جامعة المستقبل
AL MUSTAQBAL UNIVERSITY

قســـم الانظمة الطبية الذكية
المرحلة الثالثة

Subject : Medical image processing

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Lec 2 : MEDICAL IMAGE ACQUISITION AND IMAGING MODALITIES

IMAGE FORMATION

- **Data /Image acquisition:** The first integral step in the image formation is an acquisition of raw imaging data. It contains the original information about captured physical quantities describing internal aspects of the body. This information becomes the primary subject for all subsequent steps of image processing
- The images are obtained using various imaging modalities and technologies designed to visualize specific tissues, organs, or systems. Each modality is suited for particular clinical applications, and the choice depends on factors such as the area of interest, suspected condition, and desired level of detail.

➢ COMMON MODALITIES OF MEDICAL IMAGE ACQUISITION:

1. **X-Ray Imaging: (Radiography):** Uses ionizing radiation to produce 2D images of dense structures like bones.

- X-ray or radiography uses **a very small dose of ionizing radiation to produce pictures of the body's** internal structures.. They are often used to help diagnose (**X-rays are the oldest and most frequently used form of medical imagined)** fractured bones, look for injury or infection and to locate foreign objects in soft tissue

APPLICATION OF X-RAY

1. **Fractures and Bone Disorders**: Detecting broken bones, arthritis, or osteoporosis.
2. **Chest Imaging**: Identifying lung infections
3. **Dental Imaging**: Evaluating tooth decay, alignment, and jaw structure.
4. **Mammography**: Screening for breast cancer.

OVERVIEW

2. Computed Tomography (CT): Combines X-ray images taken from different angles to create cross-sectional (3D) views.

- X-ray imaging produces summation images, where all attenuation coefficients along the path are integrated.. This is different with CT, where the absorption is determined in 3D for each volume element (voxel). For imaging, a volume is acquired slice by slice, and each slice is reconstructed from several measures in different angulation.

CT can give detailed information than conventional x-rays

CT SLICE PARAMETERS

- Computed Tomography (CT) scan slice parameters refer to the technical settings and adjustments used to acquire and reconstruct CT images. These parameters are critical for optimizing image quality and reducing patient radiation dose:
- **Slice Thickness: Definition**: The width of the reconstructed CT slice, typically measured in millimeters, rang (0.5 mm to 10 mm.)
  - Thinner slices (e.g., 0.5–1 mm) improve spatial resolution
  - Thicker slices (e.g., 5–10 mm) reduce noise and are used for routine imaging or larger structures
- **Slice Interval : Definition**: The distance between the center of one slice to the next in a series.

- **Pitch:** The ratio of table movement per rotation to the beam collimation width. Rang (0.5 to 2.0)
- Formula

$$pitch = \frac{table\ movment\ per\ rotation}{total\ \text{collimation beam width}}$$

Low pitch (<1): Overlapping data acquisition, higher image resolution, but increased radiation dose.

High pitch (>1): Faster scans, lower dose, but possible loss of detail

- **Example:**
- If the **table movement per rotation** is 5 mm and the **total collimated beam width** is 10 mm:
- Pitch= $\frac{5\,mm}{10\,mm} = 0.5$ acquisition.
  - **Advantages**: High image resolution and detail.
  - **Disadvantages**: Longer scan time and increased radiation dose.

CT PARAMETERS

- **Reconstruction Kernel/Filter:** Algorithms used to optimize the image for specific purposes.
- Types:
- Soft tissue kernels :Reduce noise and highlight soft tissues.
- Bone kernels : Enhance edges and bone details.
- Lung kernels: Improve detail in high-contrast areas like the lungs.

- **Matrix Size:** The number of pixels in the image grid (e.g., 512 x 512 or 1024 x 1024).

Considerations: Larger matrices improve spatial resolution but increase processing time.

CT Parameters

- **Reconstruction Algorithms standard :** The Filtered Back Projection (FBP) algorithm is the basis for image reconstruction (converting from the measured data to the image) on modern CT scanners. FBP is a fast and direct method to generate CT images
- AI-based algorithms to reduce noise and dose.(https://youtu.be/2pzR2VyUuNw)

APPLICATIONS:

- Tumor detection
- Trauma assessment
- Abdominal Disorders: Diagnosing appendicitis, kidney stones, or liver disease.

CT SCAN IMAGING

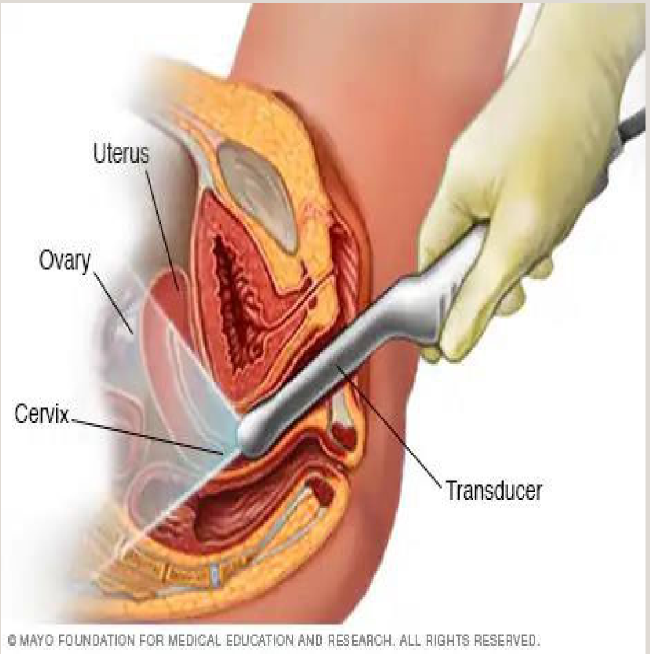
- **Magnetic Resonance Imaging (MRI):** is a non-invasive imaging technology that produces three dimensional detailed anatomical images. It is often used for disease detection, diagnosis, and treatment monitoring. It Uses strong magnetic fields and radio waves to produce detailed images of soft tissues.
- Applications: Brain imaging, spinal cord disorders, joint injuries.
- **Advantages in Image Processing**
- MRI avoids interference from bones, unlike CT, enabling easier segmentation and processing
- .MRI inherently provides volumetric datasets, facilitating advanced 3D image processing techniques such as visualization, and 3D modeling
- **Disadvantages**
- **High Noise Sensitivity**
    1. MRI images are prone to noise, requiring advanced denoising algorithms.
    2. MRI images often suffer from **bias field inhomogeneity**, causing non-uniform intensity across the image. This complicates segmentation and classification tasks.
- **Large Data Size**

High-resolution, 3D datasets require significant computational resources for processing and storage.

Ultrasound

- In contrast to CT and MRI, ultrasound is a medical imaging modality that is based on reflection of sound waves. Sometimes called a sonogram, is a procedure that uses high-frequency sound waves to create an image of part of the inside of the body. Depending on the transducer, 1D to 4D data is obtained.

- Applications: Pregnancy monitoring, abdominal organ assessment, guided biopsies.



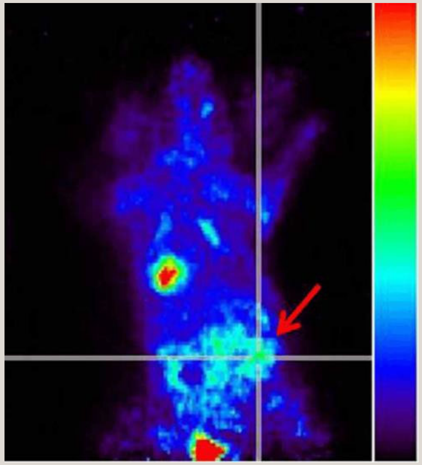
Advantages in Image Processing

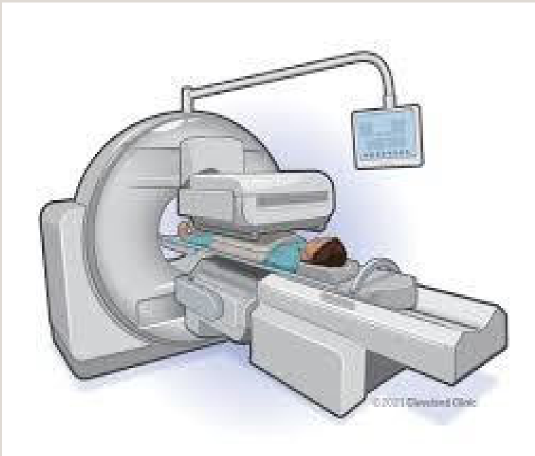
1. **High Resolution for Pelvic Structures**
2. **Clear Visualization :** High-quality grayscale images enhance segmentation and detection

Disadvantages

1. **Artifact Challenges:** Shadows, reverberations, and speckle noise in ultrasound images can interfere with automated processing algorithms, requiring advanced filtering techniques.
2. **Dependence on Operator Skill**
3. **Variability in image acquisition** (e.g., angle and depth of probe insertion) can affect consistency, reducing reproducibility in processing
4. **Low Contrast :** may have poor contrast, making detection and segmentation more difficult.

OVERVIEW





- **<u>Nuclear medicine</u>** Utilizes radioactive isotopes to capture functional information about organs. The emitted radiation is captured to create images of internal organs or physiological processes. Imaging devices, such as gamma cameras or PET scanners, detect radiation emitted from the tracer.

- Applications: Thyroid scans, bone scans, cardiac imaging.

Retinal Imaging: refers to the techniques used to capture high-resolution images of the retina, the light-sensitive layer at the back of the eye. This is crucial for diagnosing a variety of eye conditions and diseases that affect vision. Retinal imaging allows eye care professionals to assess the health of the retina, optic nerve, blood vessels, and surrounding tissues, and can detect early signs of many systemic conditions.

Common Retinal Imaging Techniques:

1. **Fundus Photography:** A standard photographic technique that captures a 2D image of the retina, including the optic nerve head and blood vessels.
2. **Optical Coherence Tomography (OCT):** A non-invasive imaging technique that uses light waves to create detailed cross-sectional images of the retina, allowing visualization of the retina's layers.
3. **Retinal Tomography:** Provides 3D imaging of the retina, using a series of high-resolution images to create detailed maps of retinal topography.

Color retinal image showing features of diabetic