قســـم الانظمة الطبية الذكية
المرحلة الثالثة

Subject : Medical image processing

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Class 3: MEDICAL IMAGE STORAGE AND FORMATS

➢ CONCEPT :

- A medical image is the representation of the internal structure or function of an anatomic region in the form of an array of picture elements called pixels or voxels. It is a discrete representation resulting from a sampling/reconstruction process that maps numerical values to positions of the body area

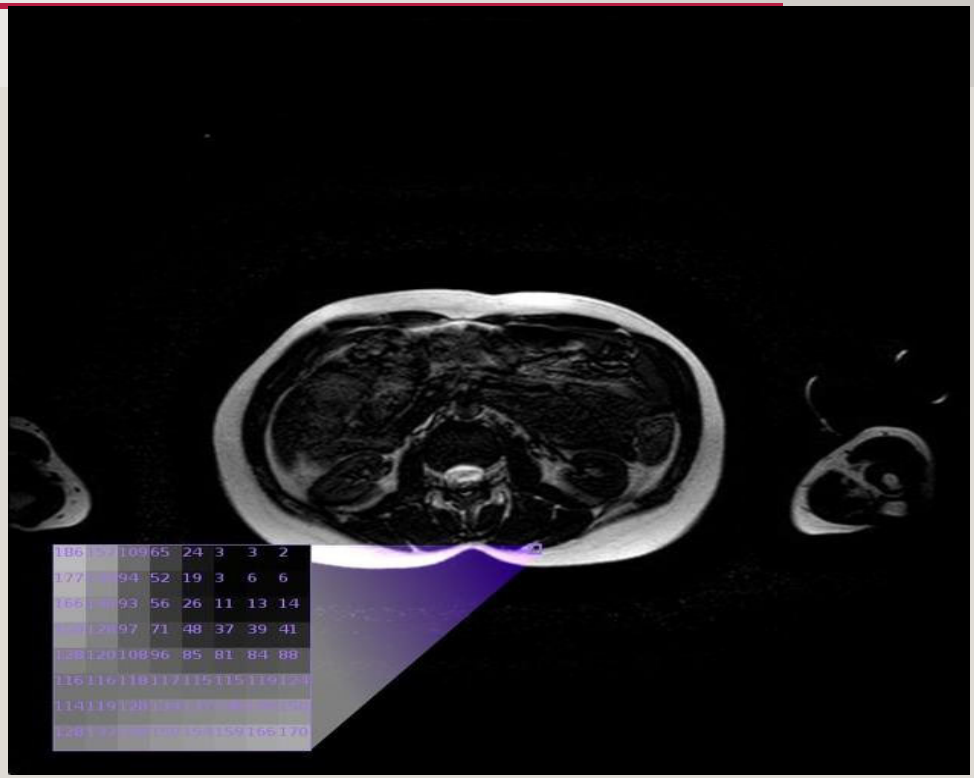
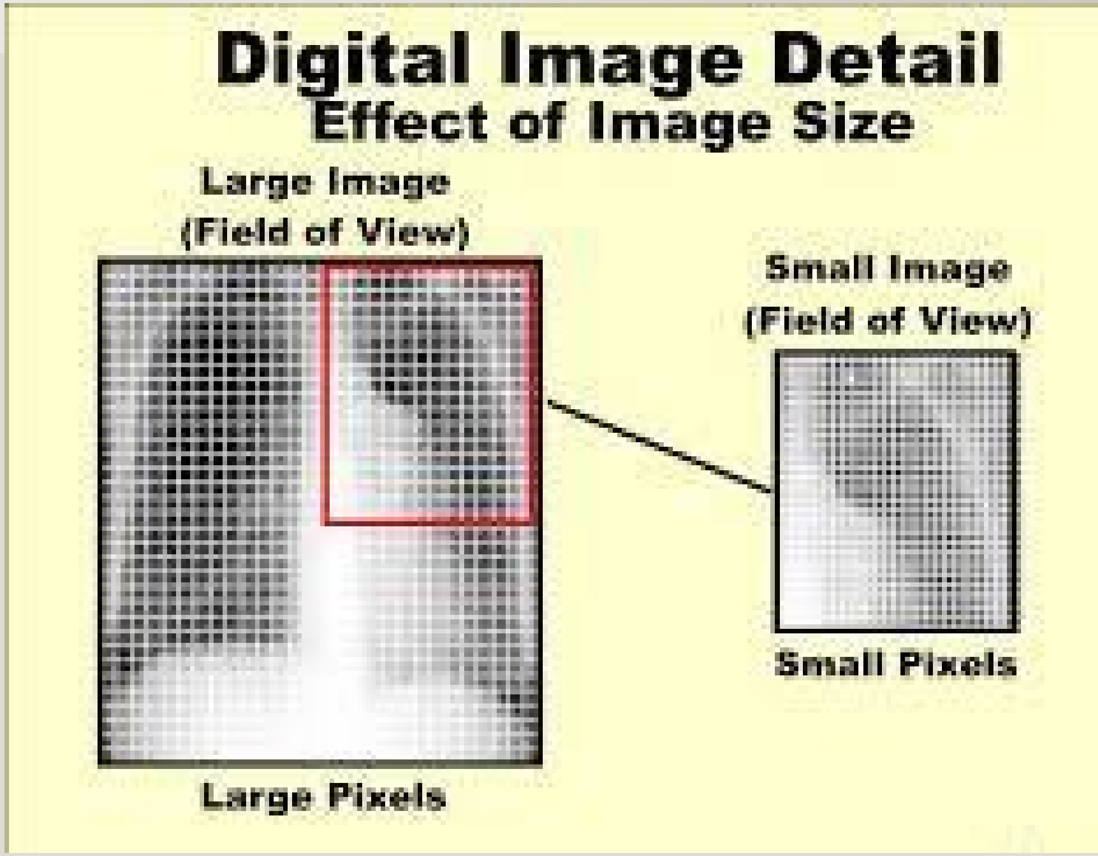


IMAGE FILE FORMAT

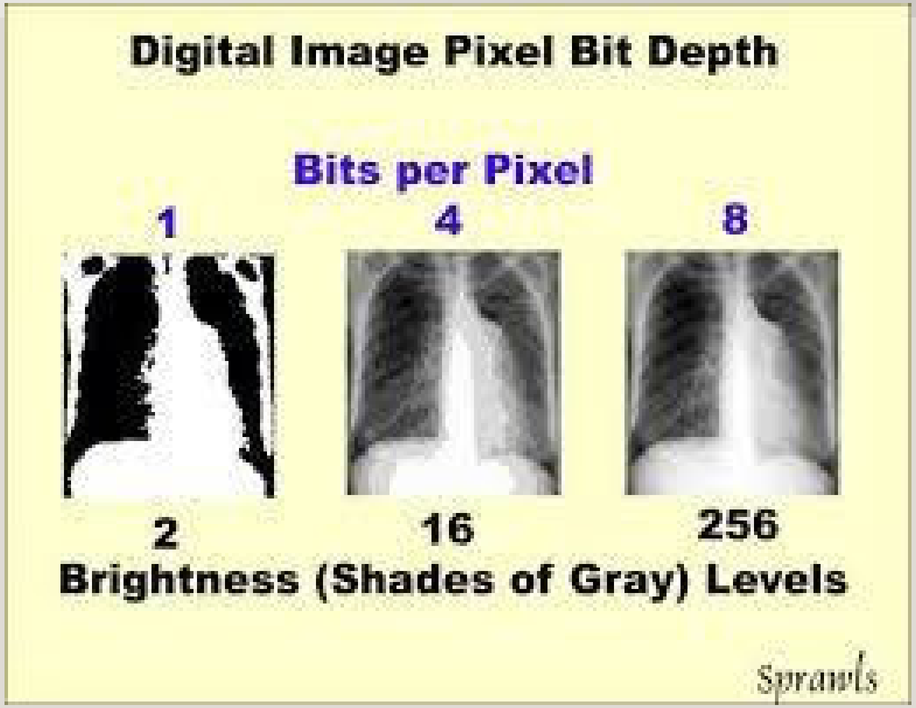
- Image file formats provide a standardized way to store the information describing an image in a computer file. A medical image data set consists typically of one or more images representing the projection of an anatomical volume onto an image plane (projection or planar imaging), a series of images representing thin slices through a volume (tomographic or multislice two-dimensional imaging), a set of data from a volume (three-dimensional imaging), or multiple acquisition of the same tomographic or volume image over time to produce a dynamic series of acquisitions (four-dimensional imaging).
- The file format describes how the image data are organized inside the image file and how the pixel data should be interpreted by a software for the correct loading and visualization

The number of pixels used to describe the field-of-view of a certain acquisition modality is an expression of the detail with which the anatomy or function can be depicted. What the numerical value of the pixel expresses depends on the imaging modality, the acquisition protocol, the reconstruction, and eventually, the post-processing



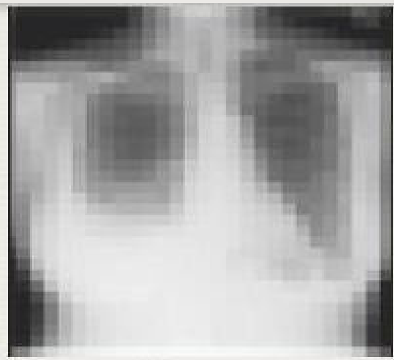
PIXEL DEPTH

- Pixel Depth: is the number of bits used to encode the information of each pixel. Every image is stored in a file and kept in the memory of a computer as group of bytes. Bytes are group of 8 bits and represent the smallest quantity that can be stored in the memory of a computer.

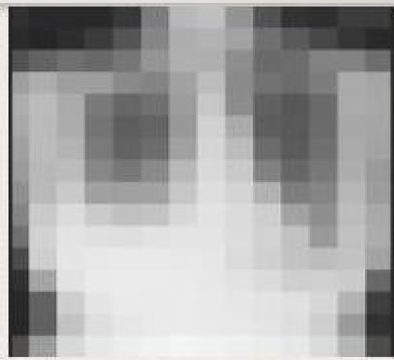


1024 x 1024

64 x 64



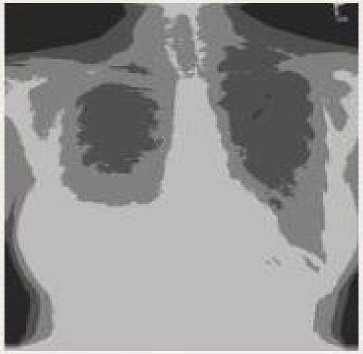
32 x 32



16 x 16

Larger pixels

1 bit/pixel



2 bits/pixel

3 bits/pixel

8 bits/pixel

More bit-depth

For an image of M x N matrix, k bytes/pixel,
the memory needed to store the image is *k x M x N* bytes

PIXEL DEPTH

This means that if :The image dimensions are 256 × 256 pixels.

- The pixel depth (bits per pixel) is either 12-bit or 16-bit., In computer memory, data is typically stored in whole bytes (8-bit units).Since 12-bit and 16-bit values both exceed 8 bits, they will be stored in 2 bytes (16 bits) per pixel. Therefore, the total memory required to store the pixel data is**:**
- **256×256×2=131,072 bytes(128 KB)**
- Thus, whether the image has a **12-bit** or **16-bit** pixel depth, the storage requirement remains the same at **131,072 bytes (128 KB)** because the system rounds up 12-bit values to fit into 16-bit storage.
- Note: 1 KB (Kilobyte) = **1024 bytes**
- **131,072/1024=128 KB**

QUIZ

If a pixel depth of 2 bytes per pixels, what is possible to codify and store integer numbers?

PIXEL DEPTH

- Sol:
- **2 bytes per pixel** means each pixel is stored using **16 bits** (since 1 byte = 8 bits, 2 bytes = 16 bits).
- A **16-bit integer** can represent values from **0 to 2^{16} - 1**.
- Since **2^{16} = 65,536**, the possible values range from **0 to 65,535** (total **65,536** values).

- Image data may also be real numbers. The Institute of Electrical and Electronics Engineers created a standard (IEEE-754) in which defines two basic formats for the encoding in binary of floating-point numbers: the single precision 32-bit and the double precision 64-bit
- Application in Images:
- Floating-point image data is useful in scientific imaging, medical imaging (e.g., CT scans).
- It allows storing very large or very small values with high precision, unlike integer-based image formats.

- **Single Precision (32-bit Floating Point)**
- Single precision is a **32-bit** representation of a floating-point number following the **IEEE-754 standard**. It is commonly used in graphics, machine learning, and scientific computing when memory efficiency is important.
- A **single-precision** floating-point number consists of three parts:
- Uses 32 bits (4 bytes).
- Stores numbers with approximately 7 decimal digits of precision.
- Structure:
- 1 bit for the sign (positive or negative).
- 8 bits for the exponent (to handle large/small numbers).
- 23 bits for fractional part

EXAMPLE

- Example: Storing 5.75 in IEEE-754 Single Precision

1- Convert 5.75 to binary:

5 in binary: 101

0.75 in binary: 0.11, repeatedly **multiply by 2**, keeping track of the integer part (0 or 1) and using only the decimal fraction for the next step.

Step	Decimal Value × 2	Integer Part	Fraction Part
1	0.75 × 2 = **1.50**	**1**	0.50
2	0.50 × 2 = **1.00**	**1**	0.00 (Stop here)

- So, 5.75 in binary: 101.11

- Normalize it in scientific notation:. Shifting the dot. Left or right to closed 1, Scientific notation for binary works just like decimal scientific notation but with **base 2**.The goal is to express the number in the form:
- Move the binary point **right 2 places**

1.0111×2^2

- Since we moved **right**, the exponent is **negative, left is positive**

- **Can you** Convert back to decimal?

APPLICATIONS OF SINGLE PRECISION (32-BIT) IN MEDICAL IMAGING

1. **Real-Time Image Processing: CT Scans (Computed Tomography)** and **X-ray Imaging** often use **single precision** for real-time image reconstruction and processing. These applications require the ability to process large numbers of pixels quickly, and **32-bit precision** can be sufficient for tasks like image enhancement, filtering, and noise reduction.

2.Medical Image Enhancement: Techniques like contrast adjustment, edge detection, and noise removal are commonly performed using **single precision** to make sure images are processed quickly for real-time analysis during medical procedures.

3. Image Registration involves aligning different images (e.g., MRI, CT, or X-ray images) taken at different times or from different perspectives.

4.Multi-modal Image Fusion: Combining multiple imaging modalities (like CT and MRI) to create a composite image that provides more detailed information is often done using **single precision** to balance the need for speed and accuracy.

Double precision (64-bit):double precision is a more **accurate** and **precise** representation of floating-point numbers, using **64 bits (8 bytes)** as defined by the **IEEE-754** standard. It is often used in applications that require high precision, such as scientific calculations, simulations, and high-quality graphics representation of numbers ranging from $\pm 2.2 \times 10^{-308}$ to $\pm 1.8 \times 10^{308}$

- Uses **64 bits (8 bytes)**.
- Stores numbers with approximately **15–16 decimal digits of precision**.
- Structure:
  - **1 bit** for the **sign**.
  - **11 bits** for the **exponent**.
  - **52 bits** for the **mantissa/fraction** .

- **Applications of Double Precision in Medical Imaging**
- **MRI (Magnetic Resonance Imaging)**: MRI images often have pixel values that need high precision, especially for different tissue types. Using double precision ensures there's no loss of information during the processing of these values.
- **CT Scans (Computed Tomography)**: In CT imaging, intensity values represent various tissue densities, requiring large dynamic ranges. Double precision ensures that each voxel (3D pixel) retains all necessary data for accurate diagnosis.
- **Medical Image Segmentation**: When identifying and isolating structures (like organs or tumors) from medical images, algorithms can be very sensitive to small differences in pixel values. Double precision helps ensure these subtle differences are preserved during segmentation

NOTE

- Single precision (32-bit) floating point is widely used in **medical imaging** for applications that require high performance, large-scale processing, and reasonable accuracy. It strikes a balance between speed and memory usage, making it ideal for real-time imaging, image enhancement, AI-based analysis, and medical simulations where extreme precision is not always necessary..