Introduction to Image Processing
What is an Image?

• An image is a 2D function $f(x,y)$
  – $f$ is the amplitude or “gray level”
  – $(x,y)$ are the spatial plane coordinates
  – Conceptually, $(x,y)$ are continuous, although in practice we limit them to discrete (integer) values

• In general, the function value can be vector-valued
  – Example: Color can be represented by (red, green, blue)
    $$\vec{f}(x, y) = \begin{pmatrix} r \\ g \\ b \end{pmatrix} = (r, g, b)^T$$

• The function domain can be $N$-dimensional
  – Example: Computed Tomography (CT) images are 3D
  – $f(x,y,z)$ represents the x-ray absorption at point $(x,y,z)$
Demos

• Matlab
  – Display gray scale image
    \[
    I = \text{imread(‘moon.tif’)};
    \text{imtool}(I);
    \]
  – Display color image
    \[
    \text{imtool(‘peppers.png’)}
    \]
  – Plot image as a surface
    \[
    \text{surf(double}(I(1:8:end,1:8:end)))
    \]
What is Digital Image Processing?

• DIP refers to computer processing to
  - Extract information
  - Restore or correct aberrations
  - Transform image to a more useful form
    - Enhance for viewing
    - Compress for storage or transmission

• Began in earnest in 1960’s

FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. Ranger 7 took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)
Example

- Digital images from remote spacecraft

(August 2012) This image is the first high-resolution color mosaic from NASA's Curiosity rover, showing the geological environment around the rover's landing site in Gale Crater on Mars. From http://mars.jpl.nasa.gov/msl/multimedia/images/

- Also see an interactive panorama at
Image Processing vs. Related Areas

• Image Processing (CSCI 510 / EENG 510)
  – Usually low level techniques (eg, compression, edge detection)
  – Quantitative measurements
  – 2D (image in, image out)

• Computer Vision (CSCI 512 / EENG 512)
  – Higher level techniques (eg, object recognition)
  – Artificial intelligence (emulate human intelligence)
  – Semantic (instead of quantitative) output
  – 3D
  – There is overlap

• Other related fields
  – Signal processing, communications
  – Photogrammetry
  – Pattern recognition
Example Applications

- Industrial inspection

**FIGURE 1.14**
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.

(Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)
Example Applications

- Remote sensing

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Name</th>
<th>Wavelength (μm)</th>
<th>Characteristics and Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Visible blue</td>
<td>0.45-0.52</td>
<td>Maximum water penetration</td>
</tr>
<tr>
<td>2</td>
<td>Visible green</td>
<td>0.52-0.60</td>
<td>Good for measuring plant vigor</td>
</tr>
<tr>
<td>3</td>
<td>Visible red</td>
<td>0.63-0.69</td>
<td>Vegetation discrimination</td>
</tr>
<tr>
<td>4</td>
<td>Near infrared</td>
<td>0.76-0.90</td>
<td>Biomass and shoreline mapping</td>
</tr>
<tr>
<td>5</td>
<td>Middle infrared</td>
<td>1.55-1.75</td>
<td>Moisture content of soil and vegetation</td>
</tr>
<tr>
<td>6</td>
<td>Thermal infrared</td>
<td>10.4-12.5</td>
<td>Soil moisture; thermal mapping</td>
</tr>
<tr>
<td>7</td>
<td>Middle infrared</td>
<td>2.08-2.35</td>
<td>Mineral mapping</td>
</tr>
</tbody>
</table>

**FIGURE 1.10** LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)
Example Applications

- Target recognition

Vehicles in a synthetic aperture radar (SAR) image
Example Applications

• Medical diagnosis
Sources of Image Data

• Normally images are formed from EM radiation (light, x-rays, radio waves)

**FIGURE 1.5** The electromagnetic spectrum arranged according to energy per photon.
(a) Inject patient with isotope
(b) Positron emission tomography
(c) Gas cloud in constellation Cygnus
(d) Radioactive valve

Gamma rays
X-rays

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angigram. (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.)
Ultraviolet

(a,b) Fluorescence microscope
FIGURE 1.9 Examples of light microscopy images: (a) Taxol (anticancer agent), magnified 250×; (b) Cholesterol, 10×; (c) Microprocessor, 40×; (d) Nickel oxide thin film, 450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)
Infra-red

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

www.infrared-cameras.org/.../scope.htm

**FIGURE 1.5** The electromagnetic spectrum arranged according to energy per photon.

*Colorado School of Mines*
FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)

FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.
Magnetic resonance imaging (MRI)
Images formed from other sources

- Ultrasound
- Seismic
- Scanning electron microscope

*FIGURE 1.19* Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)
Topics in Digital Image Processing

Outputs of these processes generally are images

- **CHAPTER 6**: Color image processing
- **CHAPTER 7**: Wavelets and multi-resolution processing
- **CHAPTER 8**: Compression
- **CHAPTER 9**: Morphological processing
- **CHAPTER 5**: Image restoration
- **CHAPTERS 3 & 4**: Image enhancement
- **CHAPTER 2**: Image acquisition
- **CHAPTER 10**: Segmentation
- **CHAPTER 11**: Representation & description
- **CHAPTER 12**: Object recognition

Knowledge base