Introduction to Biomedical Imaging

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Outline

- Image
  - How to represent
  - How to generate
    - Imaging modalities
  - How to integrate
  - How to manage
- Image Analysis
  - Radiology
  - Pathology
  - Big picture

Imaging Informatics

- Imaging Informatics
  - Subfield of Biomedical Informatics

- Deals with
  - Image generation
  - Image manipulation
  - Image management
  - Image integration

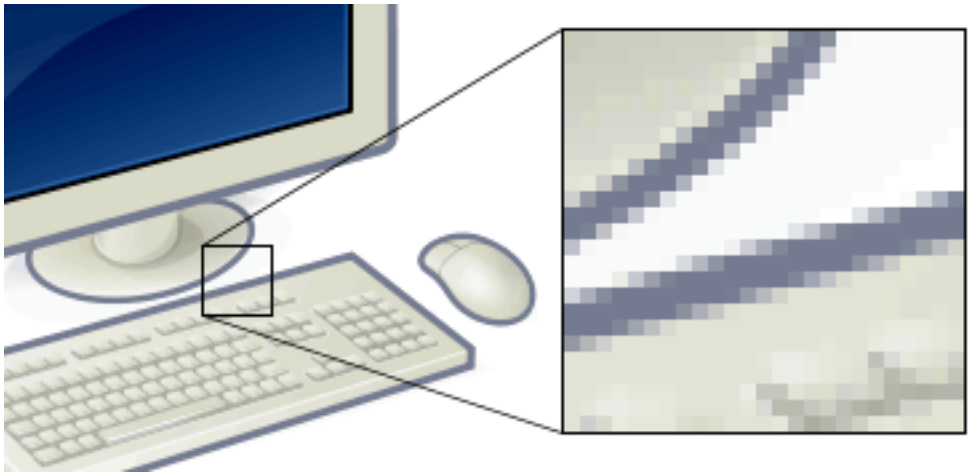
Imaging Informatics

- Image generation:
  - Generating images, converting them to digital
- Image manipulation:
  - Pre- and post-processing to enhance, visualize, or analyze images
- Image management:
  - storing, transmitting, displaying, retrieving and organizing
- Image integration:
  - Combine images with other information needed for interpretation, management and other tasks

Imaging Systems

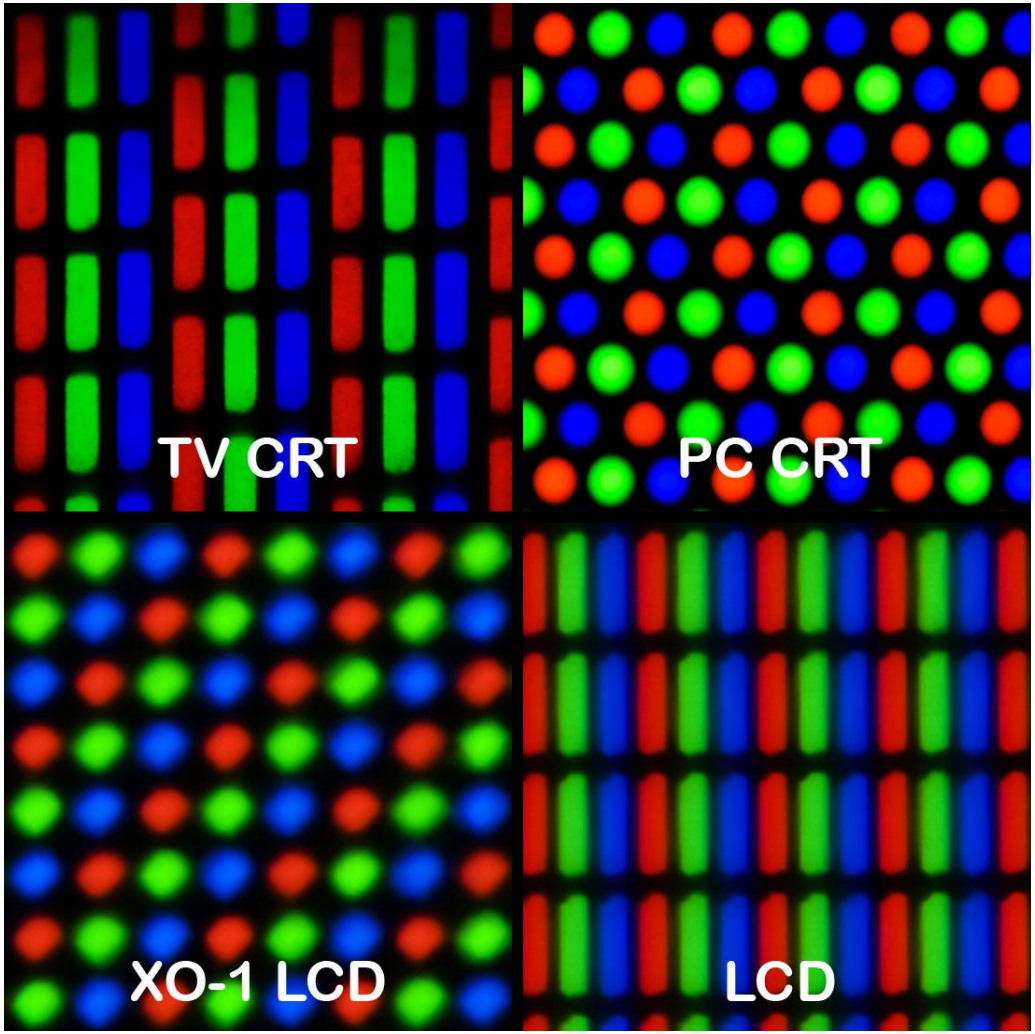
- Images
  - 2D
  - 3D
  - 4D
- Diagnostic Imaging Modalities
  - Anatomical: X-ray, fluoroscopy, CT, MRI, US
  - Functional: PET, SPECT, fMRI
- Display and Organization Systems

Pixel

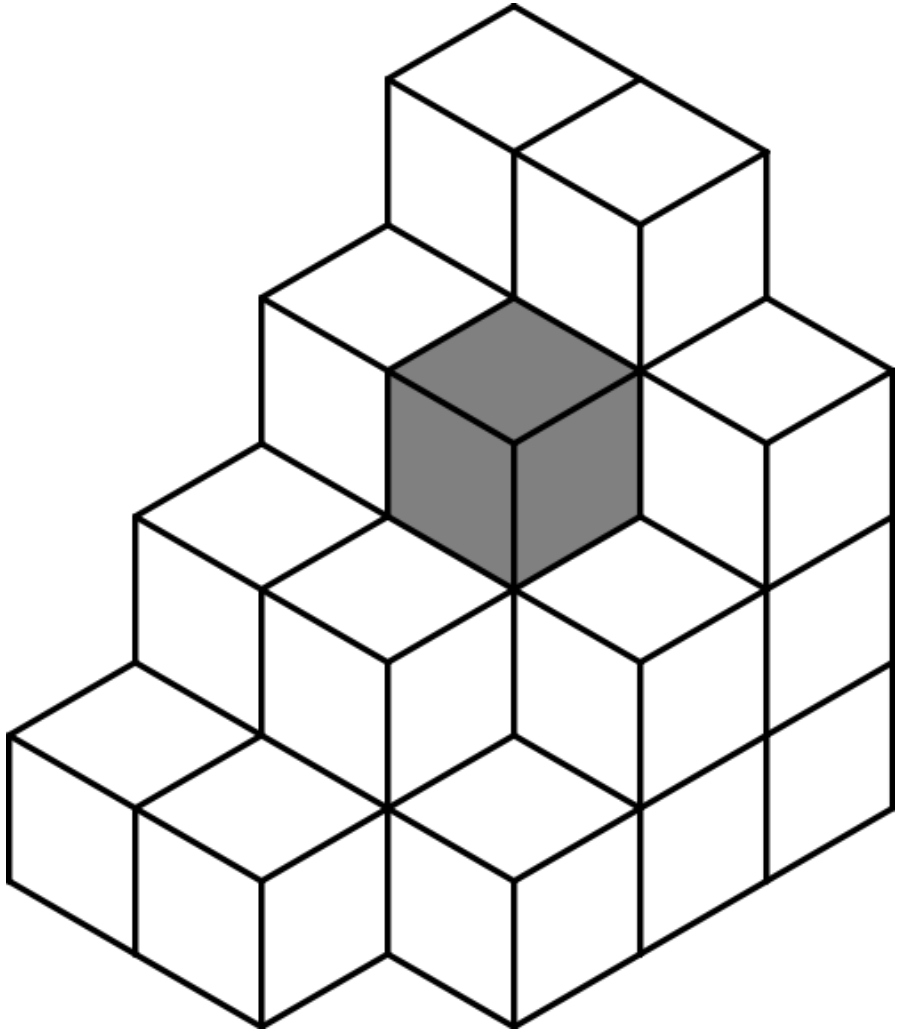


Two dimensional array of numbers

Pixel



Voxel



Time series

(a)

(b)

Image Resolution

Pixel resolution

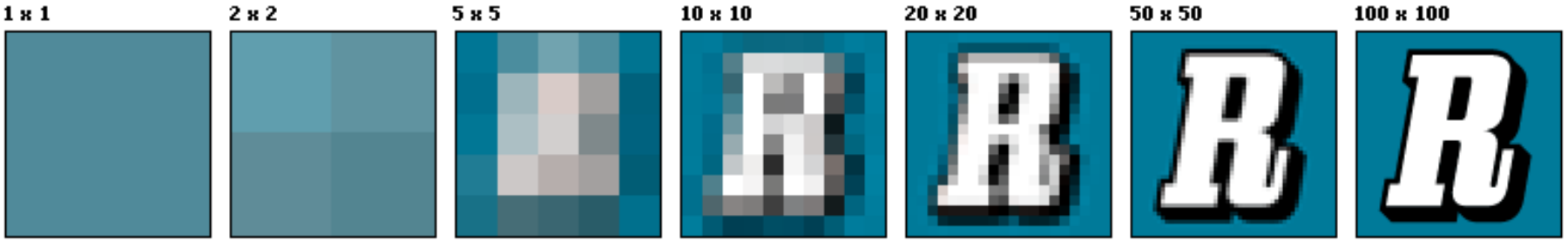


Image Resolution

Image Resolution

Spatial resolution: How well the modality can distinguish points that are close to each other

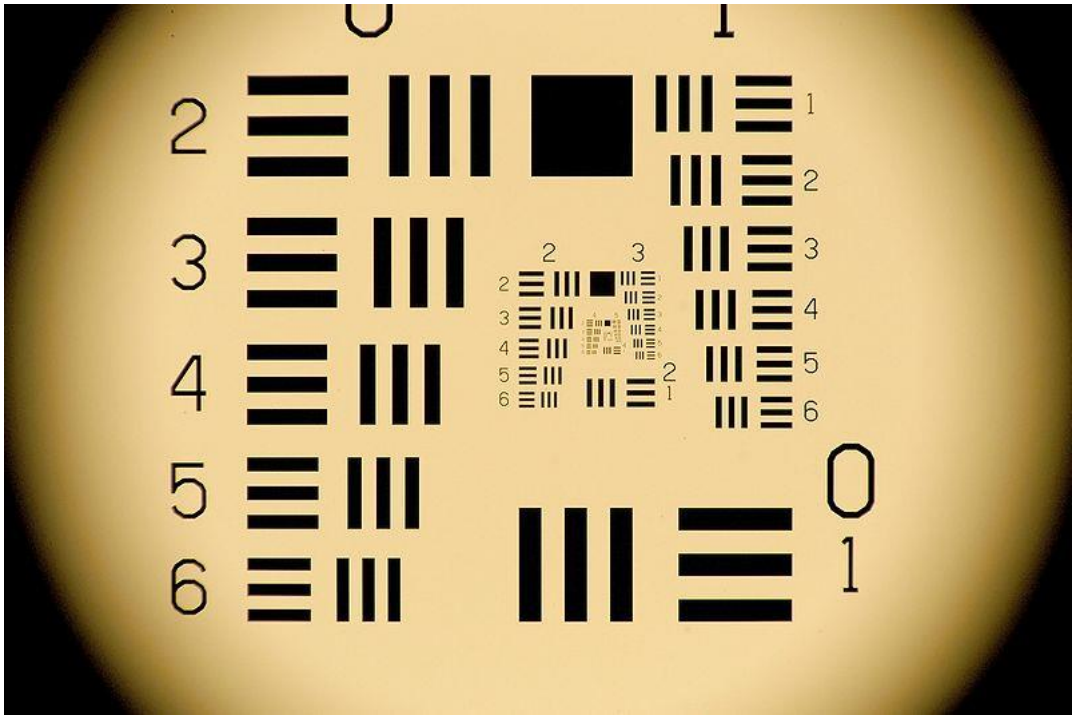


Image Properties

- Distance
- Pixel connectivity

Distance

- Eucledian

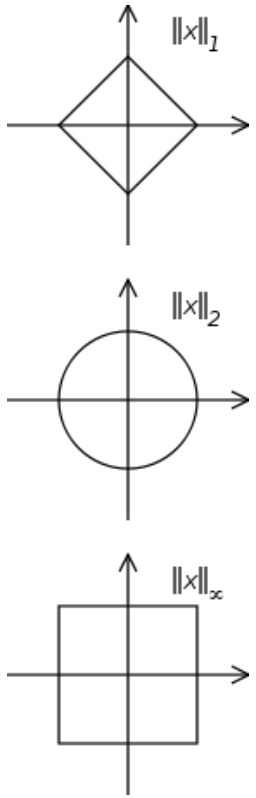
1-norm distance $= \sum_{i=1}^{n} |x_i - y_i|$

2-norm distance $= \left(\sum_{i=1}^{n} |x_i - y_i|^2 \right)^{1/2}$

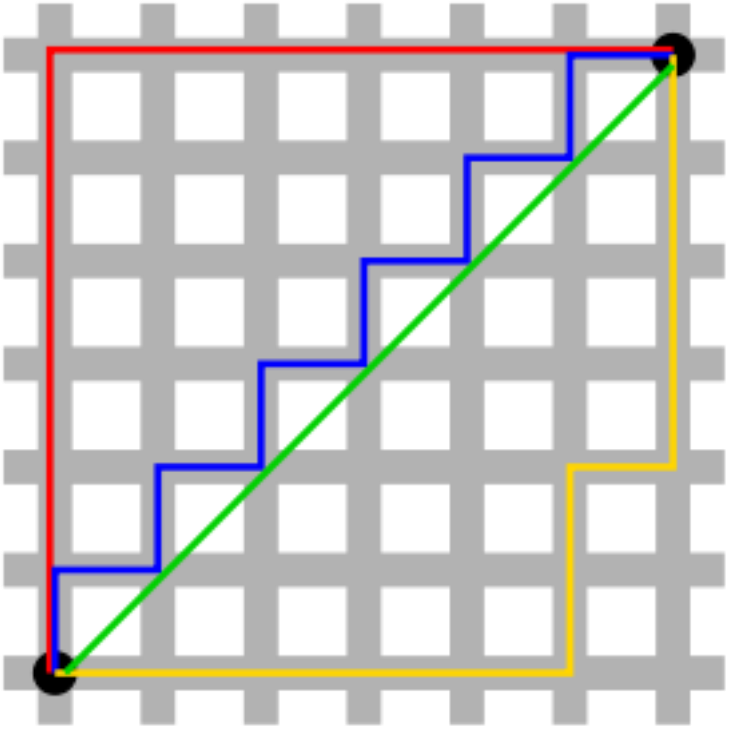
p-norm distance $= \left(\sum_{i=1}^{n} |x_i - y_i|^p \right)^{1/p}$

infinity norm distance $= \lim_{p \to \infty} \left(\sum_{i=1}^{n} |x_i - y_i|^p \right)^{1/p}$

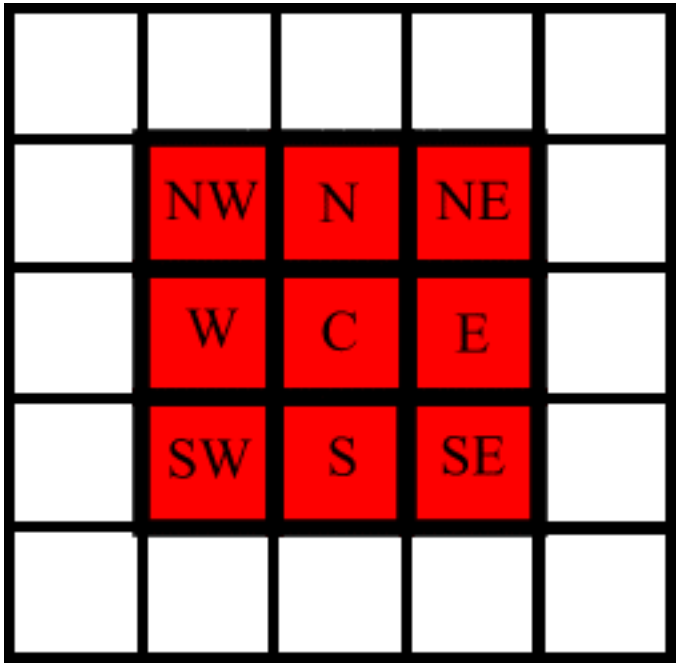
$= \max \left(|x_1 - y_1|, |x_2 - y_2|, \ldots, |x_n - y_n| \right).$



Manhattan Distance



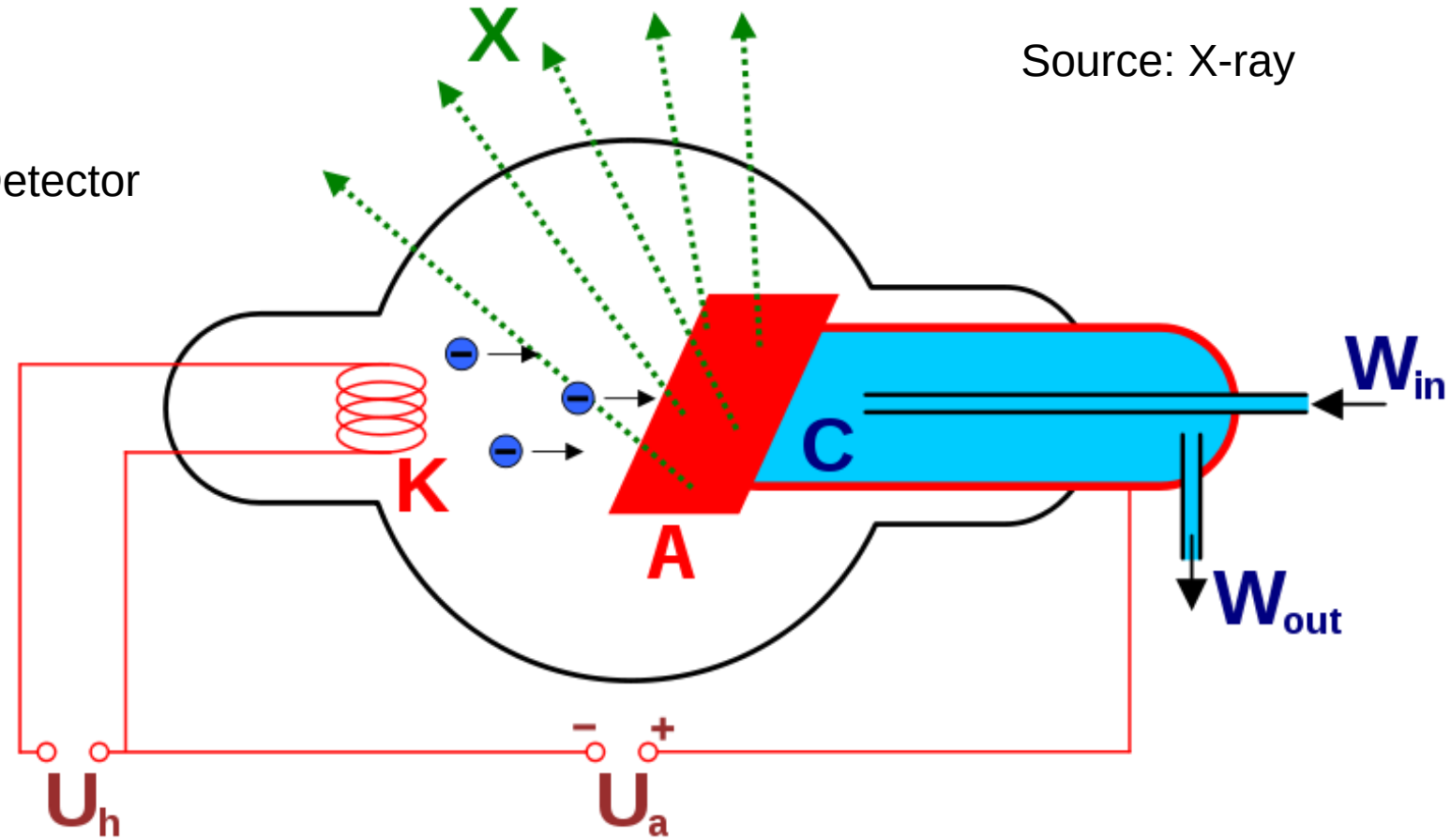
Pixel connectivity



Diagnostic Imaging Modalities

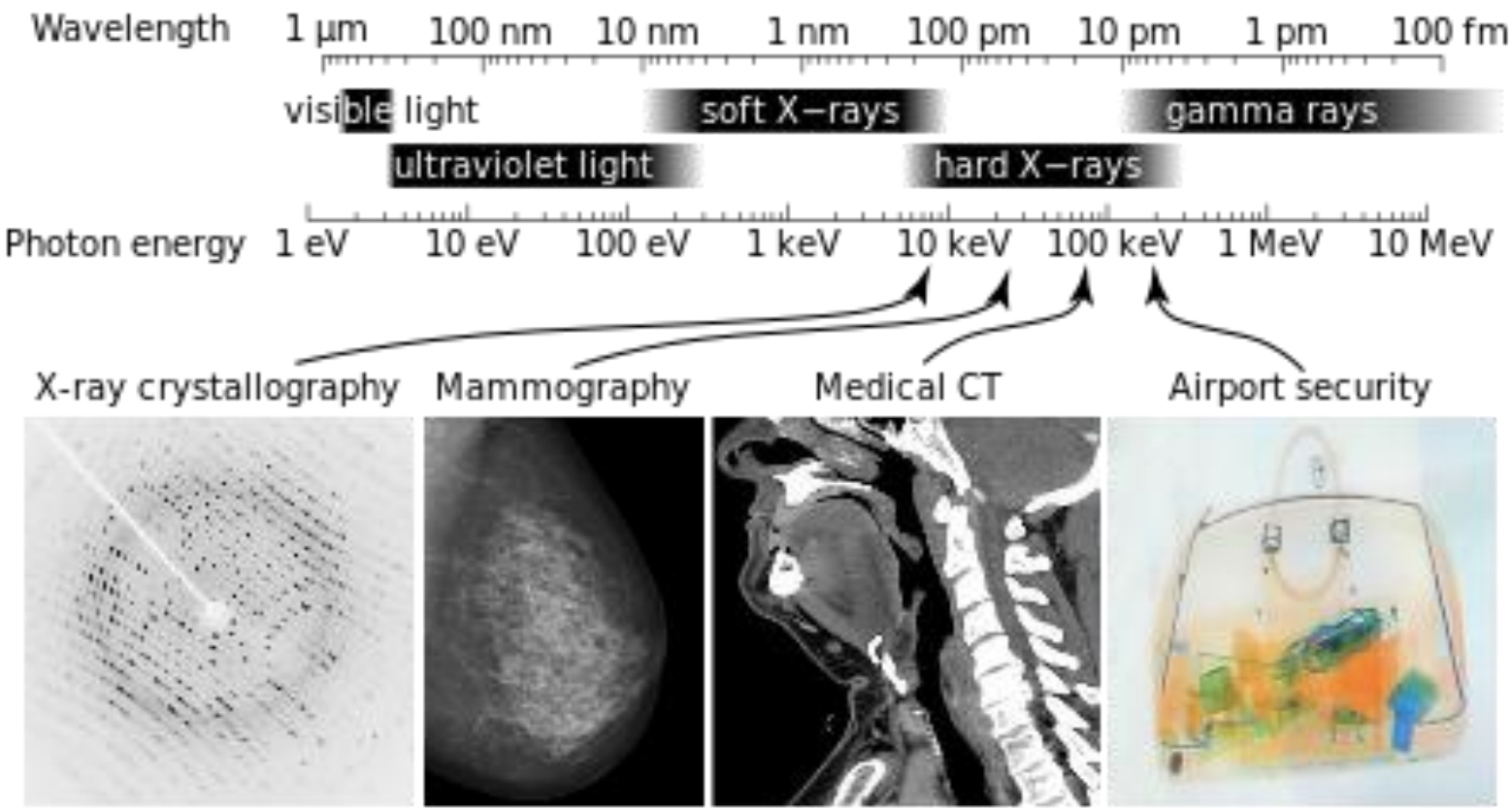
- Anatomical
  - Projection radiography (X-ray)
  - Fluorography
  - Computed Tomography
  - Magnetic Resonance Imaging
  - Ultrasound
- Functional
  - Nuclear Medicine and Positron Emission Tomography

X-ray



X-ray attenuation: Density of tissues

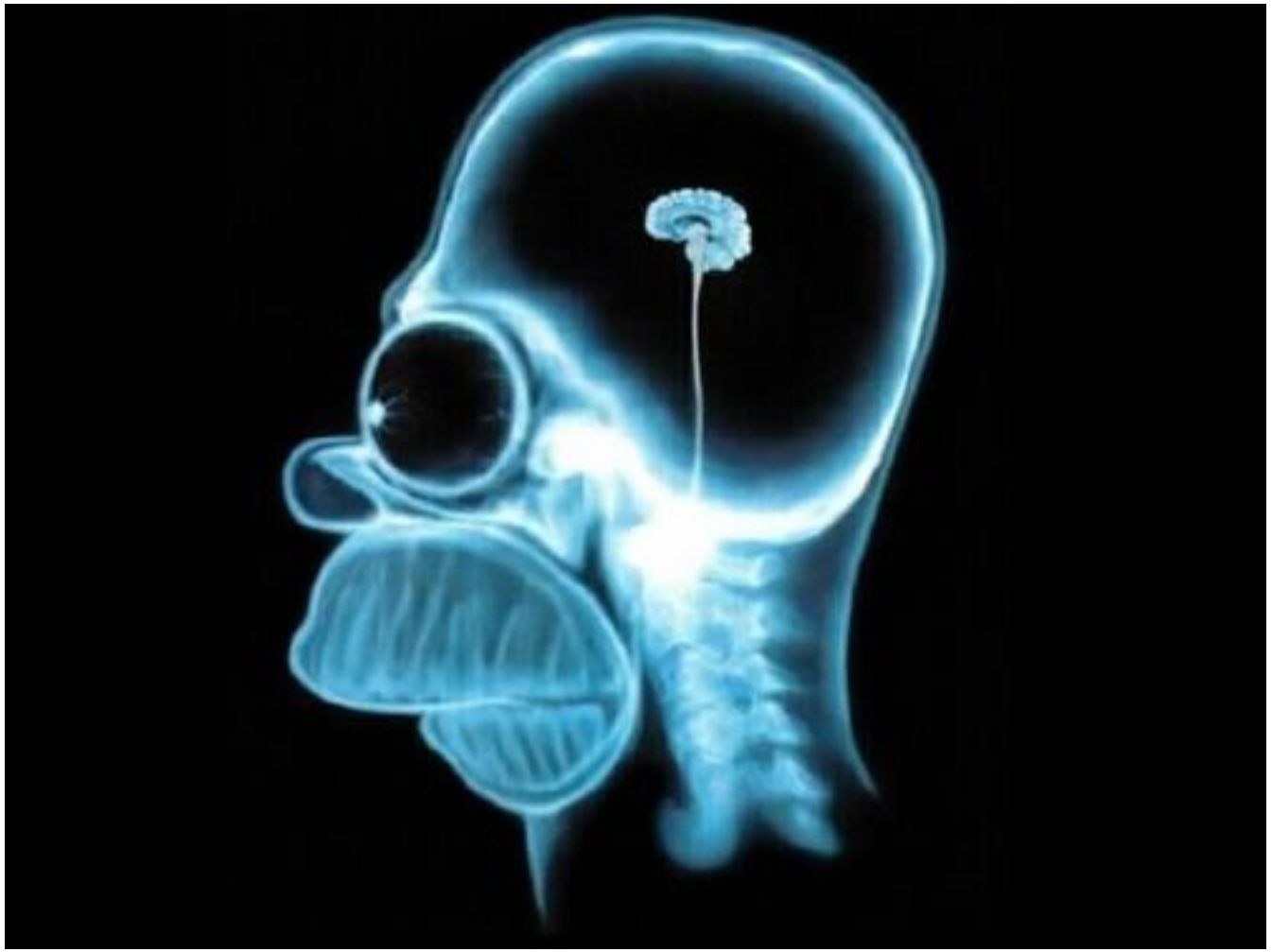
X-ray


Wavelength
1 µm
100 nm
10 nm
1 nm
100 pm
10 pm
1 pm
100 fm
visible light
soft X-rays
gamma rays
ultraviolet light
hard X-rays
Photon energy
1 eV
10 eV
100 eV
1 keV
10 keV
100 keV
1 MeV
10 MeV
X-ray crystallography
Mammography
Medical CT
Airport security

X-ray


Hand mit Ringen
Eigenthum von Prof. Zehnder
Freiburg i/B
PHYSIK. INSTITUT
DER UNIVERSITÄT

X-ray



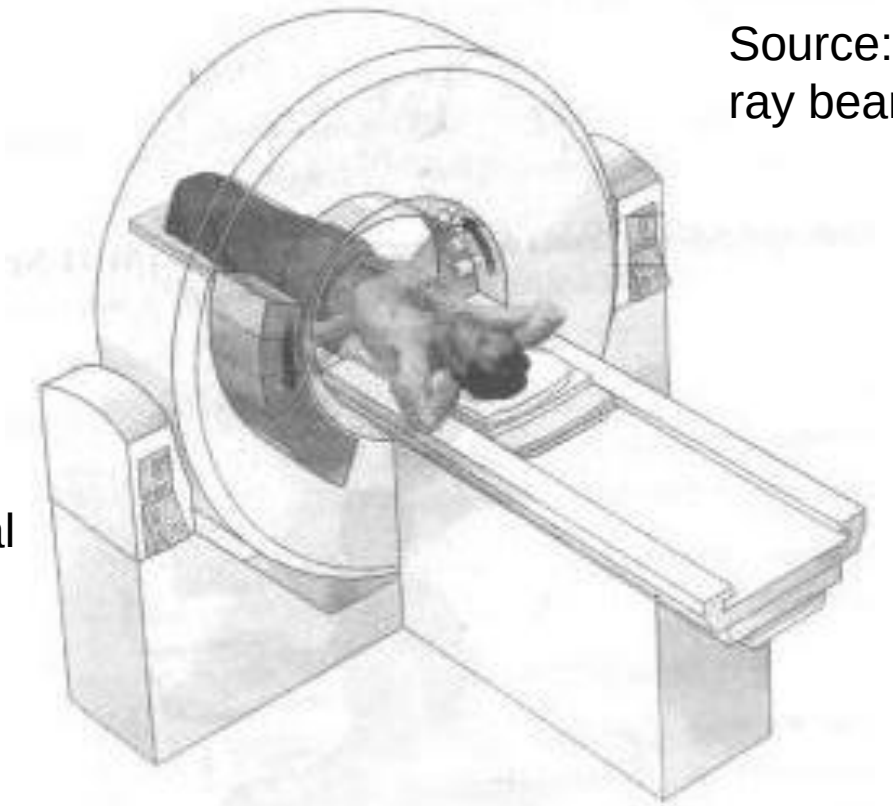
Fluoroscopy

- Source: Continuous low-power X-ray beam
- Detector: X-ray image intensifier
- Continuous acquisition of a sequence of X-ray images over time

Fluoroscopy

Computed Tomography (CT)

Source: Collimated X-ray beam

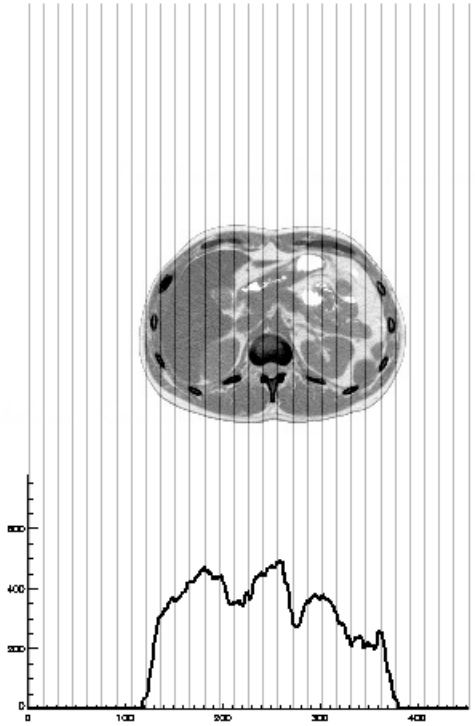


Detector: Solid state scintillators

Images: Computer processing of digital readings of detectors

Absorption values are expressed in Hounsfield Units

(True) Emission Volume



Forward Projection

angle 0°

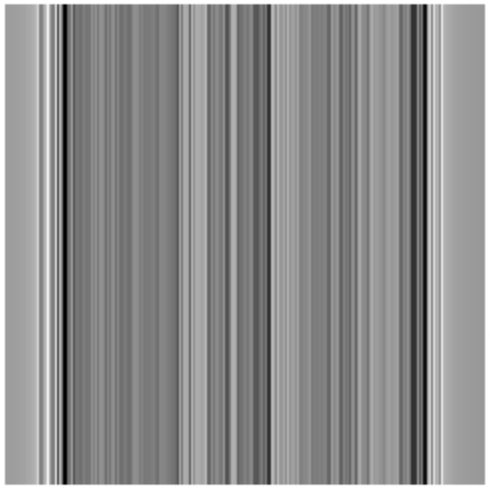
Sinogram (stored data)

Theta (angle)

Rho (offset)

intensity profile:

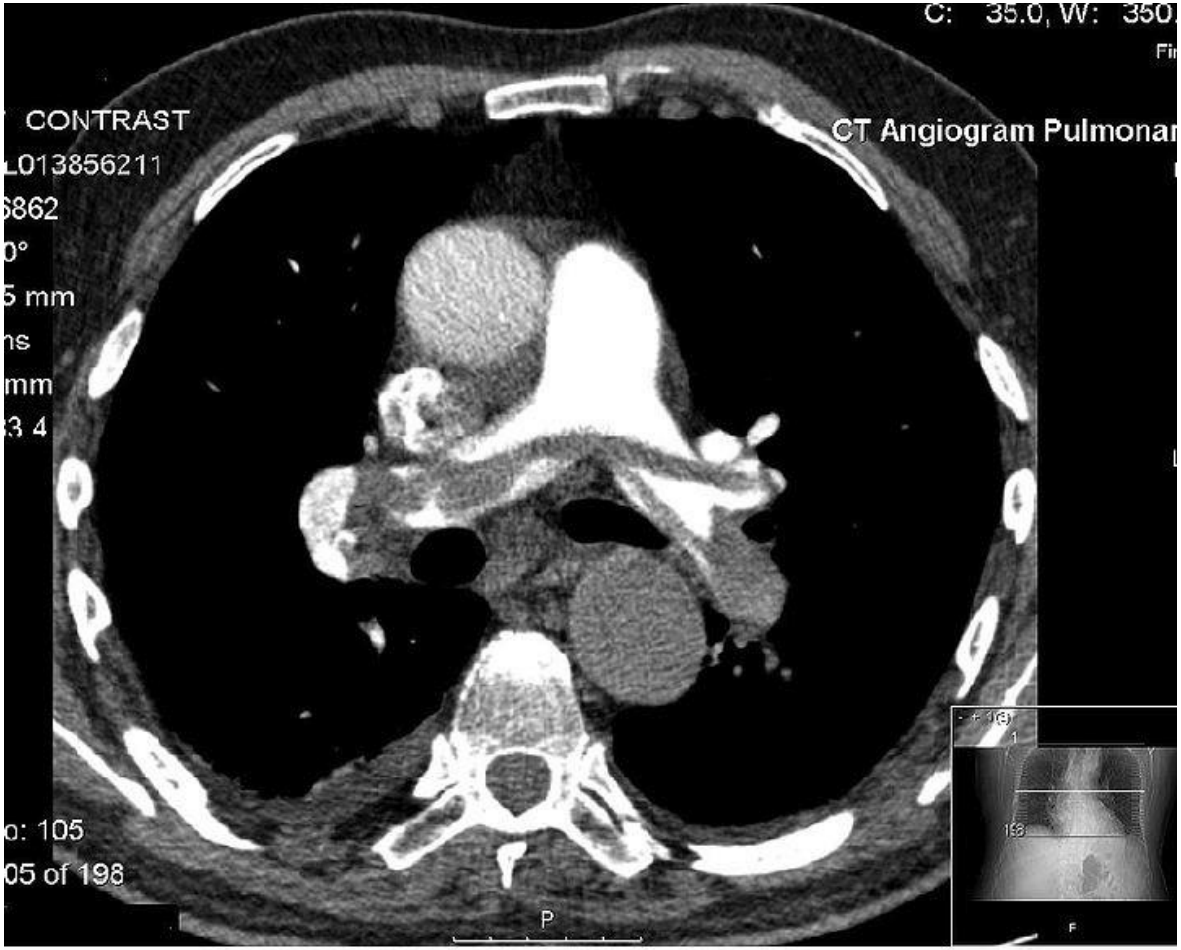
Reconstructed image



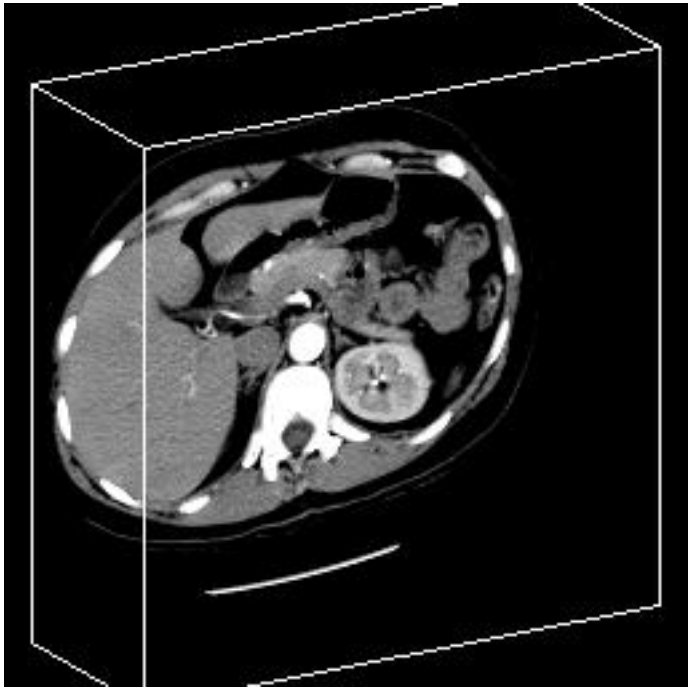
Sinogram

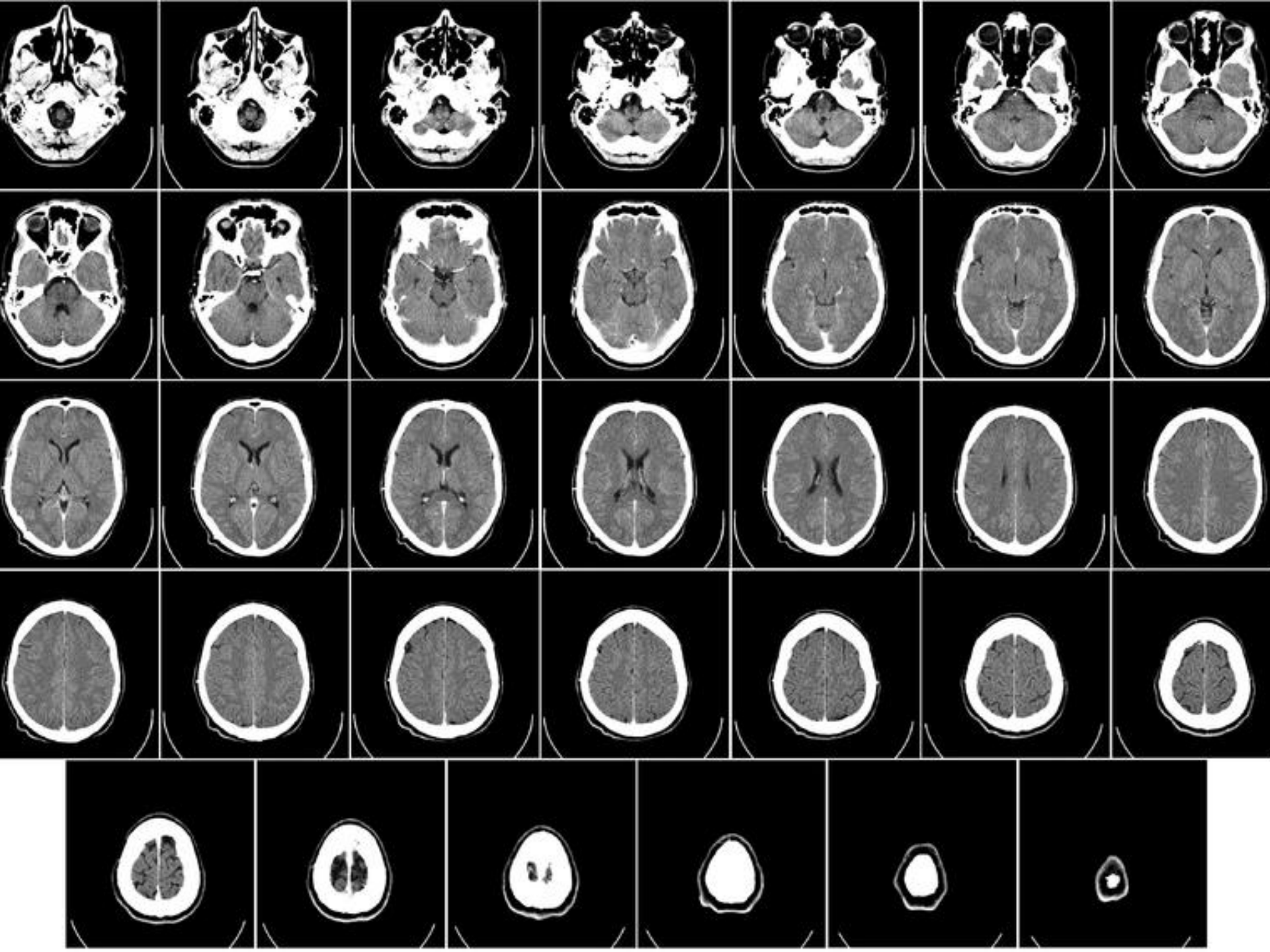
Filtered Back Projection

CT

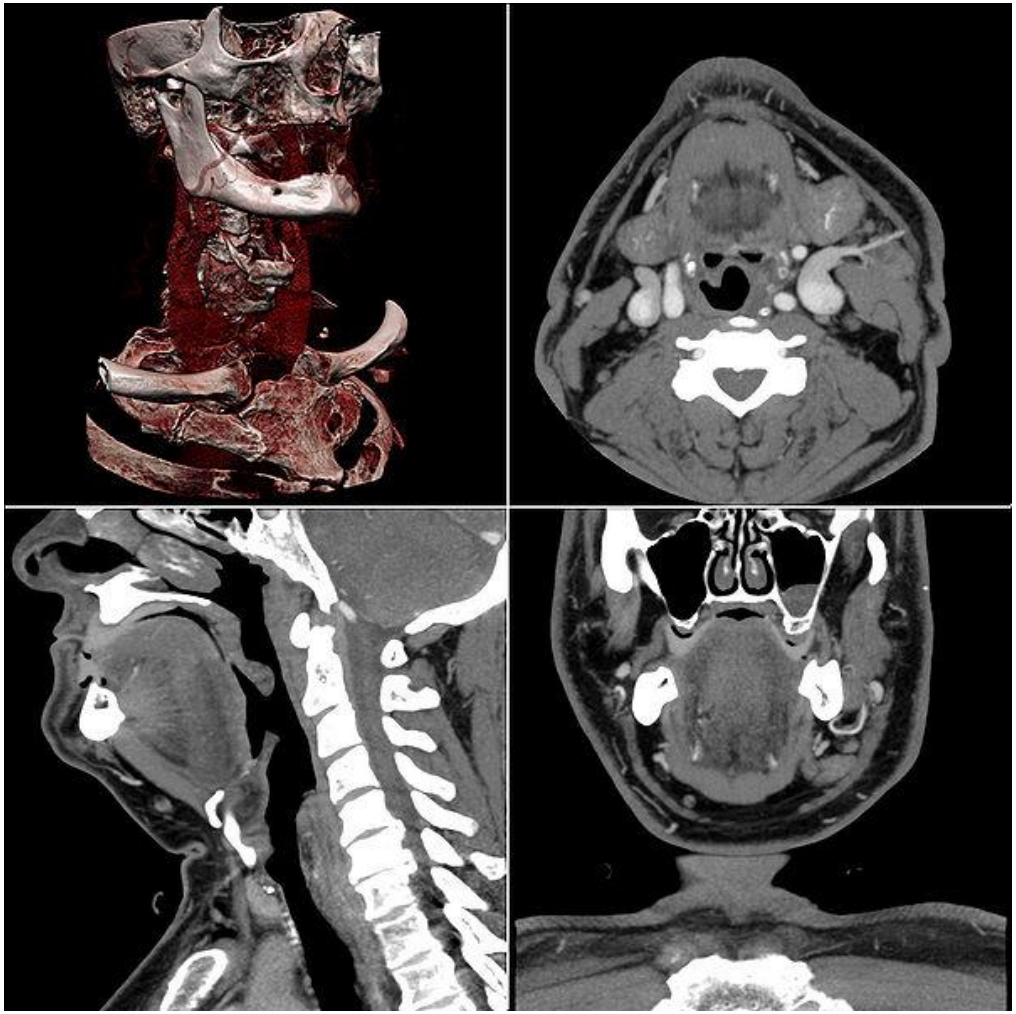

C: 35.0, W: 350
CONTRAST
CT Angiogram Pulmonar
L013856211
6862
0°
5 mm
ns
mm
3 4
o: 105
05 of 198
P

CT





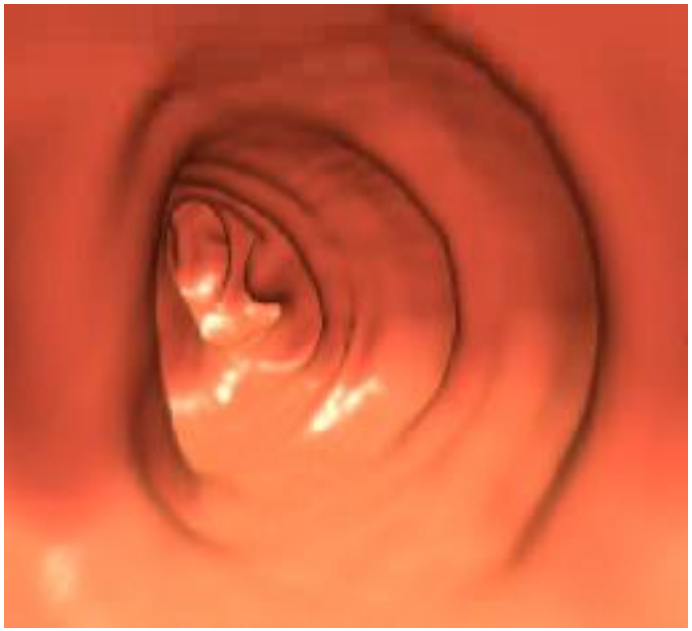
CT



Hounsfield Units

- 1000: Bone
- -1000: Air
- 0: Water

Virtual colonoscopy

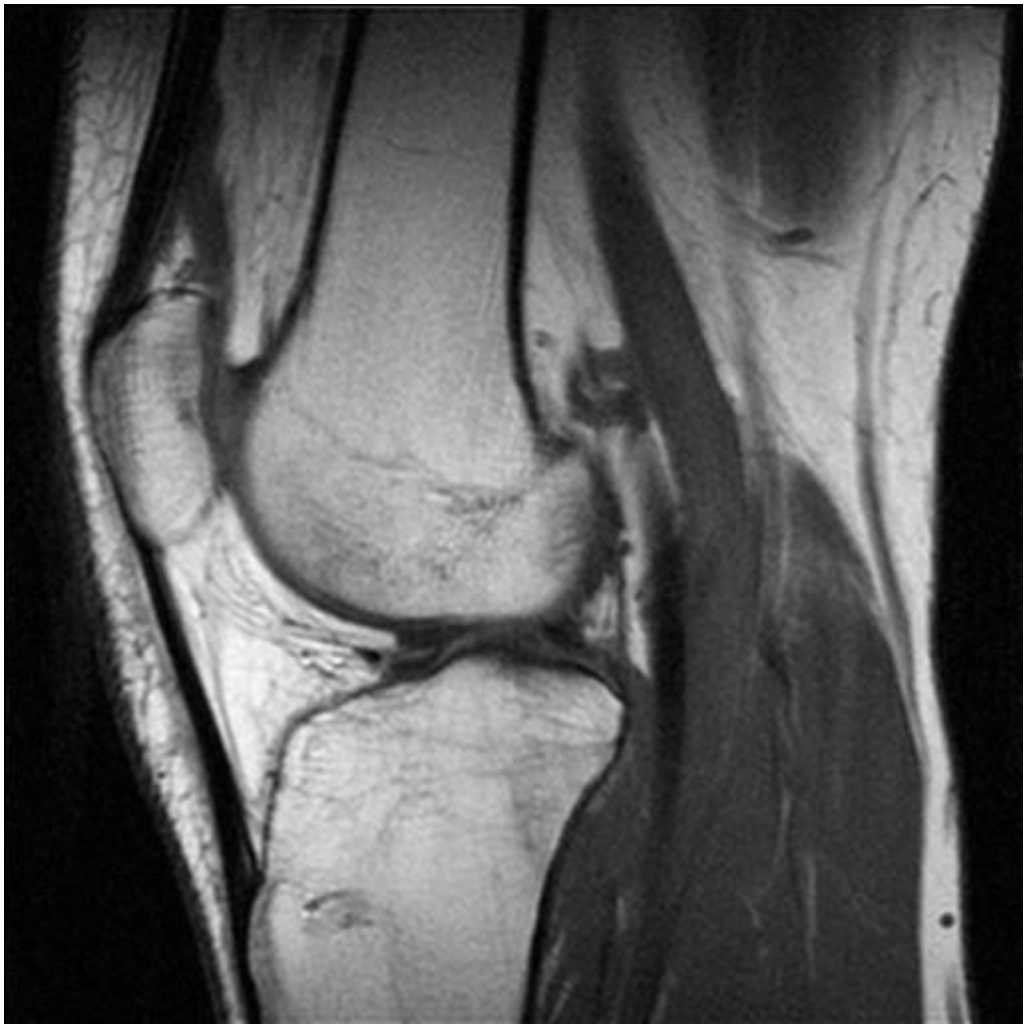


MRI

- Source: High Intensity magnetic field and radio frequency pulses (on/off)
- Detector: Phased array receiver
- RF excitations of the protons results in absorption and subsequent release of energy -> magnetic characteristics of the tissue
- Pictures of organs, bone, soft tissue
- Computer generated images

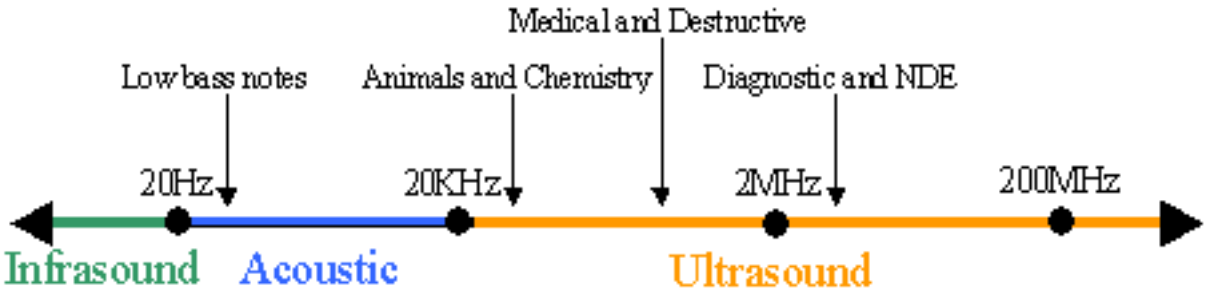
MRI

Non-iodizing



Excellent soft-tissue contrast detail

Ultrasound



Source: High frequency sound waves
Detector: Source tranducer also acts as a receiver

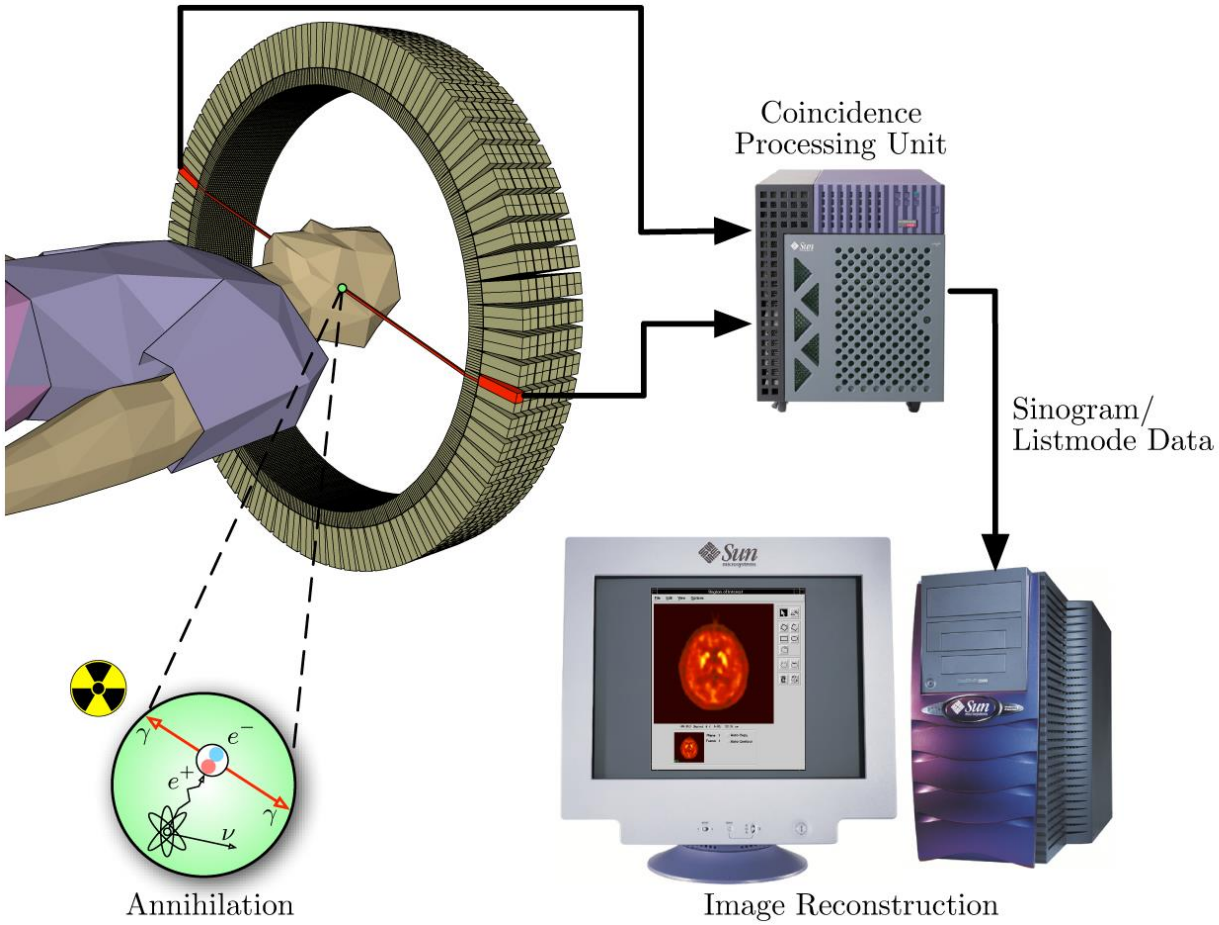
Images: Sound waves are affected by the different types of tissues encountered and reflected back

Ultrasound

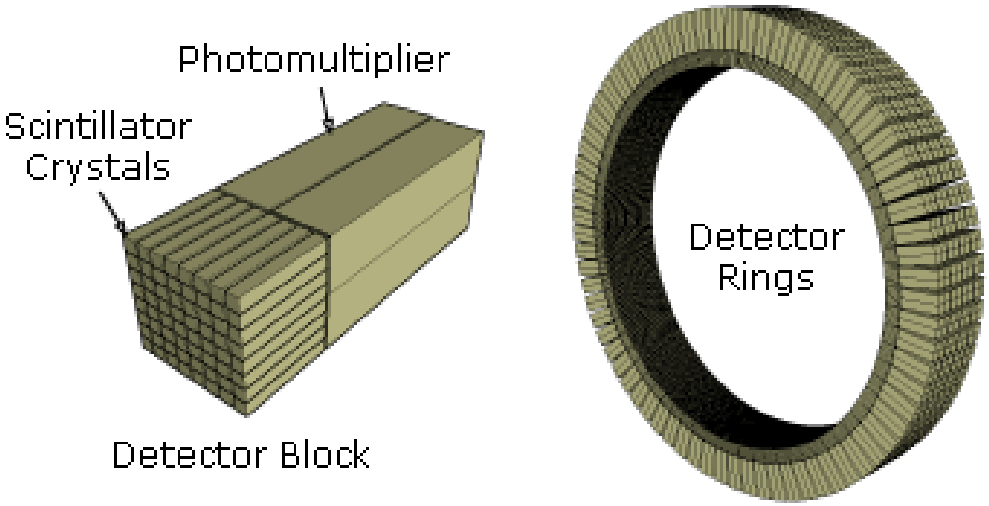
Bundesarchiv, Bild 183-1990-0417-001
Foto: Grubitzsch (geb. Raphael), Waltraud | 17. April 1990

3D Ultrasound

PET

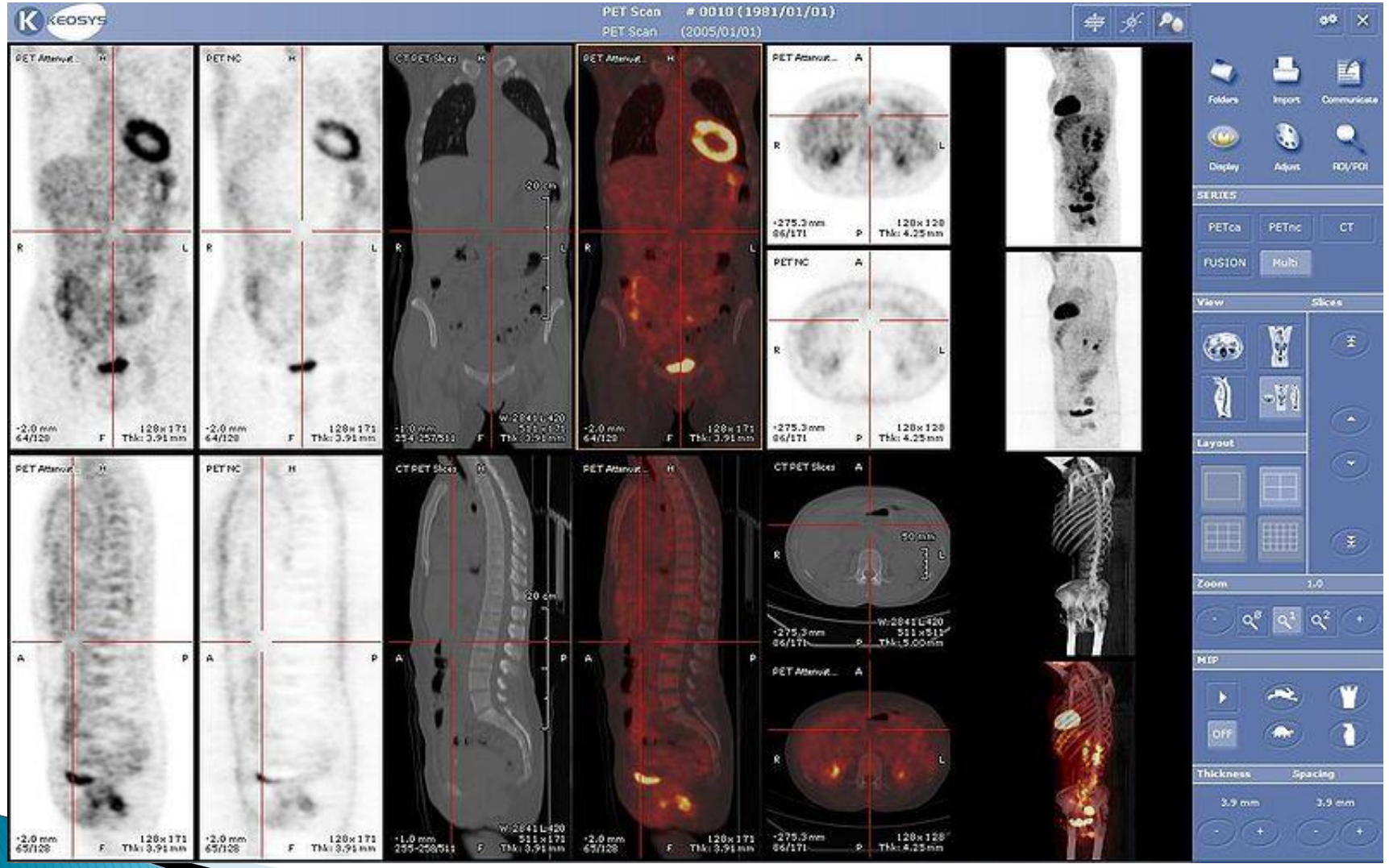

Coincidence
Processing Unit
Sinogram/
Listmode Data
Annihilation
Image Reconstruction

PET

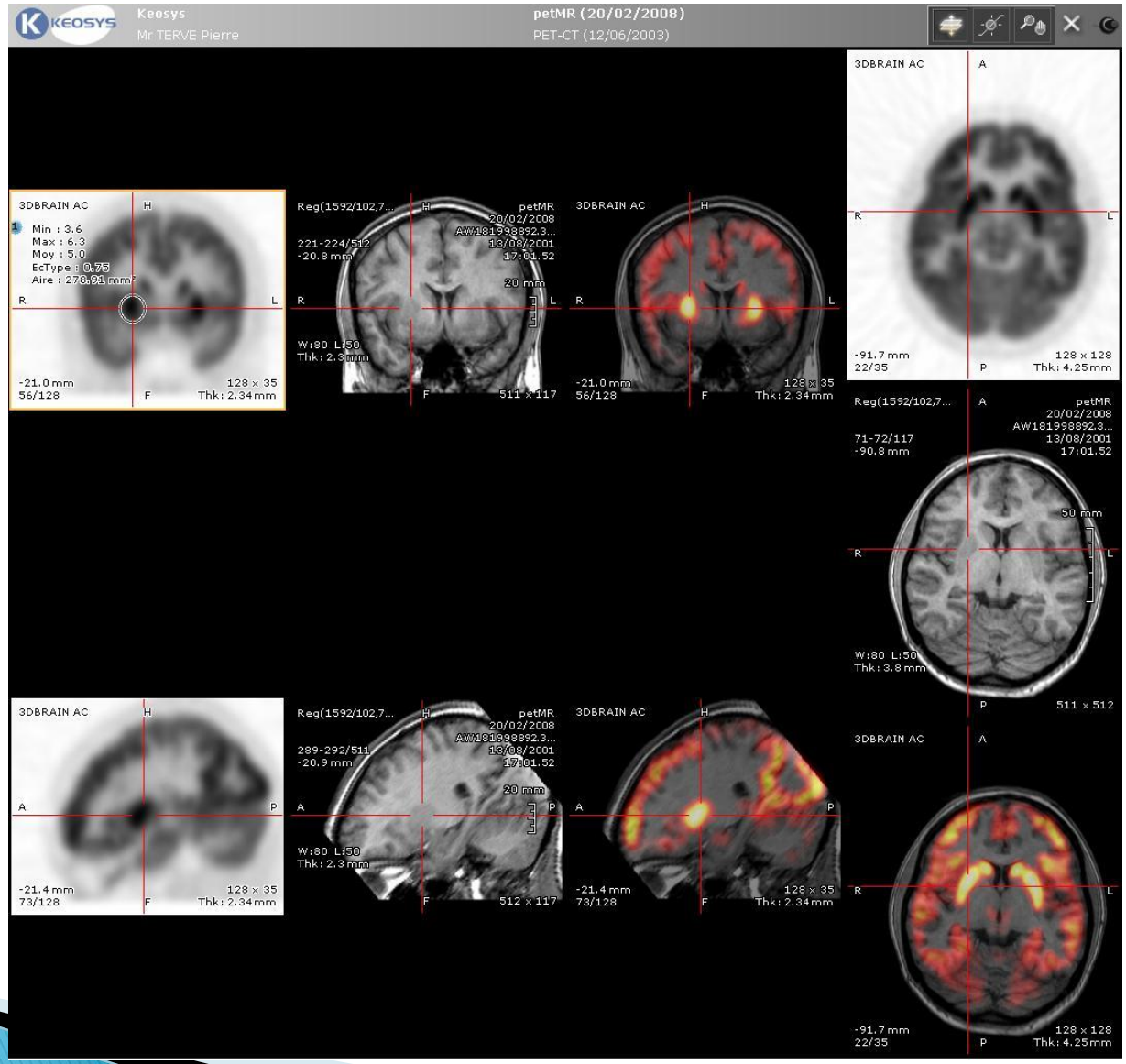


Source: X-ray or γ-ray emitting radio-isotopes are injected, inhaled or ingested
Detector: Gamma camera – measures the radioactive decay of the active agent
Image: Functional information

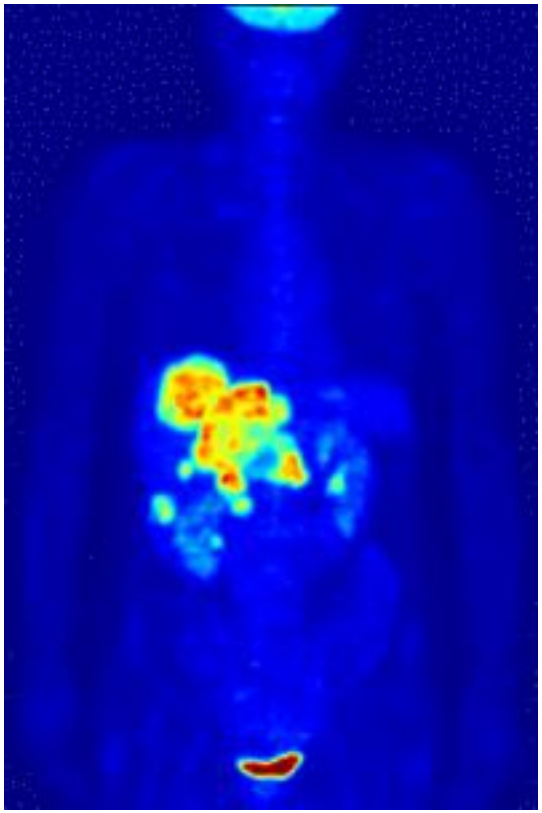
PET


KEOSYS
PET Scan # 0010 (1981/01/01)
PET Scan (2005/01/01)
Folders
Import
Communicate
Display
Adjust
ROI/POI
SERIES
PETca
PETnc
CT
FUSION
Multi
View
Slices
Layout
Zoom
MIP
OFF
Thickness
Spacing

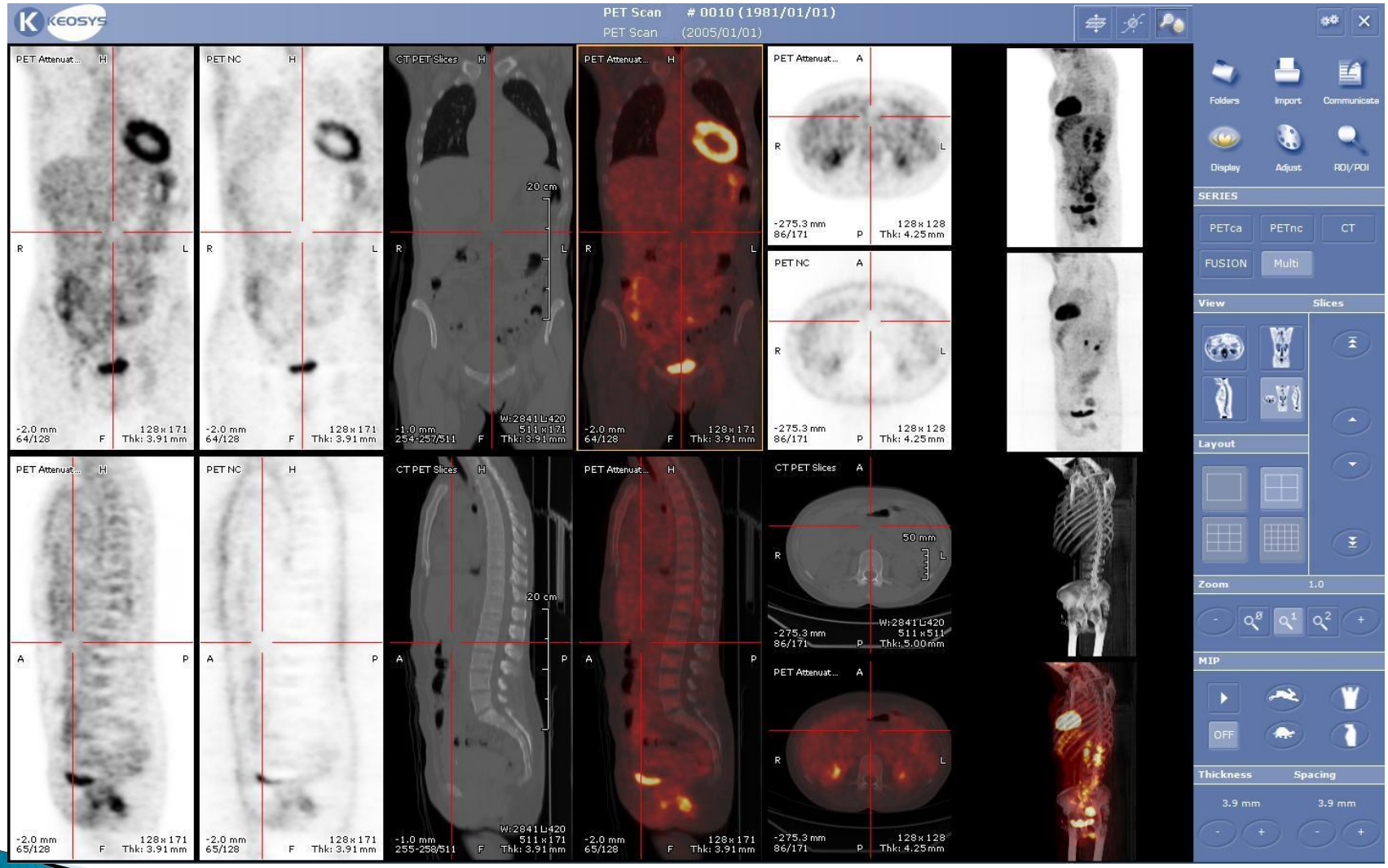
PET


Keosys
Mr TERVE Pierre
petMR (20/02/2008)
PET-CT (12/06/2003)
3DBRAIN AC
Min : 3.6
Max : 6.3
Moy : 5.0
EcType : 0.75
Aire : 278.91 mm²
-21.0 mm
56/128
128 x 35
Thk: 2.34 mm
Reg(1592/102,7...
petMR
20/02/2008
AW181998892.3...
13/08/2001
17:01.52
221-224/512
-20.8 mm
20 mm
W:80 L:50
Thk: 2.3 mm
511 x 117
-91.7 mm
22/35
128 x 128
Thk: 4.25 mm
71-72/117
-90.8 mm
50 mm
W:80 L:50
Thk: 3.8 mm
511 x 512
289-292/511
-20.9 mm
512 x 117
-21.4 mm
73/128

PET



Picture Archiving and Communications System – PACS



PACS

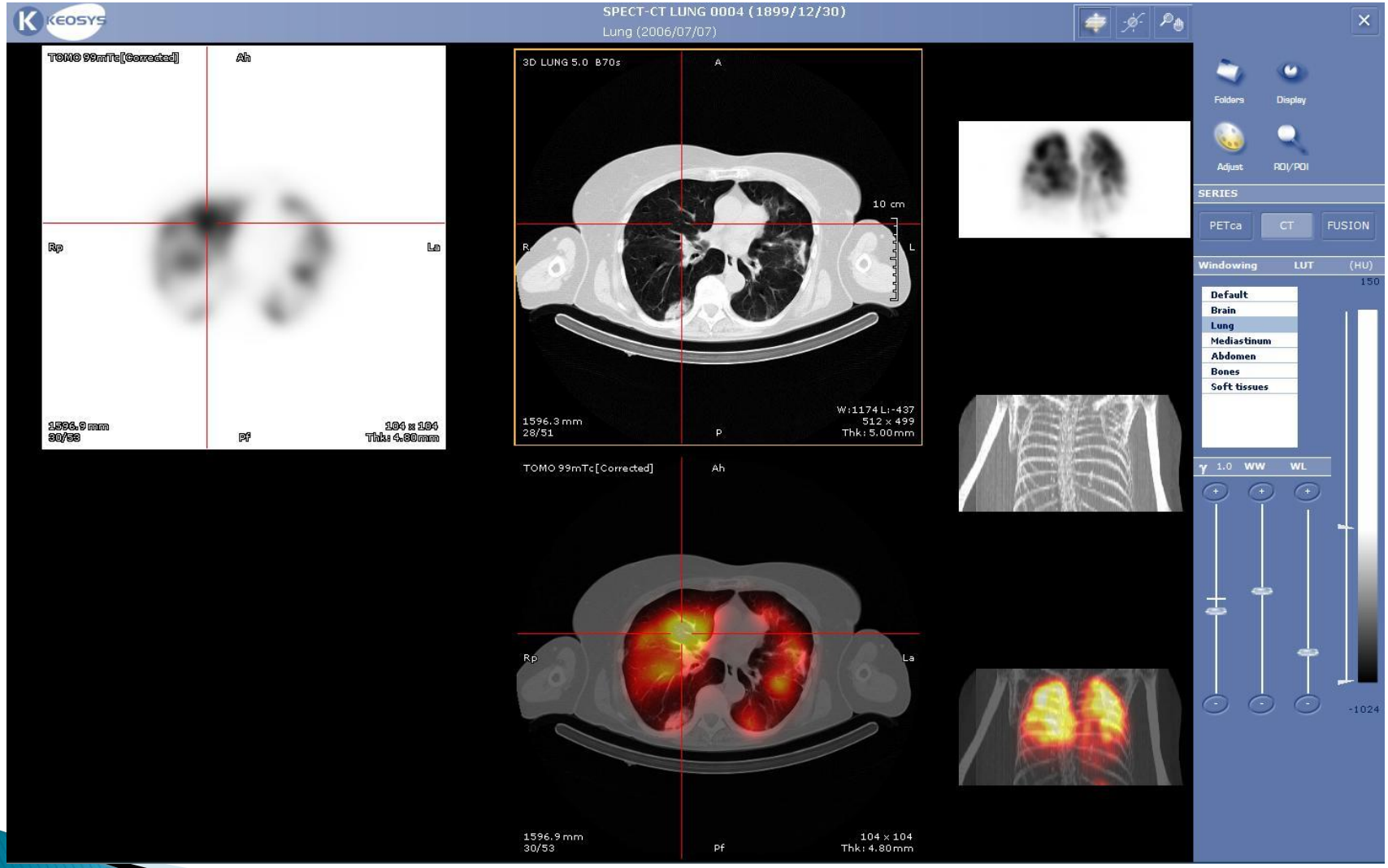
- Core function: storage, distribution and display of medical images

- Further strengthened by a hospital's other IT infrastructure
  - Hospital Information System (HIS)
  - Electronic Medical Records System (EMR)
  - Radiology Information System (RIS)

PACS

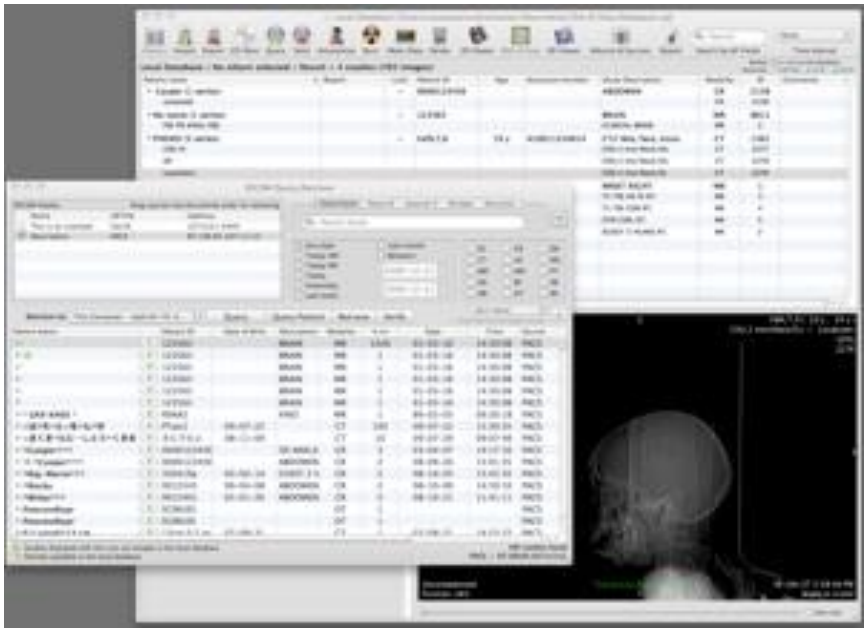
- Uses:
  - Hard copy replacement
  - Remote access – teleradiology
  - Integration with other electronic systems
  - Radiology workflow management

DICOM Viewer



DICOM

- Digital Imaging and Communication in Medicine
- Standard format for PACS files and messages
  - A standard for handling, storing, printing, and transmitting information in medical imaging
  - File format definition and network communication protocol
- DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format.



DICOM viewer

- eFilm
- OsiriX – open source
- ImageJ