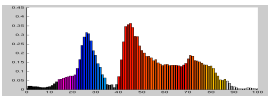
*Dr. Qadri Hamarsheh*



# Digital Image Processing (730474)

## Lecture 1

## Outline of the Lecture

- **Introduction.**
- **Image Generation (Sources).**

## Introduction

- Image Processing is a subclass of **signal processing** concerned specifically with **pictures**.
- **Principal Application Areas:**
  - Improve image quality (pictorial information) for **human perception and interpretation.**
  - Improve image quality for **computer interpretation** (processing for image data for storage, transmission and representation for autonomous machine perception).

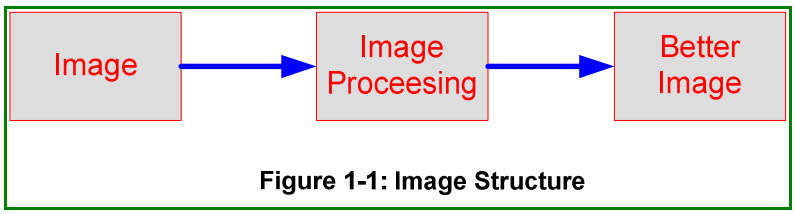
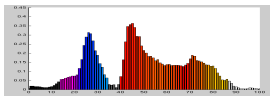



**Figure 1-1: Image Structure**

- **Image Processing Fields:**
  1. **Image Processing** – enhancement or other manipulation of the images.
  2. **Computer Vision** -analysis of the image content.
  3. **Computer Graphics** – the creation of images.
  4. **Artificial Intelligent**.
- Sometimes image processing defined as a description in which both the input and the output of a process are images (in this classification, trivial tasks of computing the average intensity of an image would not be considered an image processing operations).
- **Computerized Processes Types:**

1. **Low-level processes.**
   - Input and output are images.
   - Primitive operations such as image preprocessing to reduce the noise, contrast enhancement and image sharpening.
2. **Mid-level processes.**
   - inputs generally are images, outputs are attributes extracted from those images (edges, contours, …).
   - Tasks:
     a) **Segmentation** (partitioning an image into regions or objects).



b) **Description** of those objects to reduce them to a form suitable for computer processing.

c) **Classification** (recognition) of objects.

**3. High-level processes: Image analysis.**

| Table 1 | | |
|---|---|---|
| **Input/Output** | **Image** | **Description** |
| **Image** | Image Processing | Computer Vision |
| **Description** | Computer Graphics | AI |

- **Digital Image Definition:**
  - An image may be defined as a **two-dimensional function** $f(x, y)$, where $x, y$: the **spatial** coordinate, $f$-the **amplitude** of any pair of coordinate $x, y$ is called the **intensity or gray level** of the image at that point.
  - Digital Image: $x, y$ and $f$ are all finite (**discrete** quantities).
  - Digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are called **picture elements**, image elements and **pixels**.

## Image Generation (Sources)

- The images sources classified by the **energy** as the following:
  - **Radiation from the Electromagnetic Spectrum (EM).**
  - **Acoustic.**
  - **Ultrasonic.**
  - **Electronic** (in the form of electron beams used in electron microscopy).
  - **Synthetic images** generated using computer for modeling and visualization.
- Humans are limited to the **visual band** of the Electromagnetic Spectrum (EM), imaging machines cover almost the entire EM spectrum from Gamma to Radio Waves.
- **Radiation from EM Spectrum:**

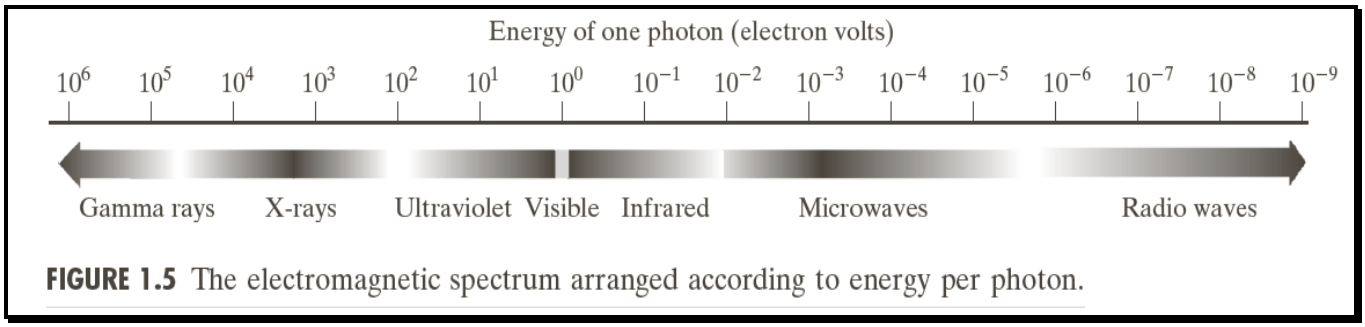
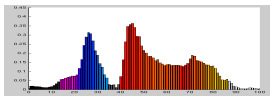



**FIGURE 1.5** The electromagnetic spectrum arranged according to energy per photon.

  - Images based on EM spectrum are the most familiar, especially in **x-ray** and **visual band**.
  - EM waves: a stream of mass less particles (proton), each traveling in a wavelike pattern and moving at the speed of light.



- Spectral bands and their applications are grouped by energy per photon: **Gamma Rays, X-Rays, Ultraviolet, Visible, Infrared, Microwaves and Radio waves** as shown in table 2.

**1. Gamma Rays Imaging:**

- Positron emission tomography (PET scans): the patient is given a radioactive isotope that emits positrons (Gamma rays) as it decays, these positrons are collected and detected by gamma ray detectors and tomography image is created, PET scans used an internal source of Gamma rays, the PET scan is similar to X-Ray imaging, an example of PET scan is a bone scan.

**2. X-Ray Imaging :**

- The X-rays are used in
  - Medical Diagnostics Imaging
    - CAT scan: computerized axial tomography or CT scan for short.
- CT scan: the process in which
- **Ring of detectors** encircles an object (or patient) and X-rays source rotates around the object.
- X rays pass through the object and then collected at the opposite end by the corresponding detectors in the ring.
- Tomography consists of algorithms that use the sensed data to construct an image that represent a "**Slice**" through the object.
- Motion of the object in a direction perpendicular to the ring of detectors produces a set of slices (**3-D image**)
- X-rays for medical and industrial imaging are generated using X-ray tube, which is a vacuum tube, with cathode and anode. The cathode is heated, causing free electron to be released. When electron meets nucleus energy is released in the form of X-ray.
- Examples of medical diagnostics applications are chest x-ray, aortic angiogram, head CT.

➡ Angiography: x-ray contrast medium injected with catheter through blood vessels, angiography is a major area of digital image processing where image subtraction is used to enhance further the blood vessels being studied.

  - Industrial Imaging (for example : circuit board)
  - Astronomy (Cygnus loop )

**3. Imaging in the Ultraviolet band.**

**4. Imaging in Visible and Infrared bands.**

**5. Imaging in Microwave band.**

- To explore inaccessible regions of the earth's surface (clarity of the image details unencumbered by clouds or other atmospheric conditions that normally interfere images in visual band), we use imaging radar.

**6. Imaging in Radio wave band.**

In Magnetic Resonance Imaging (MRI) technique, the patient in a powerful magnet is placed, and radio waves through body in short pulses are passed. Each pulse causes a responding pulse of radio waves to be emitted by the patient's tissues. These locations are determined by computer which produces a 2-D image.

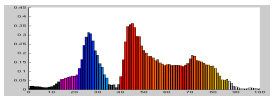


**Table 2: Image Source by energy**

| | Band Name | Energy per one photon | Applications |
|---|---|---|---|
| 1. EM Spectrum | Gamma Rays | $10^{6}-10^{4}$ (highest) | • Nuclear Medicine (PET scan)<br>• Astronomy (Cygnus loop )<br>• Nuclear Reactor (natural radiation) |
| | X-Rays | $10^{3}-10^{2}$ | • Medical Diagnostics Imaging<br>➡ CAT scan<br>➡ Angiography<br>• Industrial Imaging<br>• Astronomy (Cygnus loop ) |
| | Ultraviolet | $10^{1}$ | • Industrial Inspection<br>• Microscope (fluorescence)<br>• Laser<br>• Biological Imaging<br>• Astronomical Observations |
| | Visible | $10^{0}$ | • Astronomy<br>• Light Microscopy<br>• Remote Sensing<br>• Industry<br>• Law Enforcement |
| | Infrared | $10^{-1}-10^{-2}$ | |
| | Micro wave | $10^{-3}-10^{-5}$ | Imaging Radar |
| | Radio wave | $10^{-6}-10^{-9}$ (lowest) | • Medicine (MRI)<br>• Astronomy |
| 2. Acoustic (low end of the sound spectrum, hundred of HZ) | | | • Geological application<br>➡ Mineral exploration<br>➡ Oil exploration<br>➡ Seismic Cross-Sectional Images |
| 3. Ultrasonic | | | • Manufacturing<br>• Medicine (baby, Muscle layers showing lesion) |
| 4. Electronic | | | Electronic Microscopy |
| 5. Synthetic (based on mathematical rules) | | | • Fractals images<br>• 3-D Computer Modeling |

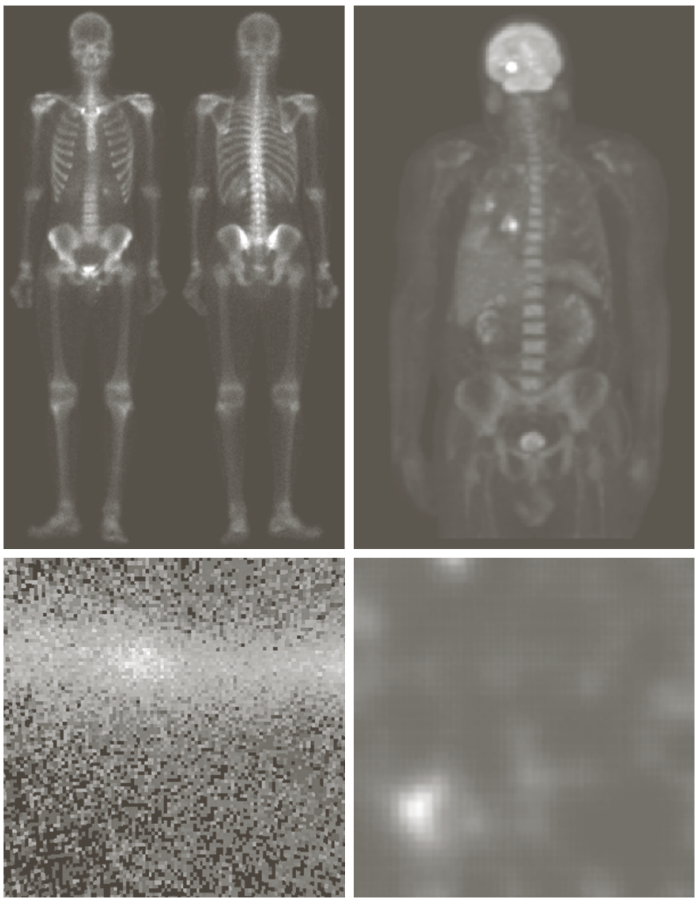


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**FIGURE 1.6** Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

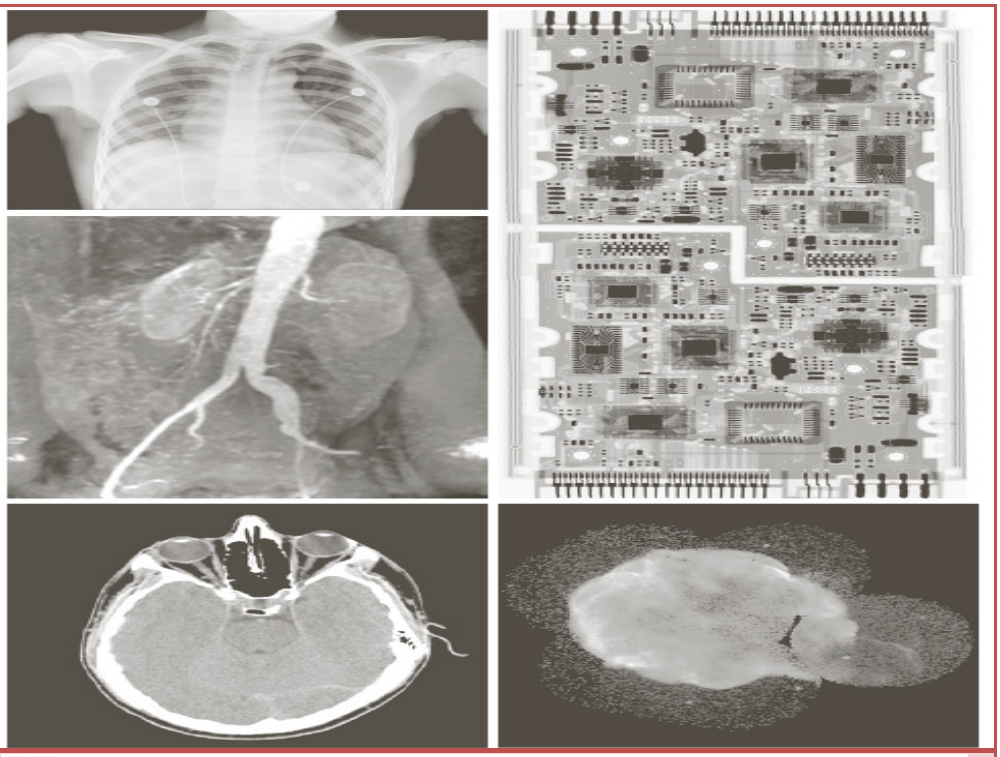

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**FIGURE 1.7** Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

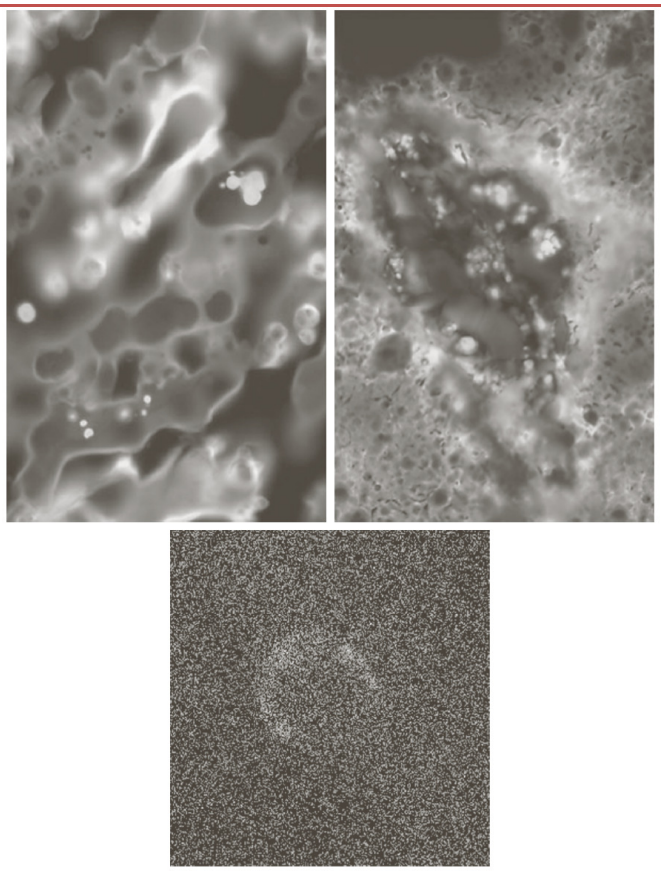

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**FIGURE 1.8**
Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)

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

**TABLE 1.1**
Thematic bands in NASA's LANDSAT satellite.

**Visible Band Example**