<u>Lecture 1 Part 1: Introduction</u>

Digital Image Processing

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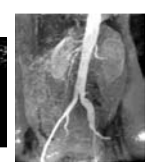
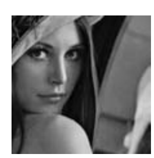
http://www.ee.columbia.edu/dvmm

Most images are downloaded from the web site of the textbook

Digital Image Processing

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





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
Mars Global Surveyor

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

Images downloaded from the NASA/JPL web site

Some images by visible lights

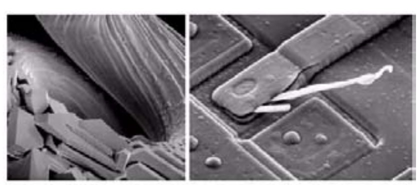
a b
c
d

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.)

Images by infrared lights – Visualize electricity energy consumption

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

Scanning Electronic Microscope (SEM)



a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure. (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

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 spatial-temporal resolutions?
- Enhancement (Chap 3)
  - Contrast, noise, smoothness, sharpness

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 atmospheric interference, motion, noise, etc.

DIP Components (3)

- Feature extraction & segmentation (Chap 10 and 11)
  - Edge detection, connection
  - Region segmentation and representation
  - Motion estimation
- Morphological Image Processing (Chap 9)
- Image/Video compression (Chap 8)
- Image Reconstruction from Projections (Jain Chap 10)
  - X-ray CT scanning

Logistics

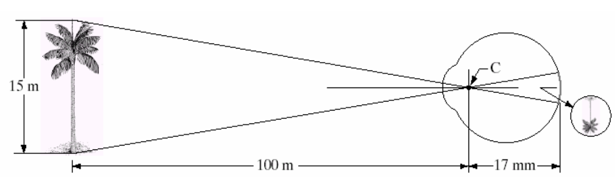
- Required background
  - Signals and Systems
  - Probability, Linear Algebra, and Matrix Operations
- Textbook
  - Gonzalez and Woods, Digital Image Processing, 2nd edition, Prentice Hall, 2001. (Required)
  - Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989. (reference)
- Office Hours
  - Mondays 1-2:30pm, CEPSR RM 709
- Bi-weekly assignments (40%) including both analytical and programming experiments
- One midterm (30%), one final (30%), open books

Logistics (2)

- Software and data
  - MATLAB suggested, or other languages (see Matlab IP demos)
  - A MATLAB recitation next week
  - 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
  - Bulletin Board is available on Columbia Coursework – for discussion Q&A among students/TA/Instructor
  - Companion web site of the textbook http://www.imageprocessingplace.com/
    - Background review (such as probability and matrix)
    - Suggested projects
    - Images used in the book

A Very Simple Image Acquisition Models

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



Visual Perception Models

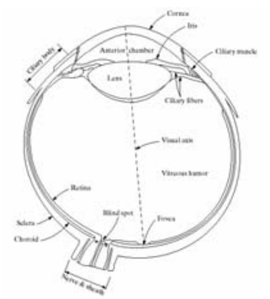


FIGURE 2.1 Simplified diagram of a cross section of the human eye.

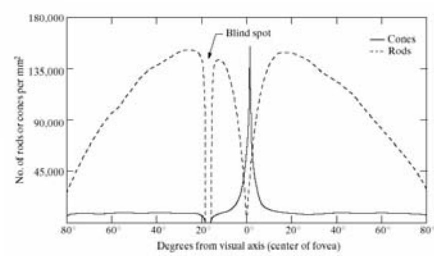
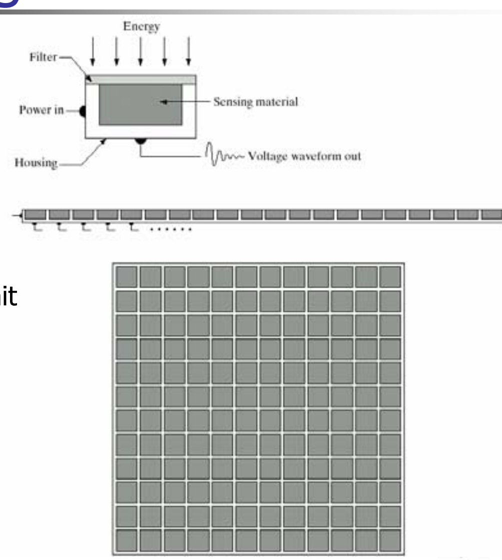


FIGURE 2.2 Distribution of rods and cones in the retina.

Imaging Sensors

a
b
c

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



Each sensor unit integrates light input from a certain area.

Image Acquisition Systems (1)

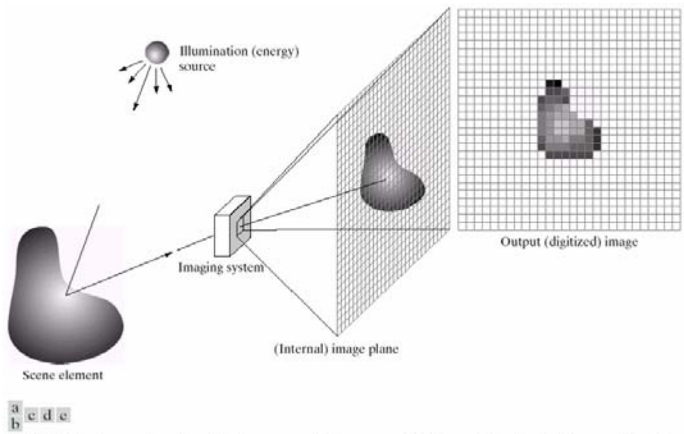


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Sampling and Quantization

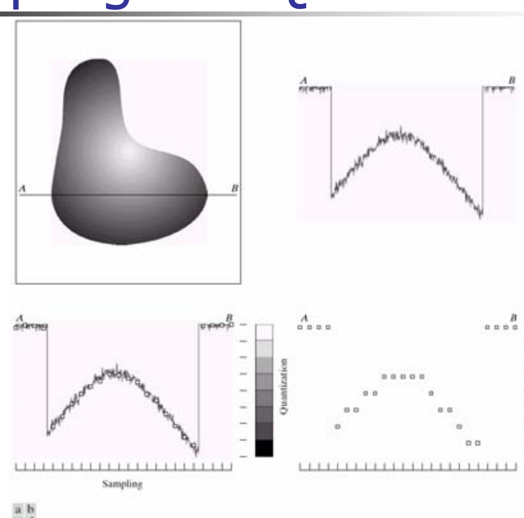


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Sampling and Quantization

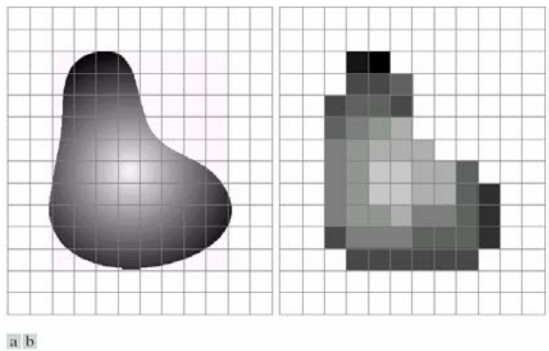


FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

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Matrix Representation

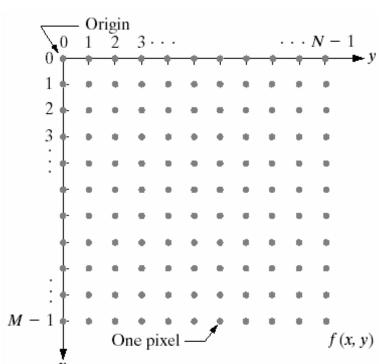

FIGURE 2.18 Coordinate convention used in this book to represent digital images.

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RGB Color Cube

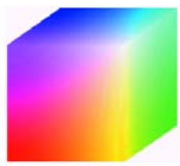
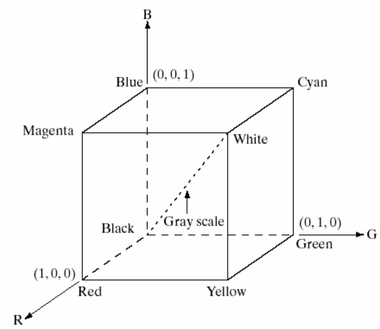


FIGURE 6.8 RGB 24-bit color cube.



Perceptual colors

- Intensity and Brightness
  - Intensity is the strength of the incoming light
  - Luminance is the output of the intensity receptor
  - Brightness is the perceived phenomenon (subjective)
- Hue
  - The attribute used to distinguish different colors such as Red, Green, Blue etc
  - Wavelength is not a good measure of hue. E.g., purple is not a spectral color
- Saturation
  - Pureness of the hue. E.g., spectral colors have maximal saturation values. Pastel colors (mixture with white) have low saturation.

RGB-to-HSI conversion

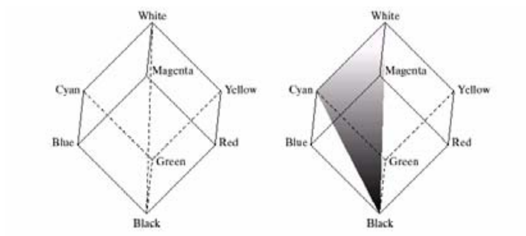


FIGURE 6.12 Conceptual relationships between the RGB and HSI color models.

HSI components

- The intensity axis, i.e., the grey line
- the intensity of a color is the intersection point of the grey line and the perpendicular plane
- A plane for each hue: defined by Black, White, and a color (e.g., R, G, or B)
  - Defined by the angle between the hue plane and the reference plane (e.g., Red)
- The saturation is the distance between the color and the intensity axis.

Different HSI shapes

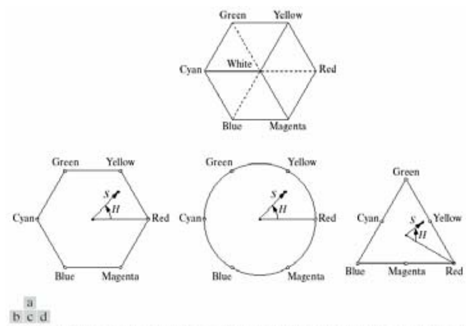


FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.