Biomedical Image Analysis and Understanding

Open Elective

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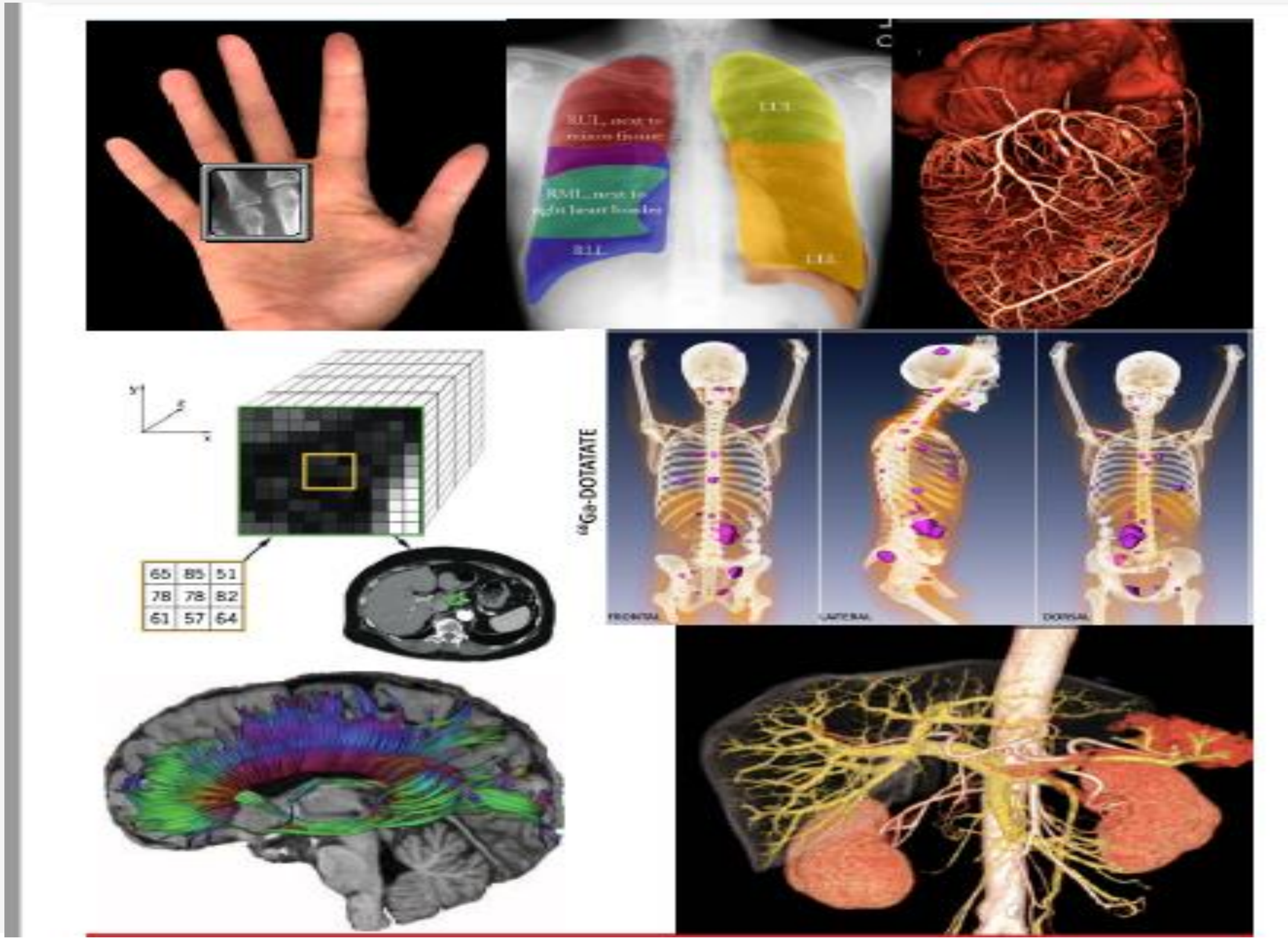
Unit – I: Introduction to Biomedical Image Processing

Content:

- Digital Image Processing System
- Medical Image modalities
- Image Algebra, Image transform (FT, DCT, DWT, HOUGH, KL)
- Image Enhancement in spatial and frequency domain
- Image Restoration
- Medical applications of Imaging
- Frontiers of Image processing in Medicine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Biomedical Imaging and Understanding

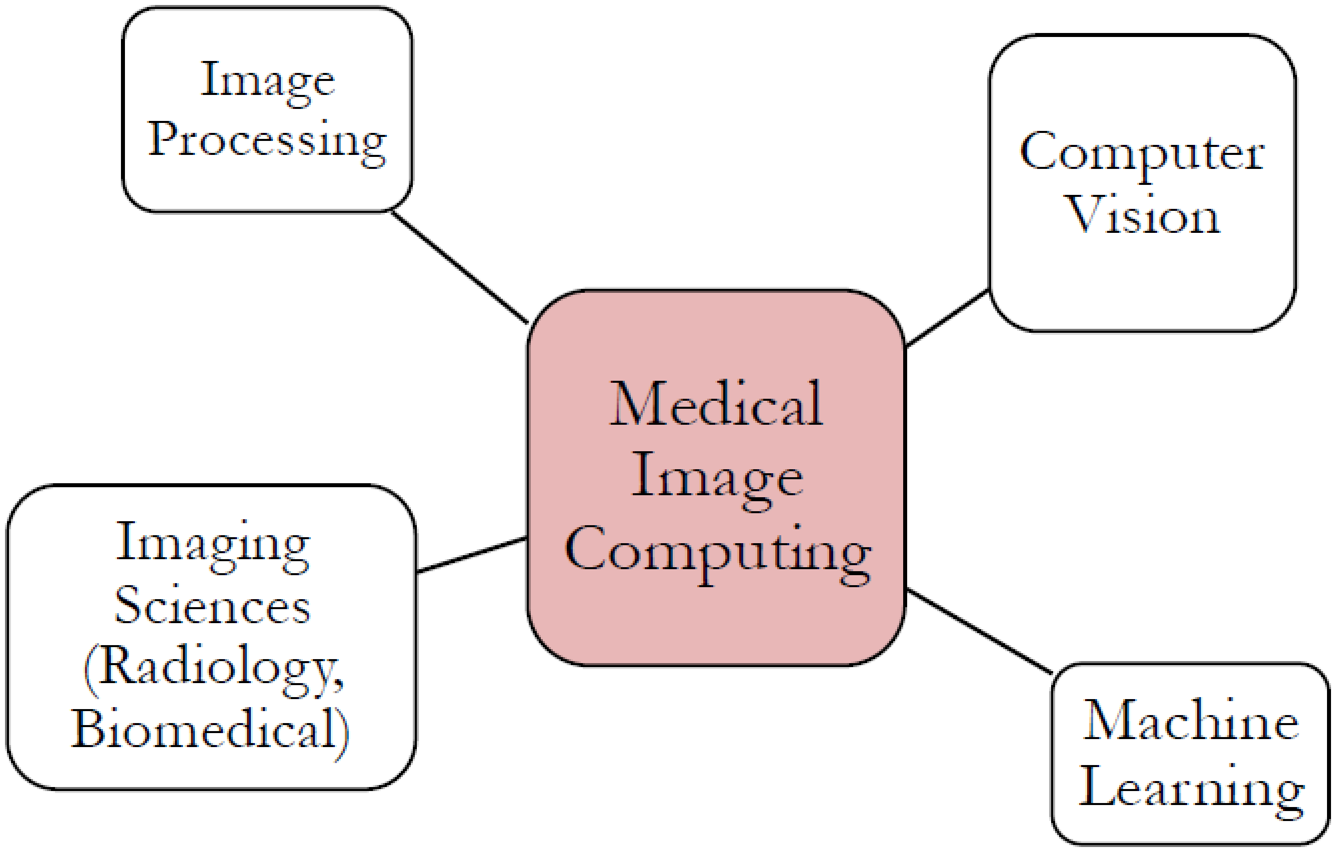
Medical Image Computing :

Biomedical imaging and its analysis are fundamental to

(1) understanding,

(2) visualizing, and

(3) quantifying information.



Biomedical Images – Modalities

- (Bio)medical images are different from other pictures

– They depict distributions of various physical features measured from the human body (or animal).

- Analysis of biomedical images is guided by very specific expectations

– Automatic detection of tumors, characterizing their types,

– Measurement of normal/abnormal structures,

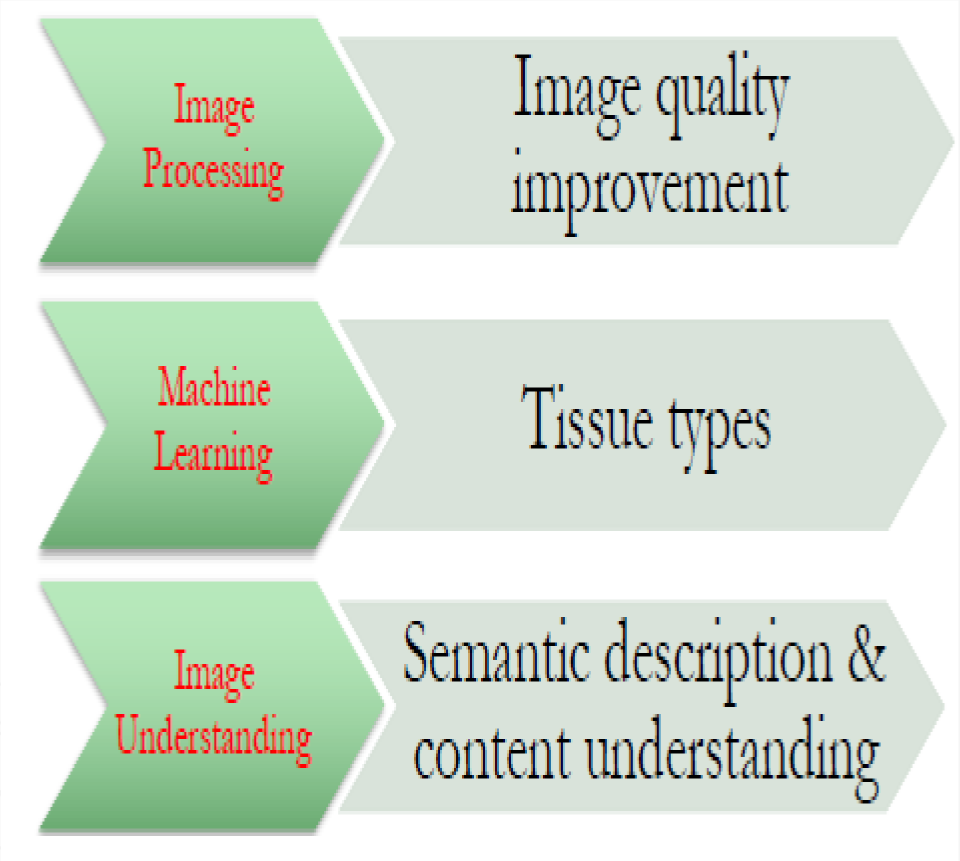
– Visualization of anatomy, surgery guidance, therapy planning,

– Exploring relationship between clinical, genomic, and imaging based markers

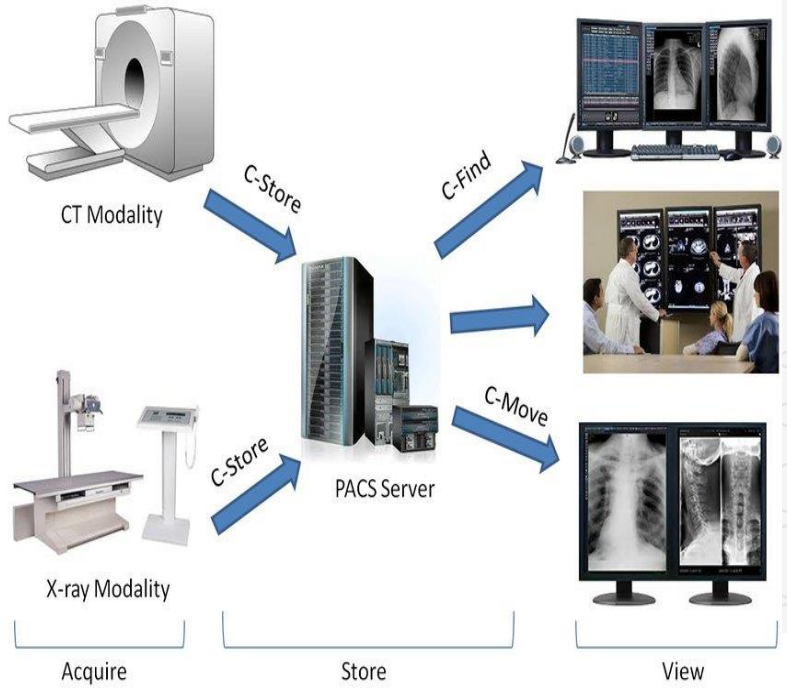
- X-ray
- Ultrasound
- **Computed Tomography (CT)**
- **Magnetic Resonance Imaging (MRI)**
- Positron Emission Tomography (PET)
- Diffusion Weighted Imaging (DWI)
- Diffusion Tensor Imaging (DTI)
- Magnetic Particle Imaging (MPI)
- Optical Coherence Tomography (OCT)

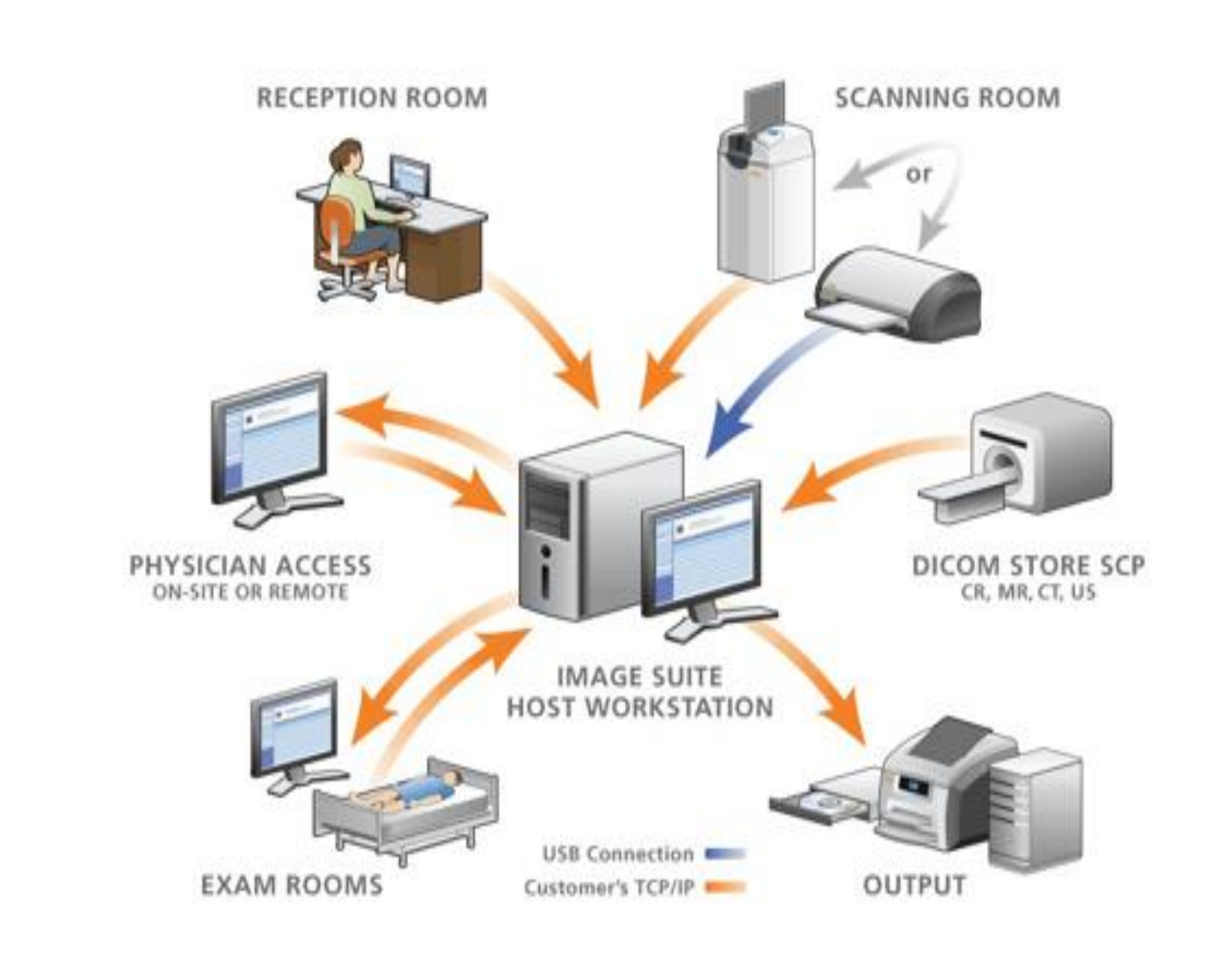
Medical Imaging

- The most direct way to see inside the human (or animal) body is cut it open (i.e., surgery)
- We can see inside the human body in ways that are less invasive or (completely non-invasive)
- We can even see metabolic/functional/molecular activities which are not visible to naked eye



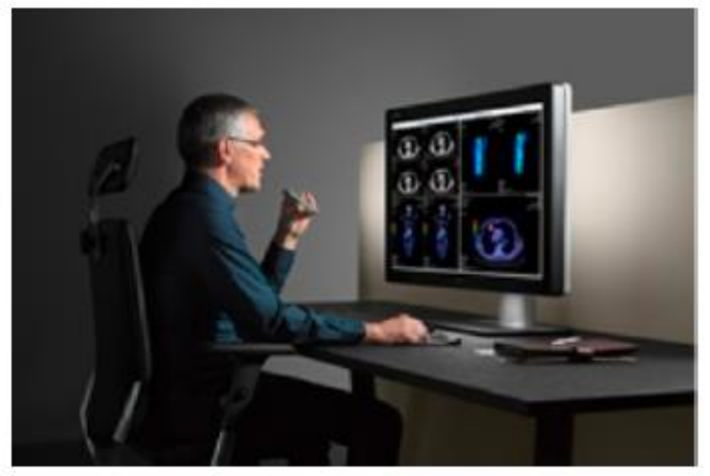
Picture archiving and communication system (PACS) is a modality of imaging technology which helps in image transmission from the site of image acquisition to multiple physically-disparate locations





where do radiologists interpret scans?

- Dedicated light source
- Darkened environment
- Limited distraction



Medical Image Analysis

• Because of the rapid technical advances in medical imaging technology and the introduction of new clinical applications, medical image analysis has become a highly active research field.

• Improvements in image quality, changing clinical requirements, advances in computer hardware, and algorithmic progress in medical image processing all have a direct impact on the state of the art in medical image analysis.

• Medical images are often **multidimensional (2D, 3D, 4D,nD)**, have a large dynamic range, are produced on different imaging modalities in the hospital, and make high demands upon the software for visualization and human–computer interaction.

– A high resolution MR image of the brain, for instance, may consist of more than 200 slices of 512 x 512 pixels each, i.e., more than 50 million voxels in total. (100MB)

– In clinical studies that involve the analysis of time sequences or multiple scans of many subjects, the amount of data to be processed can easily exceed 10 GB.

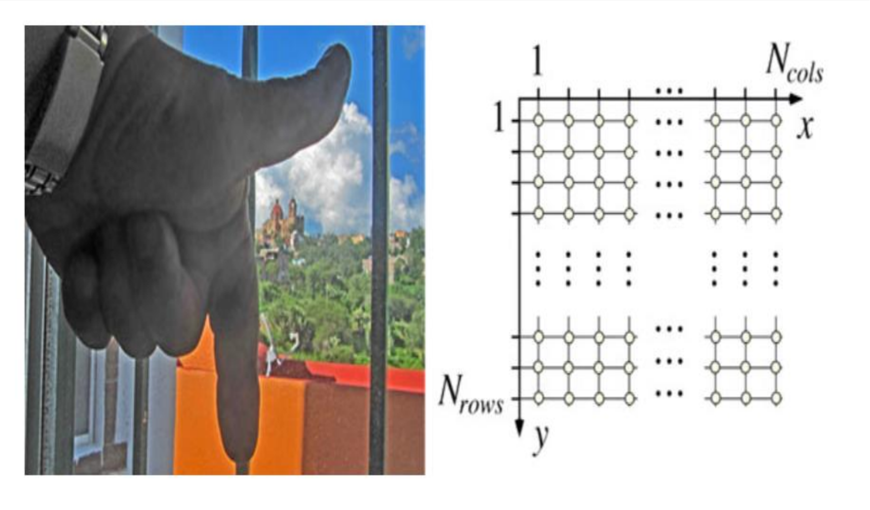
– While 8 bits or 1 byte per pixel is usually sufficient in digital photography, most medical images need 12 bits per pixel (represented by 2 bytes in the computer memory).

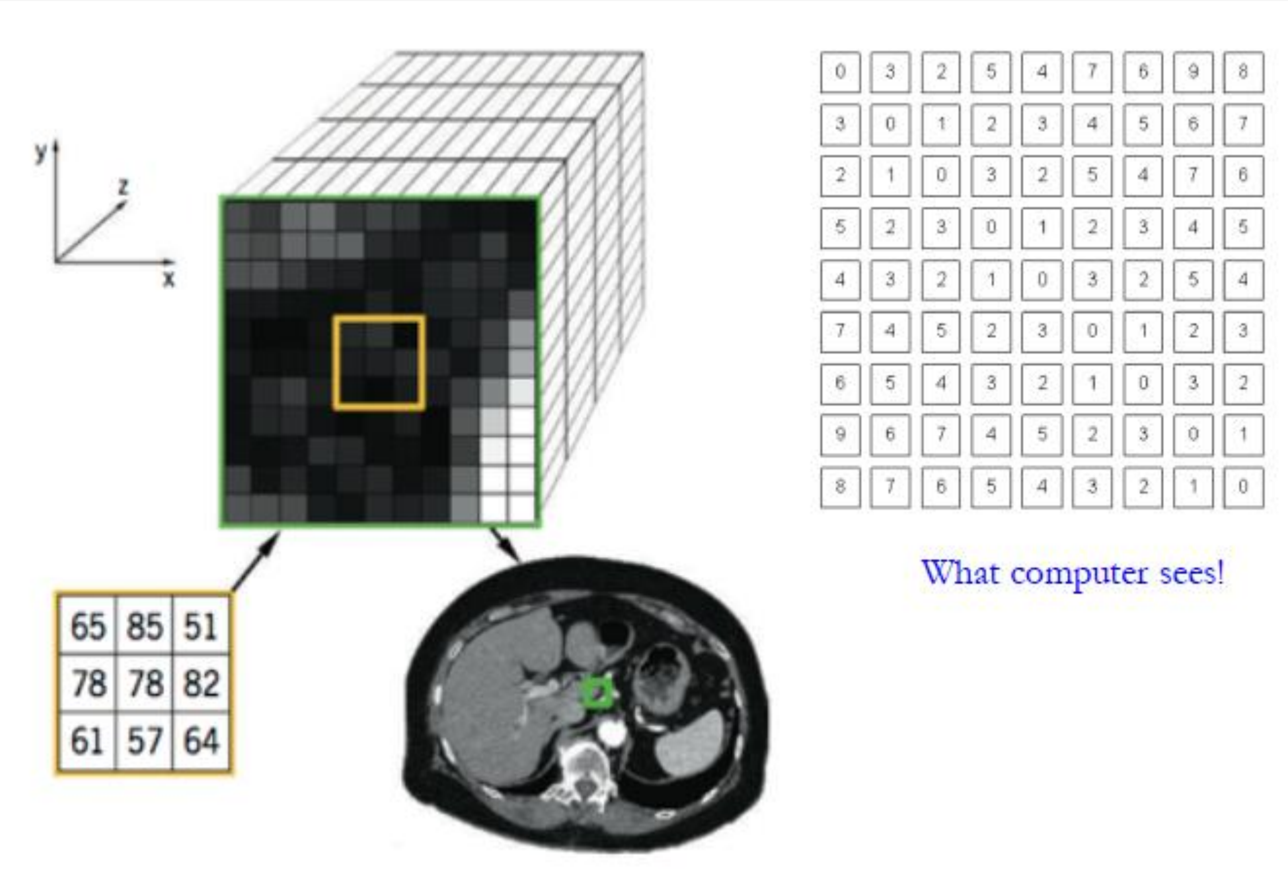
Medical Image Analysis-Automated

- Different strategies for image analysis exist. However, few of them are suited for medical applications.
- The reason is that both the medical image data and the model or prototype (i.e., the a priori description of the features to be analyzed), are typically quite complex.

Digital Images

Definition: A digital image is defined by *integrating* and *sampling* continuous (analog) data in a spatial domain





Picture Elements (Pixels), Volume Elements (Voxels)

PIXELS are ATOMIC ELEMENTS of an image.

In late 1960s, terminology 'pixel' was introduced by a group of scientist at JPL in California!

Image Types

- A scalar image has integer values

$$u \in \{0, 1, ..., 2^a - 1\}$$

a: level (bit)

Ex. If 8 bit (a=8), image spans from 0 to 255

0 black

255 white

Ex. If 1 bit (a=1), it is binary image, 0 and 1 only.

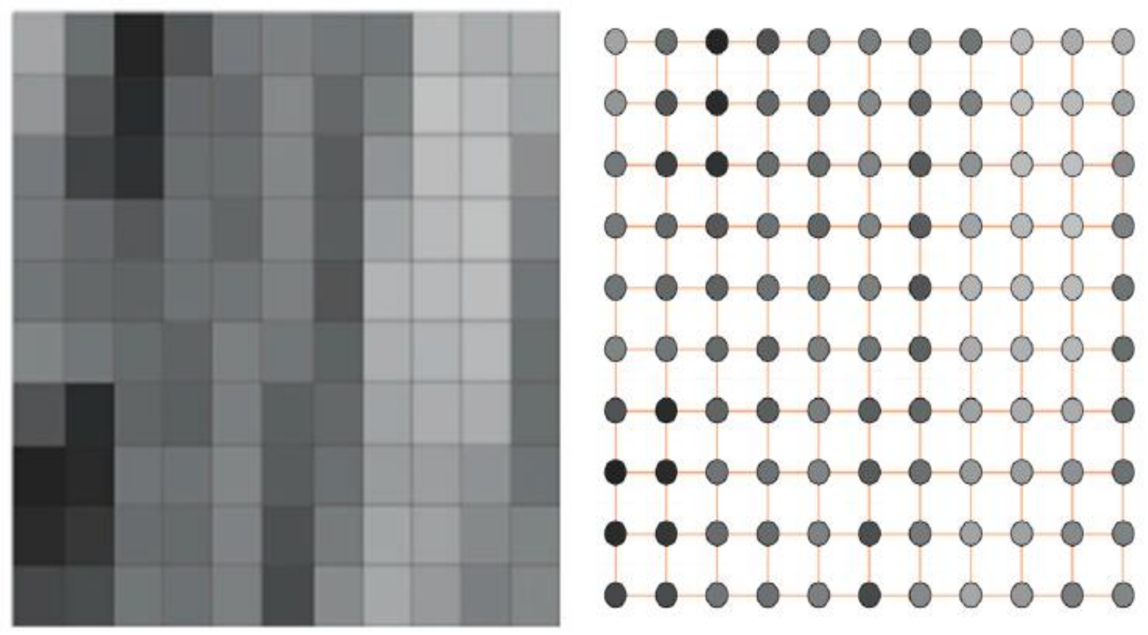
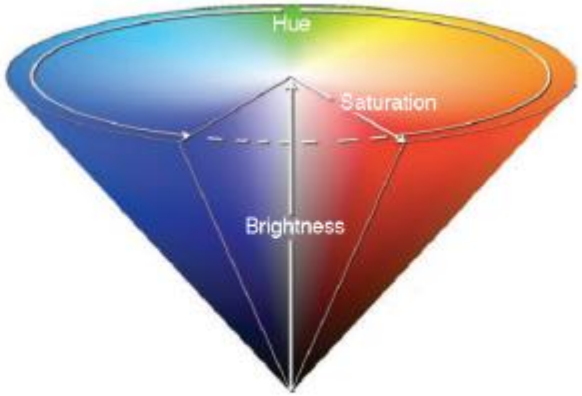
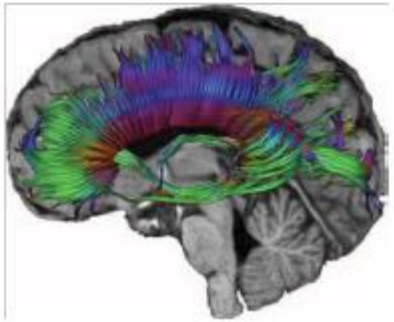


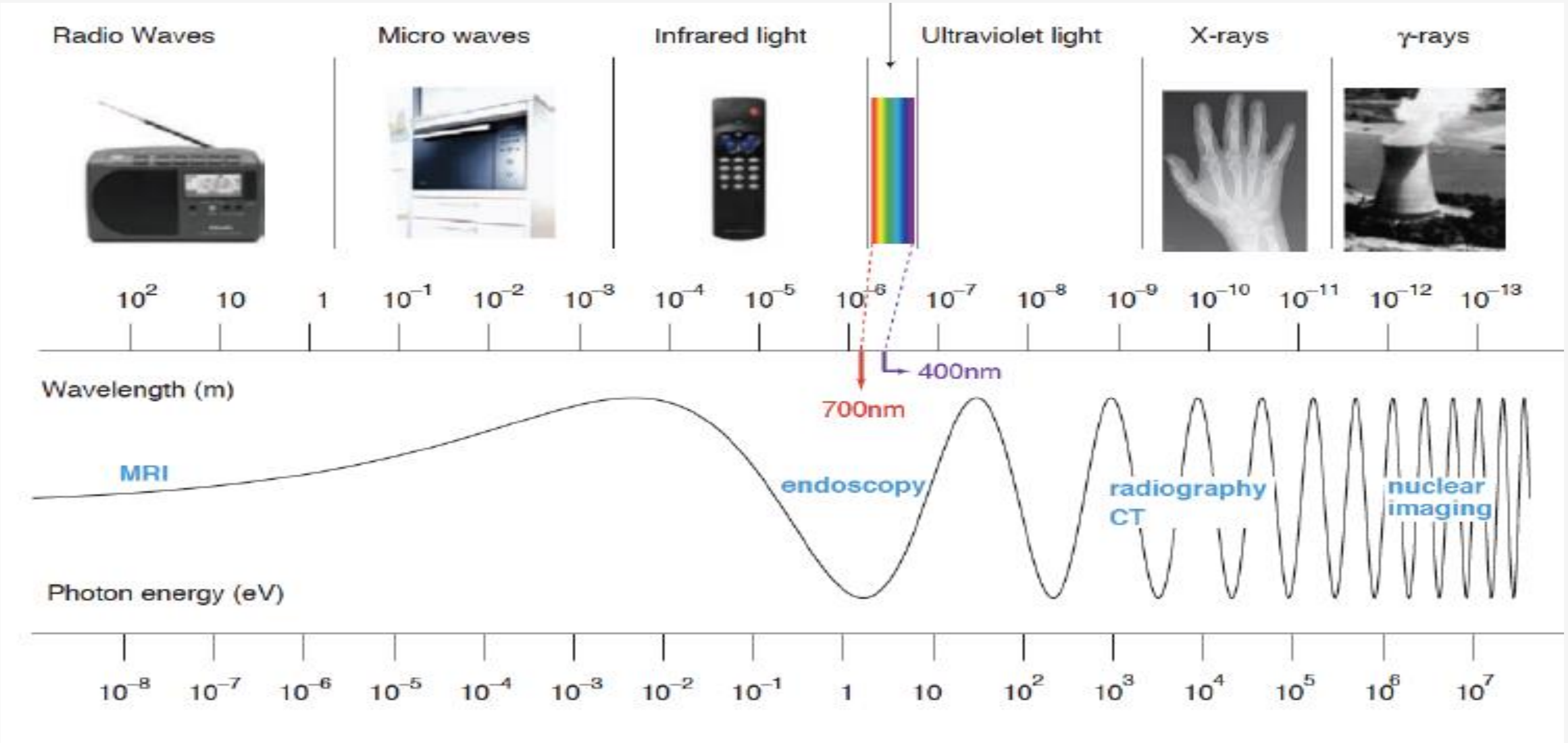
Image Types-Color



- Image has three channels (bands), each channel spans a-bit values.
- RGB, Hue-Saturation-Brightness



ELECTROMAGNETIC SPECTRUM



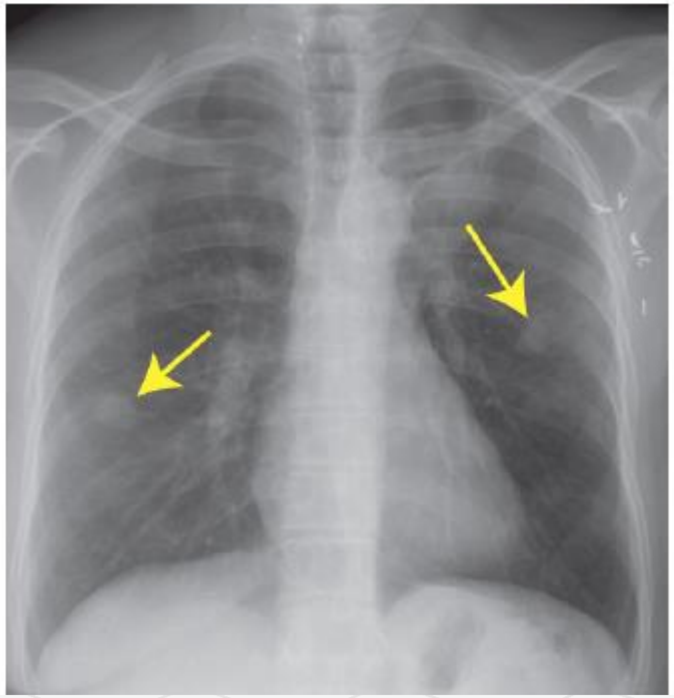
X-Ray Imaging / Radiography

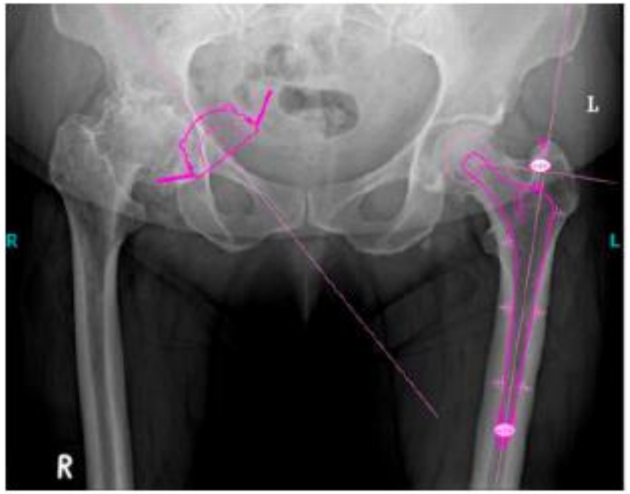
- The first published medical image was a radiograph of the hand of Wilhelm Conrad Roentgen's wife in 1895. *Nobel Prize in Physics 1901.*

<u>routine diagnostic radiography (2D images):</u>
chest x-rays, fluoroscopy, mammography, motion tomography, angiography, …

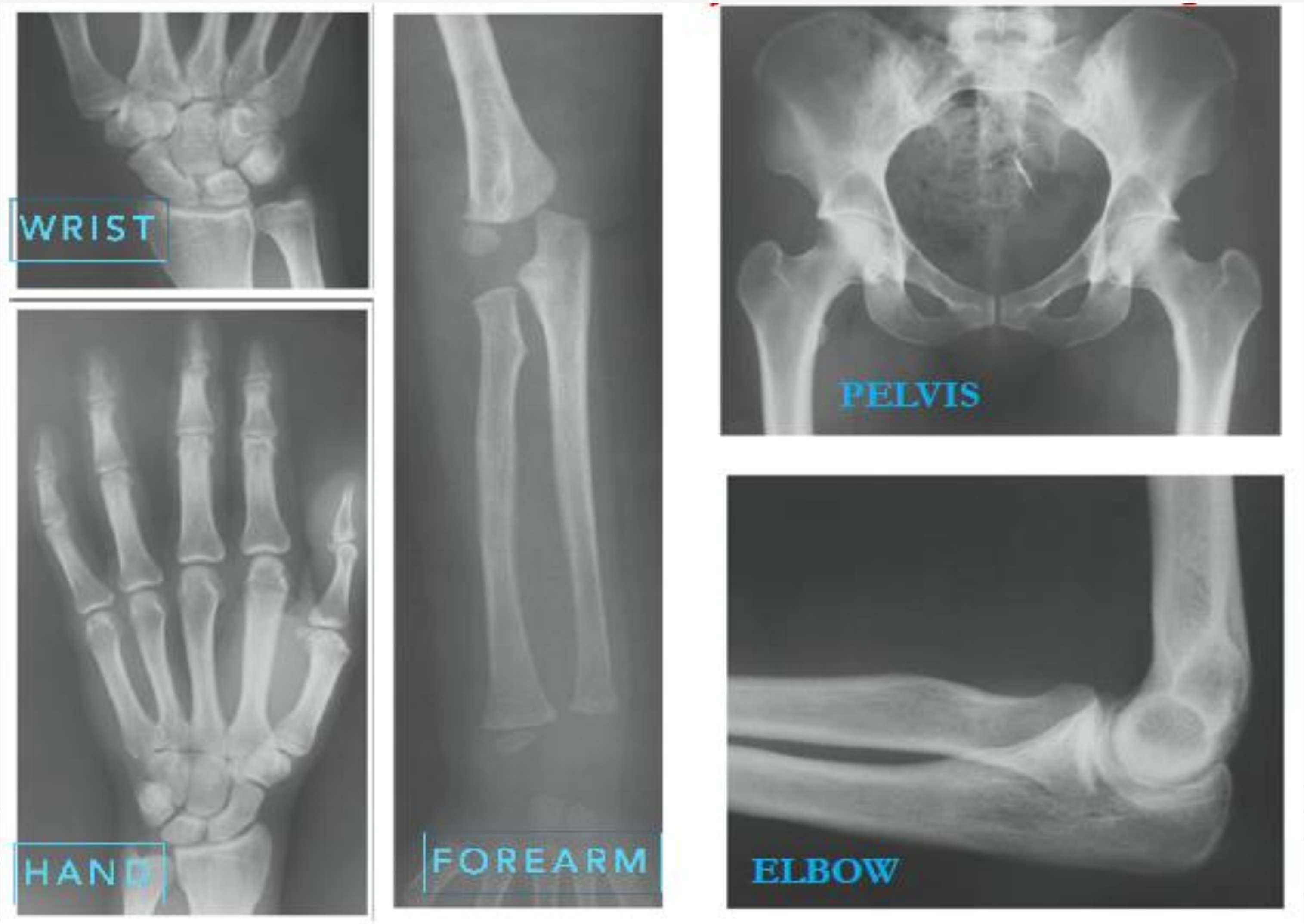
Basics Use of X-Rays

- Dental examinations
- Surgical markers prior to invasive procedures
- Mammography
- Orthopedic evaluations
- Chest examination (Tuberculosis)
- Age estimation (forensic, left hand)

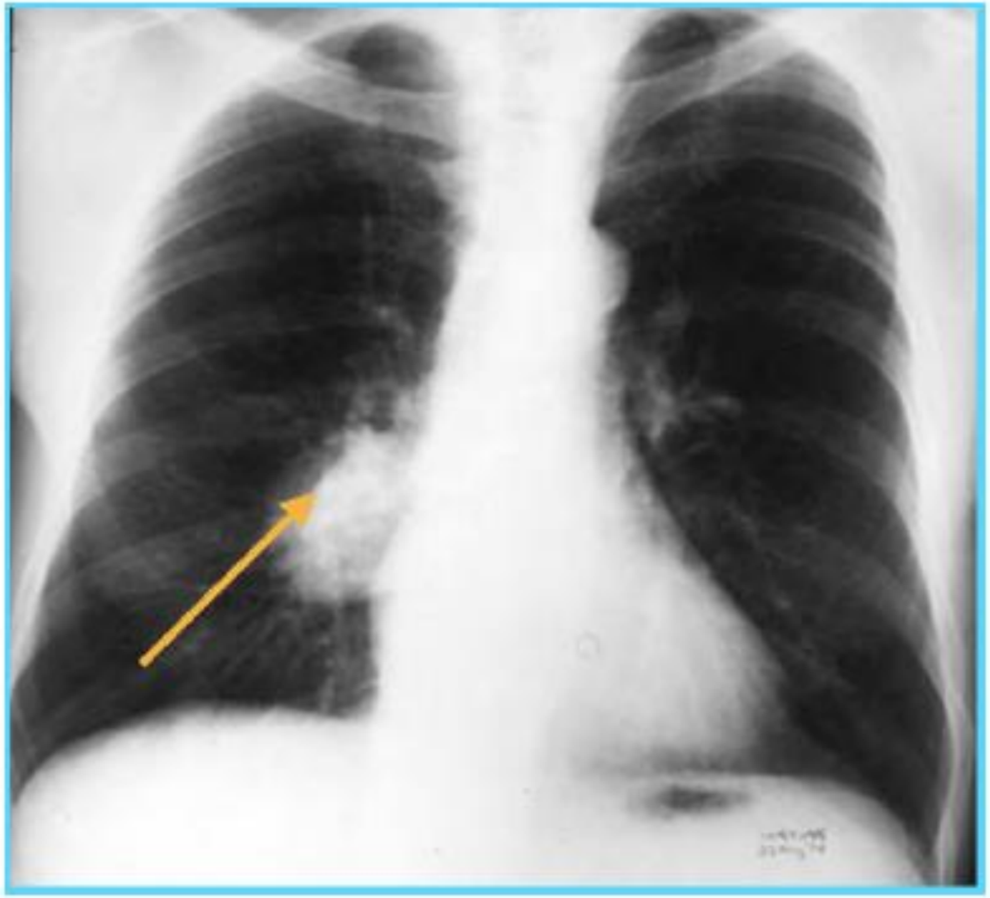




Clinical Examples – X-Rays



How Radiologists Search Abnormal Patterns in Chest X-Rays?



Radiologists often report the following

- Size, dimension, volume
- Pattern description,
- Location,
- Interaction with Nearby structures,
- Intensity distribution
- Shape
- …

Difficulties

- Noise
- vessels can be seen as small nodules
- radiologists may miss the pattern
- patterns may not be diagnostic
- CT often required for better diagnosis
- size estimation is done manually in 2D
- Shadowing
- total lung capacity computation

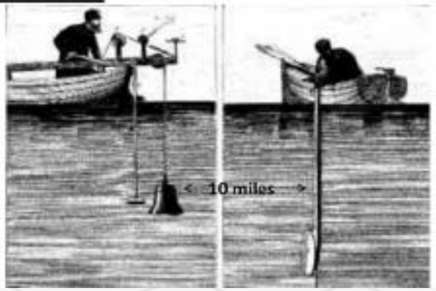
Computer algorithms can solve/simplify these problems for improved healthcare

Ultrasound Imaging

- US is defined as any sound wave above 20KHz

1794-Lazzaro Spallanzani - Physiologist
First to study US physics by deducing bats used to US to navigate by echolocation

1826-Jean Daniel Colladon - Physicist
Uses church bell (early transducer) under water to calculate speed of sound through water prove sound traveled faster through water than air.

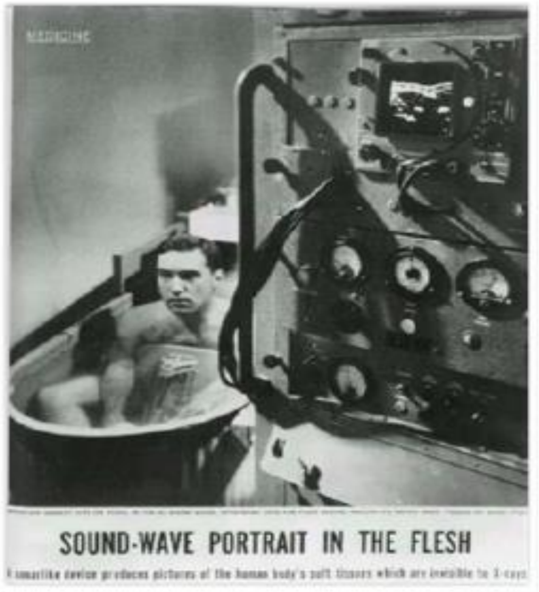


1880-Pierre&Jacques Curie
discover the Piezo-Electric Effect (ability of certain materials to generate an electric charge in response to applied mechanical

Principle of US Imaging

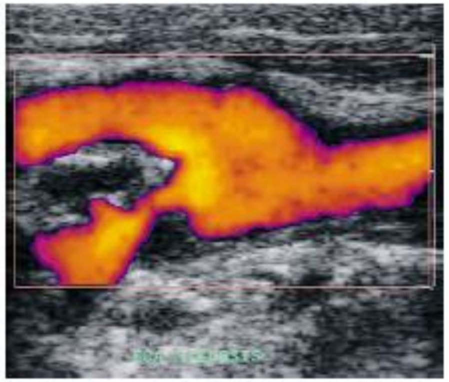
US Imaging Technology

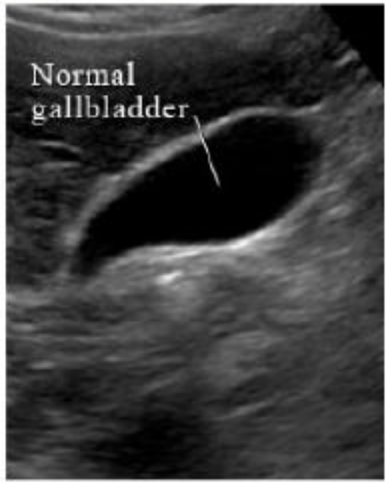
1942-Karl Dussik - Neurologist
First physician to use US for medical diagnosis
1948-George Ludwig - MD
First described the use of US to diagnose gallstones
1958-Ian Donald
Pioneers in OB-GYN



Features of US Imaging

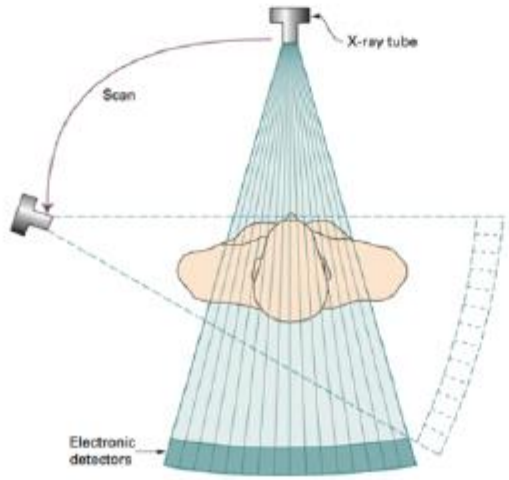
- Resolution:
  - direction of pulse propagation, pulse width 1-2mm
  - direction of scanning: beam width 2-3mm
  - low resolution and low SNR in deep region
- Ability of imaging soft tissue
- imaging in real time
- Doppler image
- Artefacts

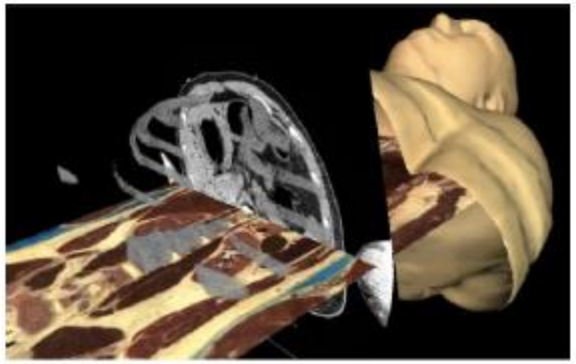


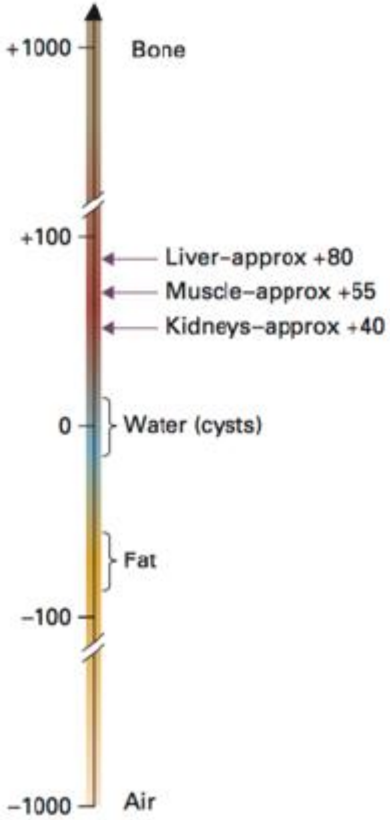


Color flow mapping shows simultaneous amplitude (US) and velocity information (doppler)

Computed Tomography (CT)



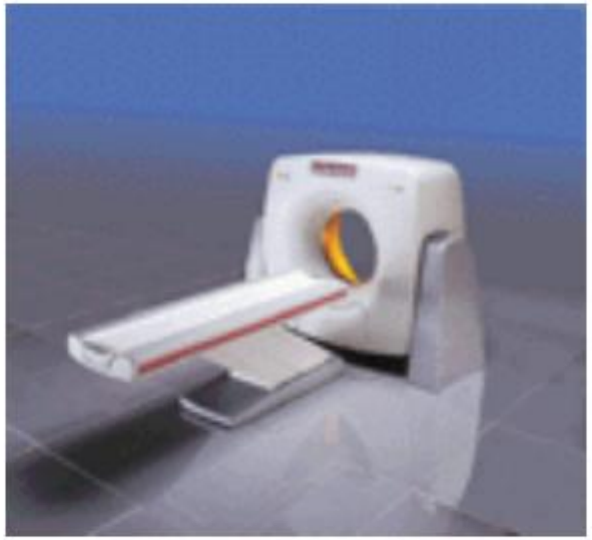




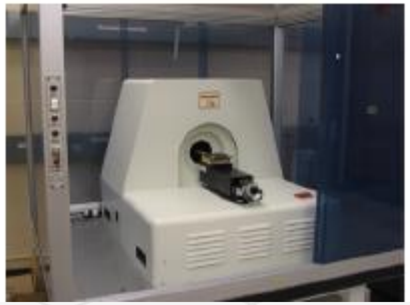
Tomo: slice/level (Greek)
Graphe: draw

CT Imaging (continue)

C-arm



CT

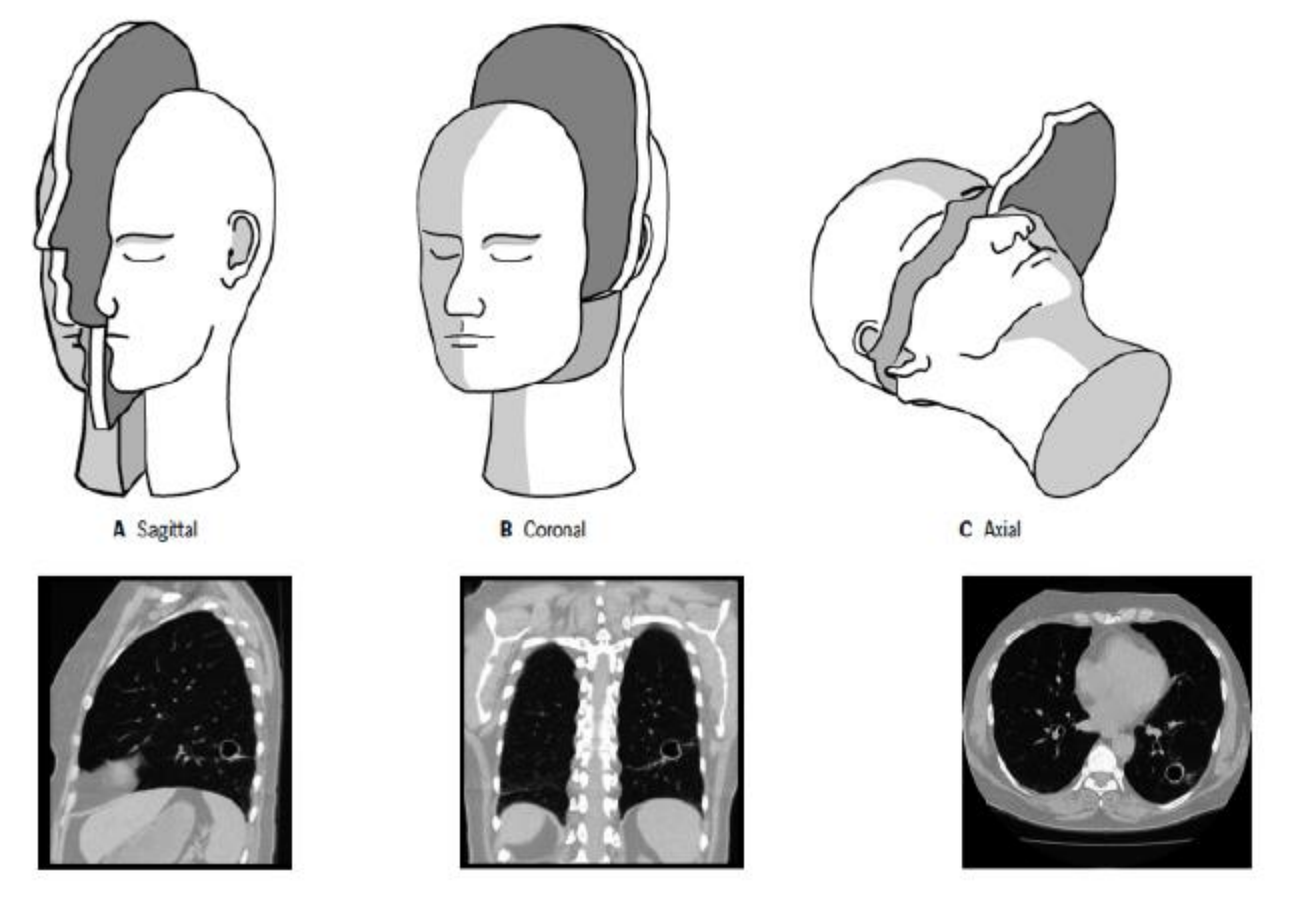


Micro-CT

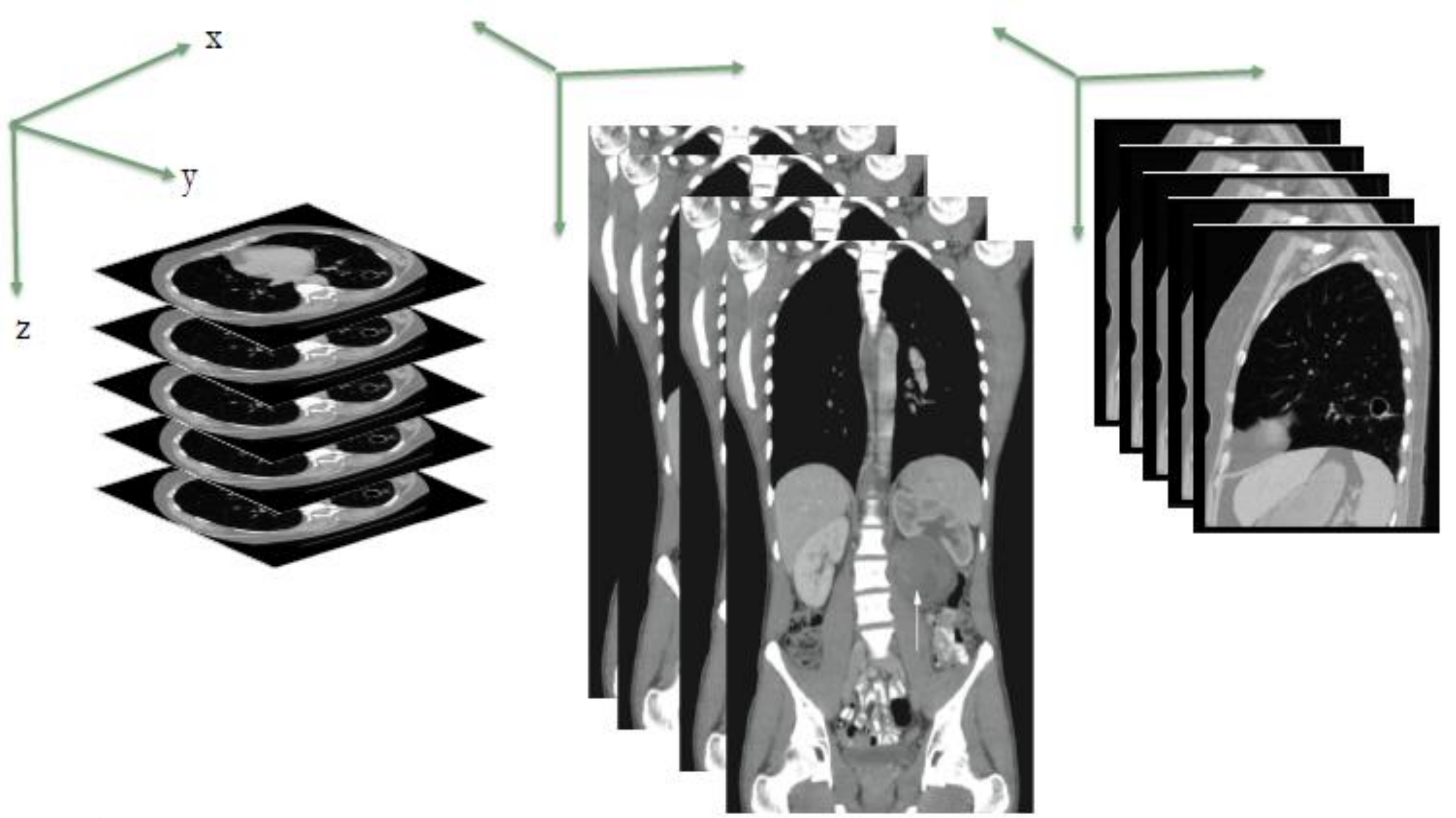
~CAT Scan (computerized Axial tomography)

3D Nature of CT

3D View Terminology



3D Images

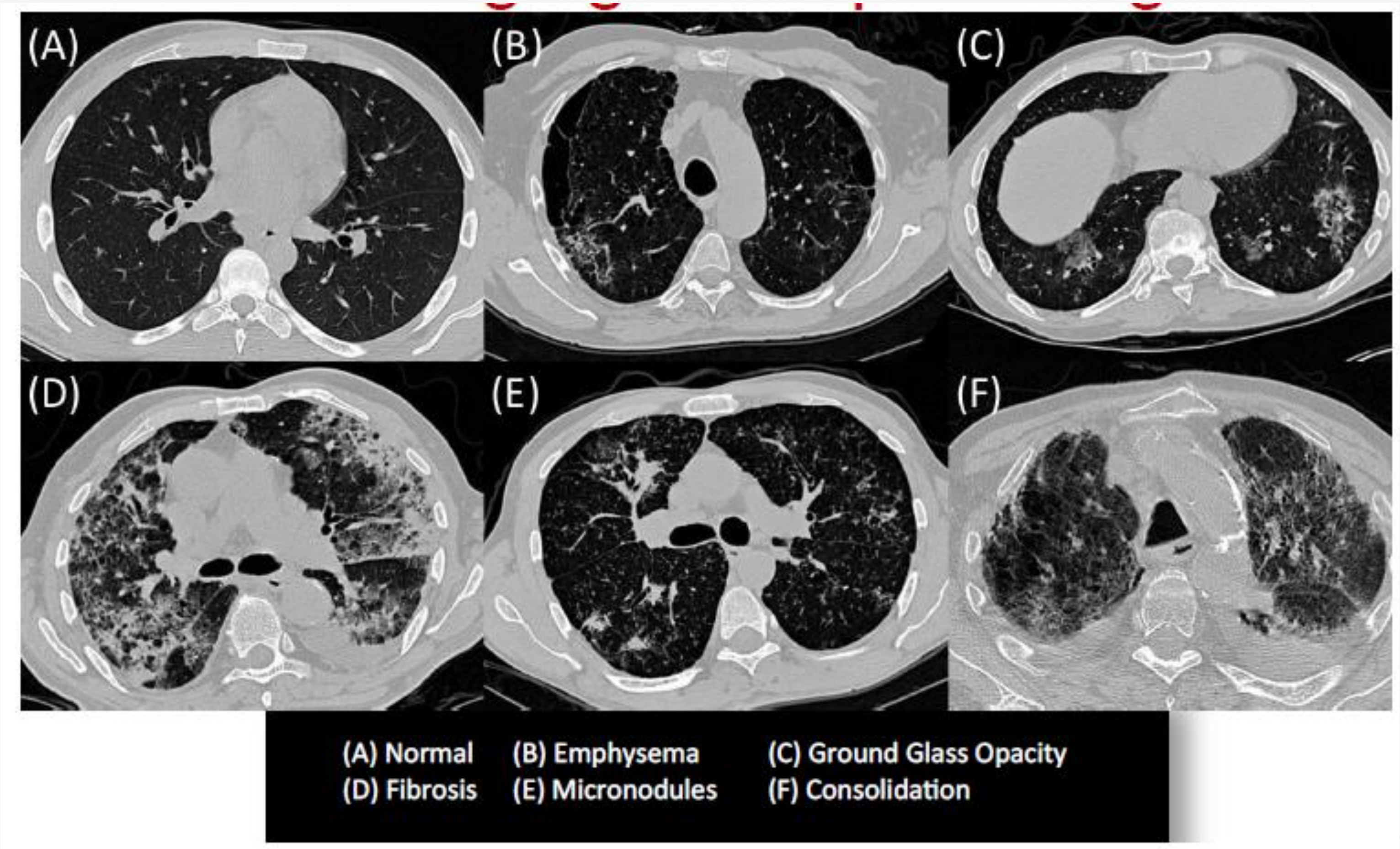


I: Image
I(x,y,z) denotes intensity value at pixel location x,y,z

Clinical Use of CT Imaging

- Standard imaging technique in many organs, particularly gold standard for lung imaging
- Fast
- Radiation exposure
- Often used in surgery rooms
- Show anatomy and pathology
- Intensity values are (more-or-less) fixed, read as HU (Hounsfield Unit)

CT Imaging Example: Lung

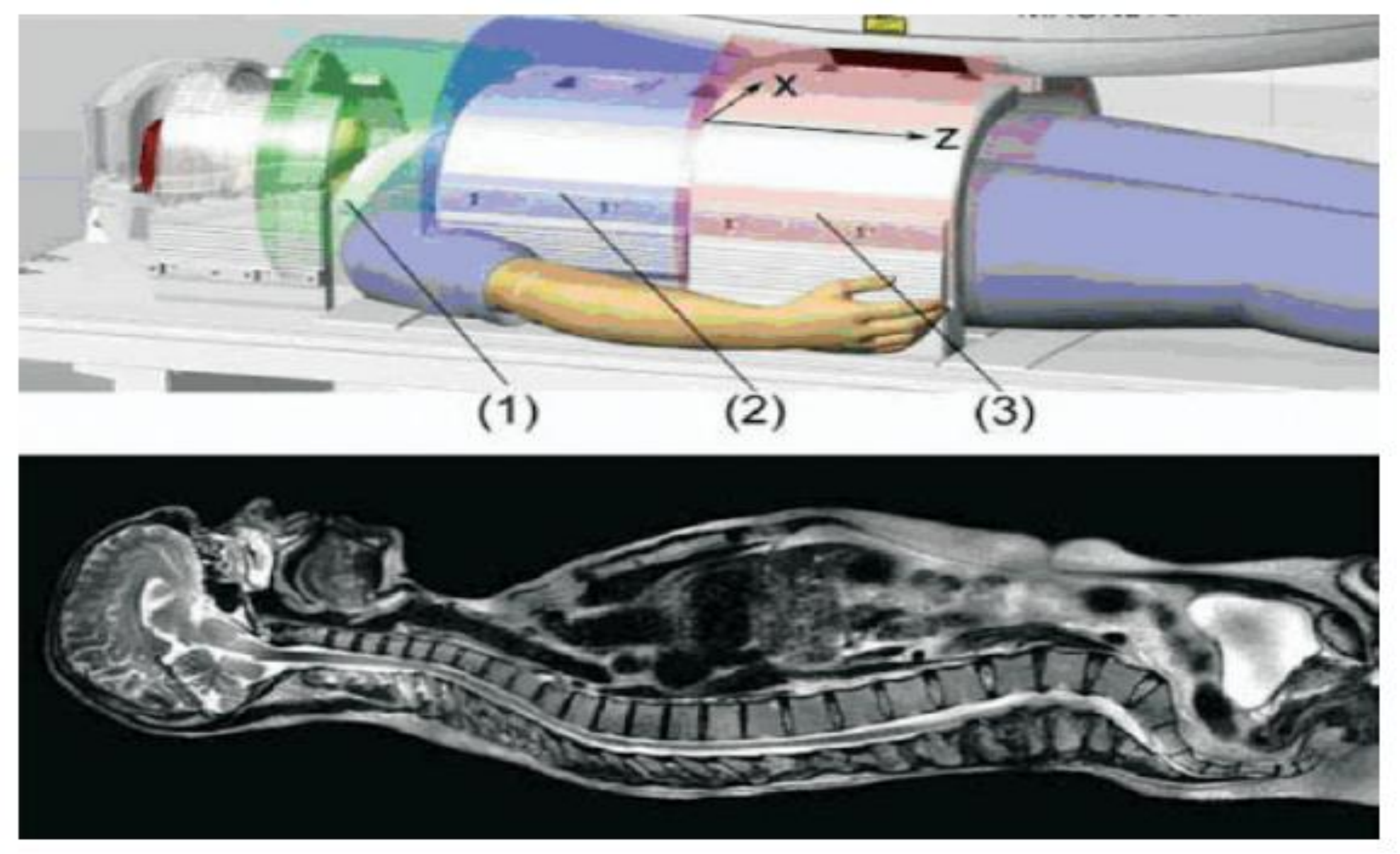


Magnetic Resonance Imaging (MRI)

- 1882-Nichola Tesla
- Discovered rotating magnetic field
- 1971-Paul Lauterbur   NOBEL PRIZE
- First invented MRI
- Late 1970-Sir Peter Mansfield (Nottingham)   NOBEL PRIZE
- Developed mathematical techniques to create clearer images and also in minutes rather than hours as Lauterbur did.

- CT is more widely used than MRI.
- MRI does not have ionizing-radiation.
- MRI has excellent soft tissue contrast, while CT is preferred for lung and bone imaging.
- CT is fast (few seconds), while MRI is slow (sparse MRI ~5-10 mins, abdomen or brain may take 30-40 mins).

MRI Basics



Shallow Comparison of Imaging Methods

	Chest	Abdomen	Head/Neck	Cardiovascular	Skeletal/muscular
CT	gold standard	Need contrast for excellency, widely used	Good for trauma	Gold standard	Gold standard
US	no use except heart or P.Effusion	Problems with gas	Poor	Poor	Elastography
Nuclear	Extensive use in heart and therapy in lung	CT or MRI is merged	PET	Perfusion	bone marrow
MRI	growing cardiac applications	Increased role of MRI	Gold standard	Will replace ct in near future	Excellent