Our General Definition of image:
- A physical property(ies) of an object.
  - Not necessarily visible.

Main Physical Property:
- Electromagnetic Radiation:
  - From Radio Waves to Cosmic rays

A categorization:
- Single Channel
- Multi Channels
The Electromagnetic Spectrum

**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.
• Digital Image, Mathematical Definition:
  - $I = f(x,y)$
  - $I$: intensity (or color)
  - $(x,y)$: Position or Coordination
  - When $(x,y)$ and $I$ are finite and discrete quantities → digital image
  - pixels, picture elements, image elements
Introduction to Image Processing

- Image Representation:

![Image diagram showing pixel representation](image.png)

**FIGURE 2.18**

Coordinate convention used in this book to represent digital images.
**Medical Image Analysis and Processing**

Introduction to Image Processing

**Bone Scan**

**PET**

**Cygnus Loop**

**Gamma Radiation from reactor valve**
Introduction to Image Processing

Chest X-Ray

Angiography

CT

Circuit Board

Cygnus Loop

FIGURE 1.7 Examples of X-ray imaging: (a) Chest X-ray, (b) Aortic angiogram, (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. Pesente, Lixi, Inc., and (e) NASA.)
UV imaging

**FIGURE 1.8** Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and
(b) Dr. Michael W. Davidson,
Florida State University,
(c) NASA.)

Normal Corn  
Smut Corn  
Cygnus Loop
Introduction to Image Processing

- Taxon (Anti cancer)
- Cholesterol
- Nickel Oxide Thin Film
- CD Surface
- Light Microscopy
- Microprocessor
- Superconductor

Figure 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)
Introduction to Image Processing

- CT
Introduction to Image Processing

- MRI
Introduction to Image Processing

- MRI
Introduction to Image Processing
Introduction to Image Processing

- US
Introduction to Image Processing

- SPECT
Introduction to Image Processing

- PET
Introduction to Image Processing

- PET
Medical Image Analysis and Processing

Introduction to Image Processing

- PET-CT
Introduction to Image Processing

- MRA
Introduction to Image Processing

• A Sample of Multi Channels imaging:
  – Satellite imaging

<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>
• MRI as a Multi Channels imaging modalities:

PD    T₁    T₂
• MRI as a Multi Channels imaging modalities:

PD weighted  

T2 weighted
• DIP applications:
  – Image Quality Enrichment
  – Data Redundancy Reduction
  – Automatic Detection
  – Machine Vision
  – Machine Recognition/Verification
• DIP applications:
  – Image Enhancement, Denoising, Reconstruction.
  – Authentication (Biometrics):
    • Face, Signature, Fingerprint, Palm, Gesture, Retina Iris.
  – Robotic Production Line (Vision)
  – OCR (Optical Character Recognition)
  – Automatic Diagnosis (Medical, Industry, and etc.)
  – Image Compression (jpg, tiff, jp2, and etc.)
Introduction to Image Processing

Medical Ultrasound imaging

FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (b) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)
Medical Image Analysis and Processing

Introduction to Image Processing

• An Example of Image Processing Results
• **Image Sampling**
  
  – How to determine the sampling rate?

  – **Nyquist sampling theorem**

    • If input is a *band-limited signal* with maximum frequency $\Omega_N$

    • The input can be *uniquely determined* if sampling rate $\Omega_S > 2\Omega_N$
      
      – Nyquist frequency : $\Omega_N$
      
      – Nyquist rate : $\Omega_S$
• Image Quantization
  – L-level digital image of size MxN
  – Means: A digital image having:
    • A spatial resolution MxN pixels
    • A gray-level resolution of L levels (0-L-1)
  – Spatial resolution in real-world space
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- Image in Matrix Form:

\[
\begin{bmatrix}
  f(0,0) & f(0,1) & \ldots & f(0,N-1) \\
  f(1,0) & f(0,1) & \ldots & f(1,N-1) \\
    \vdots  & \vdots  & \ddots & \vdots \\
  f(M-1,0) & f(M-1,1) & \ldots & f(M-1,N-1) \\
\end{bmatrix}_{M \times N}
\]

bits to store the image = \( M \times N \times k \)

gray level = \( L = 2^k \)
• \( L = 2^k \) gray levels, gray scales \([0,\ldots,L-1]\)

• The dynamic range of an image
  – \([\text{min}(\text{image}) \ \text{max}(\text{image})]\]
  – If the dynamic range of an image spans a significant portion of the gray scale \(\rightarrow\) high contrast
  – Otherwise, low dynamic range results in a washed out gray look
• Gray Levels in CT:
  – Gray levels in CT image represent attenuation coefficient in each pixel.
  – Gray levels expressed in Hounsfield units (HU)
    • Water: 0 HU
    • Air: -1000 HU
    • Bone: 400 - 3000 HU
  – Maximum CT number is 2000-4000
CT images displayed with suitable brightness and contrast.

Two important values: Window Level (WL) and Window Width (WW)

- WL is CT number of mid-grey
- WW is number of HU from black to white

Choice of WW and WL dictated by clinical need
- -1000 HU
- 0 HU
- 4000+ HU
• WL and WW effect:
Introduction to Image Processing

• Paradigm of image processing:
  – Low-level processing
    • Inputs and outputs are images
    • Primitive operations: de-noise, enhancement, sharpening, …
  – Mid-level processing
    • Inputs are images, outputs are attributes extracted from images
    • Segmentation, classification,…
  – High-level processing
    • “Make sense” of an ensemble of recognized objects by machines
Medical Image Analysis and Processing

Introduction to Image Processing

- Matlab Image Processing *Read/Write*:
  - imformats
  - imfinfo, imread, imwrite
  - dicominfo, dicomread, dicomwrite
  - analyze75info, analyze75read (Mayo Clinic)
  - interfileinfo, interfileread
Introduction to Image Processing

- Matlab Image Processing *Display*:
- `image`, `imagesc`, `imshow`, `imtool`, `subimage`
- `colorbar`, `montage`
Introduction to Image Processing

Matlab Image Processing *Type Conversion*:
- double, ind2gray, im2double
- uint16, uint8, gray2ind