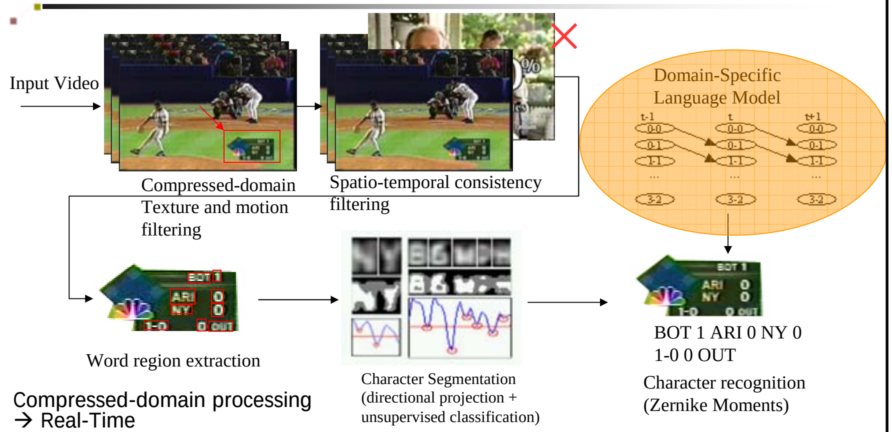
Text Detection and Recognition

(Zhang & Chang '02)



- Compressed-domain processing → Real-Time
- Explore domain-specific transition constraints (78% → 95% for sports text recognition)

98% detection, 92% recognition (demo)

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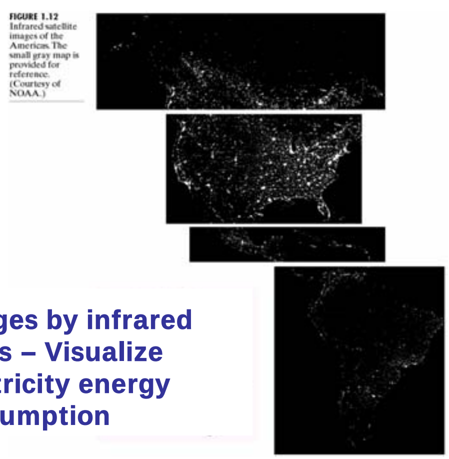
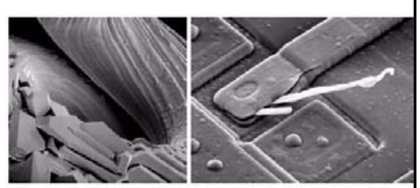
dvmm

Other Types of Images



Images by infrared lights – Visualize electricity energy consumption



Scanning Electronic Microscope (SEM)

Components of DIP (online demos)

- Representation (Chap 2 and 6)
  - Human perceptual models
  - How to represent halftone, grey-scale, color images on the computers?
  - How to determine spatio-temporal resolutions?
- Enhancement (Chap 3)
  - Contrast, noise, smoothness, sharpness

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Components of DIP (2)

- Image Transform (Chap 4 and 7)
  - Pixel domain vs. transform domain enhancement
  - Fourier, Discrete Cosine Transform, KLT, Wavelet
- Restoration (Chap 5)
  - Remove degradation/blurring due to motion, noise, interference, etc.

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DIP Components (3)

- Feature extraction & segmentation (Chap 10 and 11)
  - Edge, shape, texture
  - Region segmentation and representation
  - Motion estimation
- Morphological image processing (Chap 9)
- Object recognition (Chap 12)
- Image/video compression (Chap 8)
- Image reconstruction from projections (Jain Chap 10)
  - X-ray CT scanning

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Logistics

- Required background
  - Signals and Systems – Fourier Transform, Filters
  - Probability, Linear Algebra, and Matrix Operations
- Textbook
  - Gonzalez and Woods, Digital Image Processing, 2nd edition, Prentice Hall, 2001. (Required)
  - Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989. (reference)
- Weekly assignments (40%) including both analytical and programming experiments
- One midterm (30%), one final (30%), open books

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Logistics (2)

- **Software and data**
  - **MATLAB suggested, or other languages (see Matlab Image Processing demos)**
  - **A MATLAB tutorial next Monday**
  - **Computers available in**
    - **Mudd Rm 251 (PCs, ACIS accounts needed)**
    - **EE Teaching Labs: Rm 1235 (Linux), check with TA for access accounts**
- **Web Sites**
  - **Most information will be on the class web site**
  - **Discussion Bulletin Board is available on Columbia courseworks**
  - **Companion web site of the textbook http://www.imageprocessingplace.com/**
- **Office Hours**
  - **Instructor -- Mondays 4-5:30pm, CEPSR Rm 709**
  - **TA, Chuxiang Li – Fridays 4-6 pm, CEPSR Rm 710**

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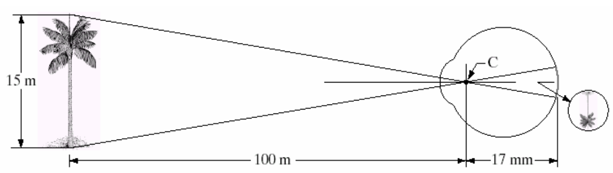
Basic Concept: Image Acquisition

FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.



- A very simple model
  - Objects captured as focused images on the image plane at retinas
  - Perspective projection based on pinhole model geometry
    - image size depends on distance of object
  - In practice, optical devices with lens

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Human Visual Perception Models

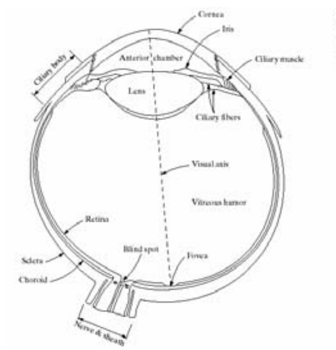

FIGURE 2.1 Simplified diagram of a cross section of the human eye.

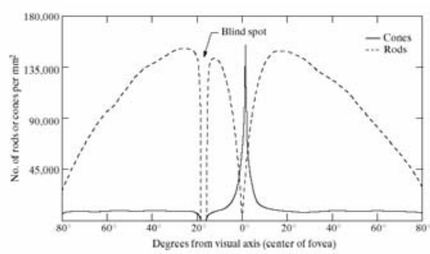

FIGURE 2.2 Distribution of rods and cones in the retina.

- Cone: color, high illumination, less
- Rod: brightness, low illumination, more

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Imaging Sensors

- **Each sensor unit integrates light input from a certain area.**
- **Digital camera: typical CCD, but CMOS cheaper, less power consumption, more noisy**
- **For color images, use a Bayer's mosaic pattern of R/G/B filters to reduce cost, then use demosaicing to construct full-resolution color images.**

a
b
c

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

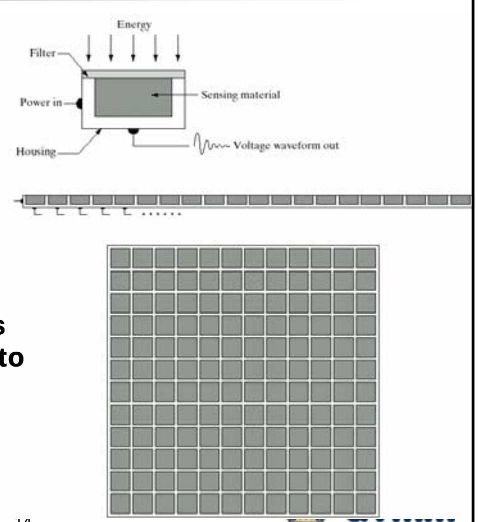

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Image Acquisition Systems (1)

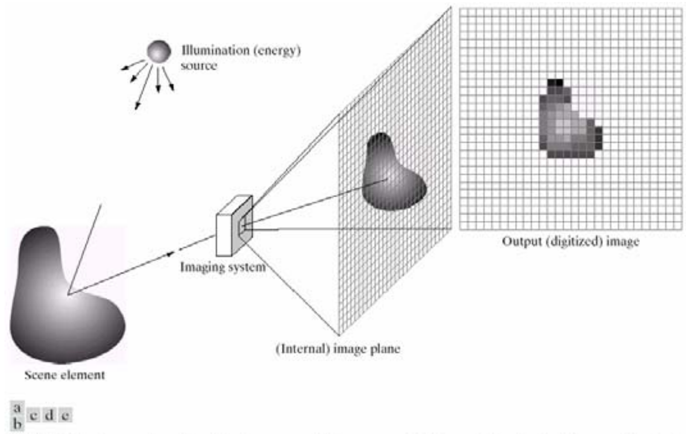

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

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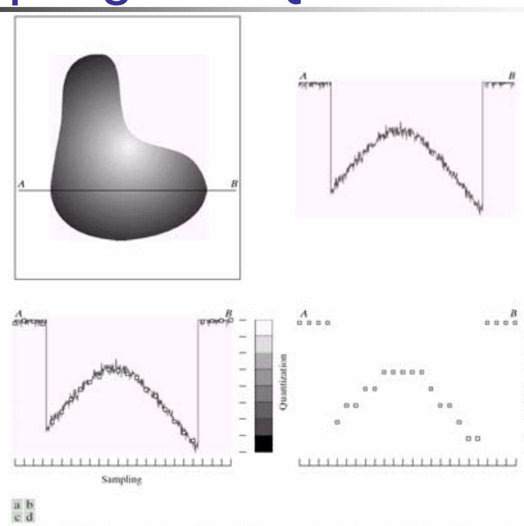
Sampling and Quantization

line profile

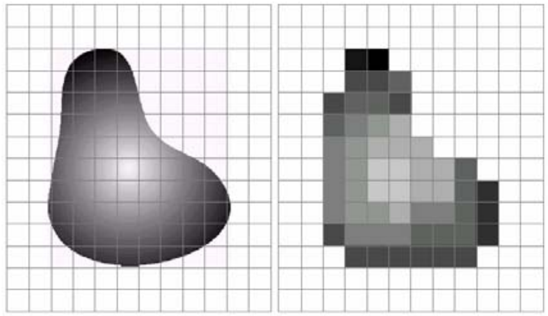
sampling



quantization

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.

Sampling and Quantization



a b

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

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Matrix Representation

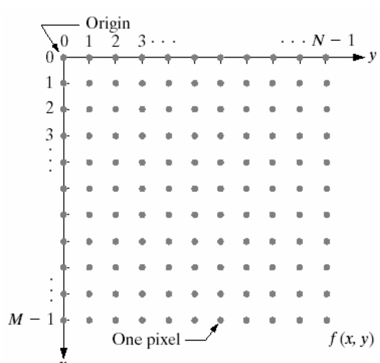

FIGURE 2.18 Coordinate convention used in this book to represent digital images.

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Next Questions

- Required resolutions in space, time, and magnitude
- Color representation
  - Uniform perceptual color spaces
- Chap 2 and 6.1-6.2

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