Radiology

Marta Anguiano Millán

Departamento de Física Atómica, Molecular y Nuclear

Facultad de Ciencias. Universidad de Granada

Overview

Introduction

Overview

Introduction

Tecniques of imaging in Radiology

Overview

Introduction

Tecniques of imaging in Radiology

Radiography

Overview

Introduction

Tecniques of imaging in Radiology

Radiography

Computerized Tomography (CT)

Introduction

X-ray beam on a patient:

Introduction

X-ray beam on a patient:

- Absorption → NO contribution to image
- Transmission → YES, contribution to image
- Dispersion → Diffuse radiation

Introduction

X-ray beam on a patient

- Absorption → NO contribution to image
- Transmission → YES, contribution to image
- Dispersion → Diffuse radiation

It depends on the characteristics of the tissue:

Introduction

X-ray beam on a patient

- Absorption $\rightarrow$ NO contribution to image
- Transmission $\rightarrow$ YES contribution to image
- Dispersion $\rightarrow$ Diffuse radiation

It depends on the characteristics of the tissue:

- Density
- Atomic number of the elements composing the tissue
- Thickness
- Kilovoltage $\rightarrow$ external parameter

After the patient:

Introduction

After the patient:

- Transmitted radiation + Diffuse radiation
- Non homogeneus distribution of intensities $\rightarrow$ Latent image
- Imaging systems $\rightarrow$ Visible image
- Contrasting zones in the visible image $\rightarrow$ makes possible to distinguish different structures

Introduction

After the patient:

- Transmitted radiation + Diffuse radiation
- Non homogeneus distribution of intensities $\rightarrow$ Latent image
- Imaging systems $\rightarrow$ Visible image
- Contrasting zones in the visible image $\rightarrow$ makes possible to distinguish different structures

Human body in a X-ray exposition:

Introduction

After the patient:

- Transmitted radiation $+$ Diffuse radiation
- Non homogeneus distribution of intensities $\rightarrow$ Latent image
- Imaging systems $\rightarrow$ Visible image
- Contrasting zones in the visible image $\rightarrow$ makes possible to distinguish different structures

Human body in a X-ray exposition:

1. Gases (air): $Z = 6,7$ and $\rho = 1$ mg/cm^3
2. Soft tissue: water($\rho = 1$ g/cm^3) and fat ($\rho =$0.9 g/cm^3).
3. Hard tissue: cartilage ($\rho =$1.1 g/cm^3 y $Z = 13$) and bone ($\rho \approx 1.8$ g/cm^3 and $Z = 14$)

Gases

- They transmit practically all the radiation.
- High number of photons to the latent image.
- More darkening in the visible image.

Introduction

Gases:

- They transmit practically all the radiation.
- High number of photons to the latent image.
- More darkening in the visible image.

Soft tissues

- Medium absorbed dose.
- Gray areas in the visible image.

Gases:

- They transmit practically all the radiation.
- High number of photons to the latent image.
- More darkening in the visible image.

Soft tissues

- Medium b dose.
- Gray areas in the visible image.

Hard tissues

- High absorption power.
- In visible image, areas nearly white.

Three external parameters:

Three external parameters

- Voltage:

  It regulates the stopping power of the radiation Increasing kVp, electrons have a higher kinetic energy.

Three external parameters

- Voltage:

  It regulates the stopping power of the radiation
  Increasing kVp, electrons have a higher kinetic energy.

- Intensity (mA):

  Intensity in the X-ray tube.
  A higher intensity, a higher number of emitted electrons.
  The production of X-rays increases.
  A higher darkening.

Three external parameters

- Voltage:

  It regulates the stopping power of the radiation
  Increasing kVp, electrons have a higher kinetic energy.

- Intensity (mA):

  Intensity in the X-ray tube.
  A higher intensity, a higher number of emitted electrons.
  The production of X-rays increases.
  A higher darkening.

- Time (ms):

  It determines the period of time in which X-rays are produced.

Techniques of imaging in Radiology

Example:Pelvis radiography

60 kV, 141 mAs

75 kV, 36 mAs

120 kV, 6 mAs

Two techniques

Techniques of imaging in Radiology

Two techniques

Technique of low voltage:

- Photoelectric effect is the main absortion way.
- The photoelectric effect depens of the atomic number.
- Bone $\rightarrow$ higher absorption.
- Fat $\rightarrow$ lower absorption.
- Tissues are distinguished according to the absorption.
- Nearby areas, but of different type, appear with a high contrast.

Two techniques

Low voltage technique:

- Photoelectric effect is the main absortion way.
- The photoelectric effect depens of the atomic number.
- Bone → higher absorption.
- Fat → lower absorption.
- Tissues are distinguished according to the absorption.
- Nearby areas, but of different type, appear with a high contrast.

High voltage technique:

- Torax radiography
- To see the lung and not the bone.
- Scattering Compton, the main interaction mechanism.
- No distintion with the atomic number.
- The bone loss contrast in the radiography.

Final radiation in the plate:

Techniques of imaging in Radiology

Final radiation in the plate

- Primary radiation beam not atenuated.
- Scattered radiation beam.

Techniques of imaging in Radiology

Final radiation in the plate

- Primary radiation beam not atenuated.
- Scattered radiation beam.

Methods to minimize the scattered radiation

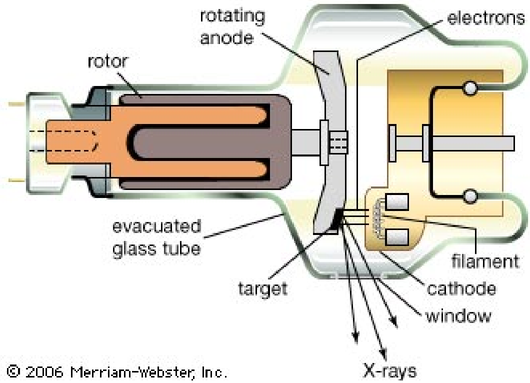
Final radiation in the plate

- Primary radiation beam not atenuated.
- Scattered radiation beam.

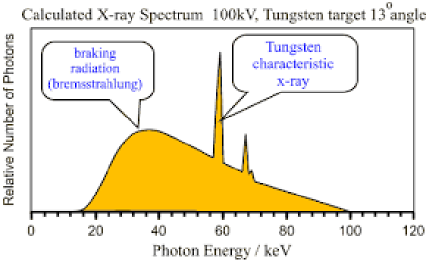
Methods to minimize the scattered radiation

1. Increasing of the voltage $\rightarrow$ a higher penetration of the beam.
2. Decreasing of the irradiated volume (tissue compressors)
3. Separation between object and film
4. Use of collimators to reduce the field size.
5. Anti-scatter grids.

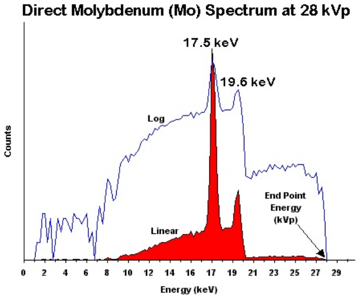
The X-ray tube



X-ray spectrum



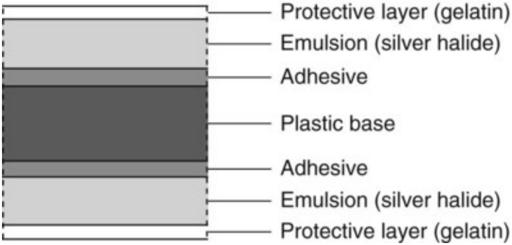
Tugsteno target



Molibdeno target

- Brehmsstrahlung continuum spectra
- Characteristic X-rays.

Radiographic film



Components in a radiographic film

Digital radiography

Introduction

Computerized tomography (CT)

Introduction

History of the CT

Computerized tomography (CT)

Introduction

History of the CT

Some technical concepts

Computerized tomography (CT)

Introduction

History of the CT

Some technical concepts

The physics of the data acquisition

Introduction

- It is one of the most important applications of the X-rays.

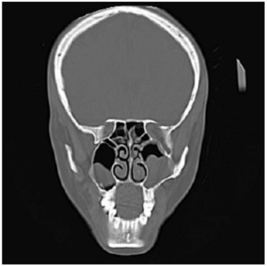
Introduction

- It is one of the most important applications of the X-rays.
- Crucial in its development, the mathematic algorithms to do the image reconstruction from different sectional cuts of the body.

Introduction

- It is one of the most important applications of the X-rays.
- Crucial in its development, the mathematic algorithms to do the image reconstruction from different sectional cuts of the body.
- The obtained images are fundamental for medical diagnosis.

- It is one of the most important applications of the X-rays.
- Crucial in its development, the mathematic algorithms to do the image reconstruction from different sectional cuts of the body.
- The obtained images are fundamental for medical diagnosis.



Tomographic image of the paranasal sinuses in the frontal plane

TAC room.

History of the CT

- From the idea of A.M. Cormack (1950) and the practical development of G.N. Hounsfield (1960).

History of the CT

- From the idea of A.M. Cormack (1950) and the practical development of G.N. Hounsfield (1960).
- A.M. Cormack (SA): "*Representation of a function by it Line Integrals, in The Journal of Applied Physics. And after, in PMB.*"

History of the CT

- From the idea of A.M. Cormack (1950) and the practical development of G.N. Hounsfield (1960).
- A.M. Cormack (SA): "*Representation of a function by it Line Integrals, in The Journal of Applied Physics. And after, in PMB.*

PHYS. MED. BIOL., 1973, VOL. 18, NO. 2, 195–207. ©1973

Reconstruction of Densities from their Projections, with Applications in Radiological Physics

A. M. CORMACK, M.SC.

Physics Department, Tufts University, Medford, MA 02155, U.S.A.

Received 3 *February* 1972, *revised version* 18 *May* 1972

ABSTRACT. The precise determination of body attenuation for X-rays or its stopping power for heavy charged particles, positron annihilation scanning, and, to a lesser extent, single γ-ray scanning all contain the same mathematical problem, namely, to determine a density distribution in space from its known projections on to one or more planes. Present methods of solving this problem involve taking slices through the distribution and considering the projected densities to be line integrals along lines through the slices and then using Fourier transforms, or orthogonal expansions of the line integrals, or a matrix inversion to determine the density distribution. An alternative method, due to Radon, enables the density to be inferred by integration. In addition, a generalization of the method to surface integrals is given and possible applications are suggested including an application to positron annihilation scanning.

History of the CT

- The practical application: G. N. Hounsfield. He works in the central laboratories of EMI Ltd.

History of the CT

- The practical application: G. N. Hounsfield. He works in the central laboratories of EMI Ltd.
- In 1967 Hounsfield develops a different system to do the image reconstruction, using all the computing power available.

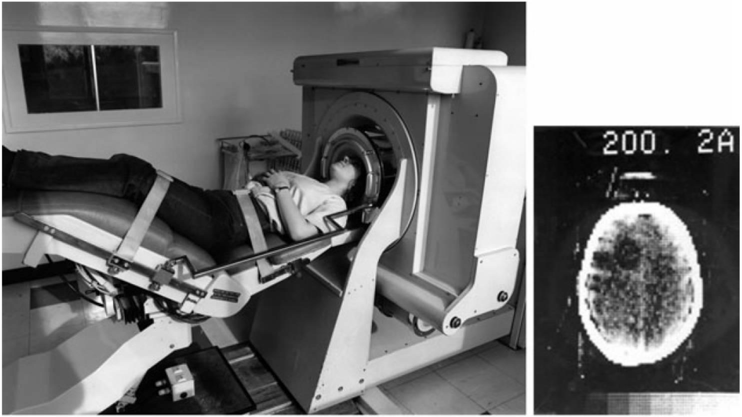
History of the CT

- The practical application: G. N. Hounsfield. He works in the central laboratories of EMI Ltd.
- In 1967 Hounsfield develops a different system to do the image reconstruction, using all the computing power available.
- In 1971, first practical application in the Atkinson Morley Hospital (Wimbledon).
- In its first scanner, Hounsfield used a different image reconstruction algorithm (*Algebraic Reconstruction Technique*, ART)

History of the CT

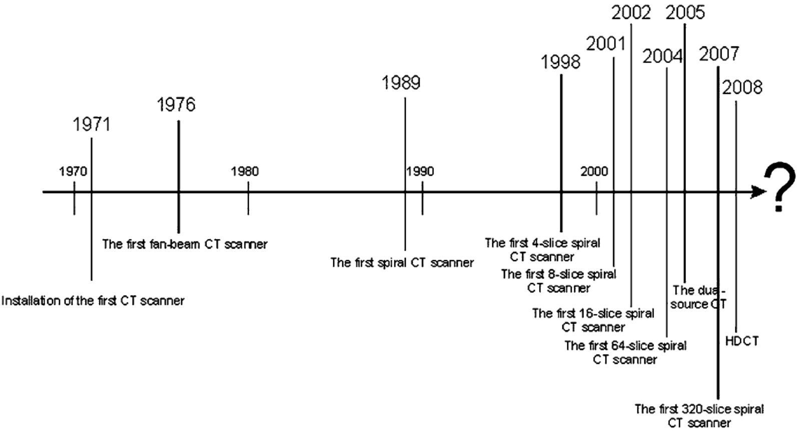
- The practical application: G. N. Hounsfield. He works in the central laboratories of EMI Ltd.
- In 1967 Hounsfield develops a different system to do the image reconstruction, using all the computing power available.
- In 1971, first practical application in the Atkinson Morley Hospital (Wimbledon).
- In its first scanner, Hounsfield used a different image reconstruction algorithm (*Algebraic Reconstruction Technique*, ART)
- Basic parameters:
  - Scanner time: 4.5 min.
  - Reconstruction time: 20 s.
  - Thickness of the cross section: 13 mm.
  - Image matrix: 80×80 pixels, each one about 3×3 m^2.

History of the CT



(a) (b)

The scanner EMI Mark I (a) and a brain cross section (b).



Important dates in the CT history.

History of the CT

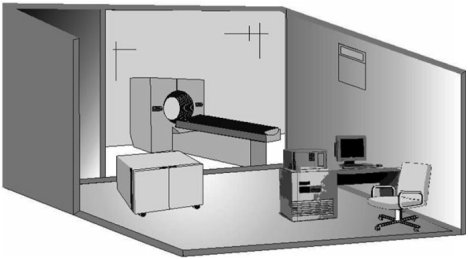
(a) (b)

Parents of the CT: (a) A. M. Cormack y (b) G. N. Hounsfield. Nobel prize of Physiology and Medicine in 1979.

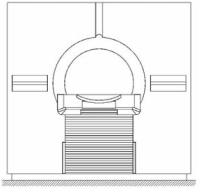
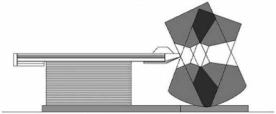
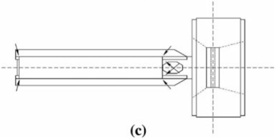
Parts of the CT scanner

1. System for data acquisition that makes the projections.
2. Computer system to do the image reconstruction from the projections.
3. An AC generator
4. A monitor system to view the images.
5. Another systems for data storage.

Instalation of a CT scanner



Data acquisition system


(a)

(b)

(c)

Different views of the data acquisition system:

- (a) Front
- (b) Side
- (c) Up

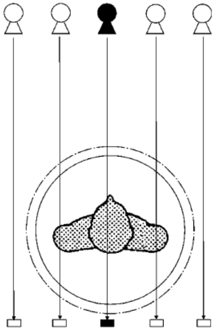
Some technical aspects

Parts of the data acquisition system

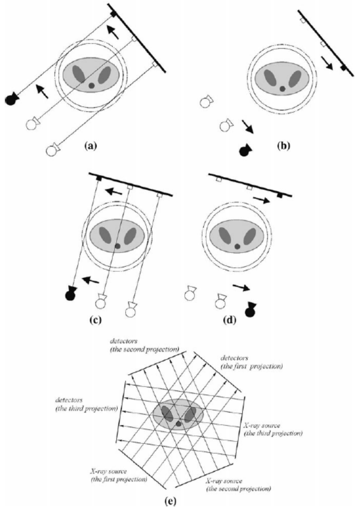
1. The *gantry*, with a central opening, in which the pacient is moving during the scanner.
2. The X-rays tube, that gives the X-rays source that is passing through the body of the patient, providing the information relevant for the image reconstruction to the system detector.
3. The system detector, that converts the projection values, given as radiation intensities, in electric quantities. This set rotates simultaneously with the X-ray tube.
4. The table, that permits to position in a right way the patient. It is possible to move it from inside to outside the *gantry*, along the body axis of the patient, and even from up to down.

CTs of the 1st generation

- They use a parallel beam projection system:

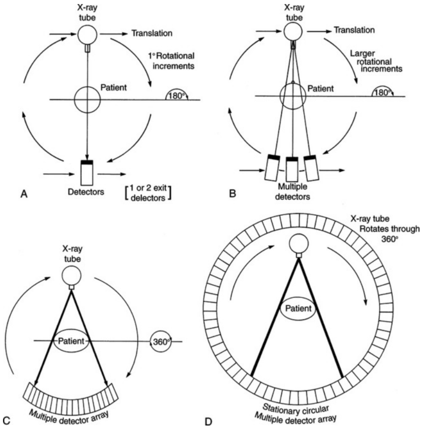


CTs of the 1^{st} generation



CTs of the 2^{nd} generation (1972)

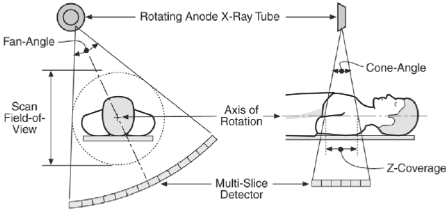
A huge number of detectors (up to 52), and a fan beam; Scanning time: 300 s.



Some technical aspects

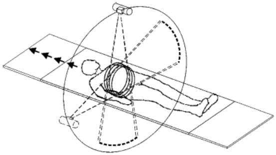
CTs of the 3^{rd} generation (1976)

- Try to eliminate the lateral moving of the tube-detector system.
- Increasing the number of detector that moves simultaneously with the X-rays tube (up to 1000).

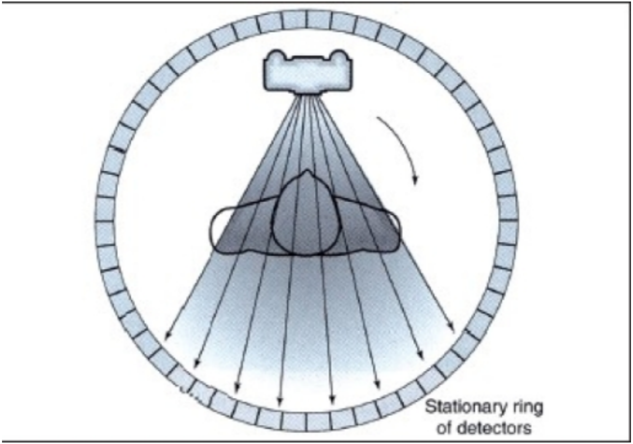


CTs of the 4^{th} generation (1978)

- The detector set is built in a stationary ring, with a radius greater than the circle describe by the tube: fixed rotating scanner.
- The number of detectors is increased up to 5000.
- Scanning time: 5 s.

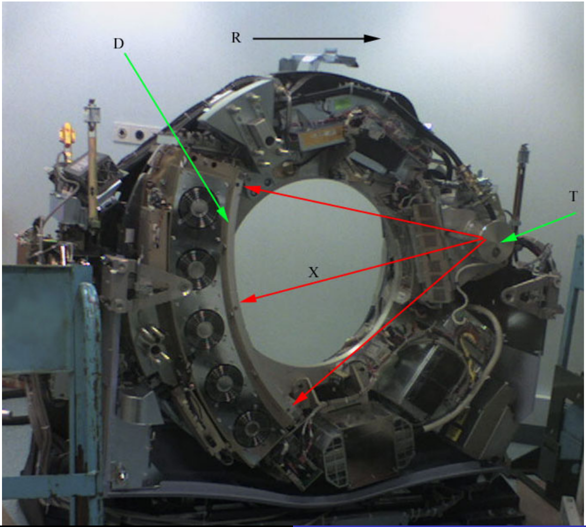


CTs of the 4^{th} generation (1978)



Some technical aspects

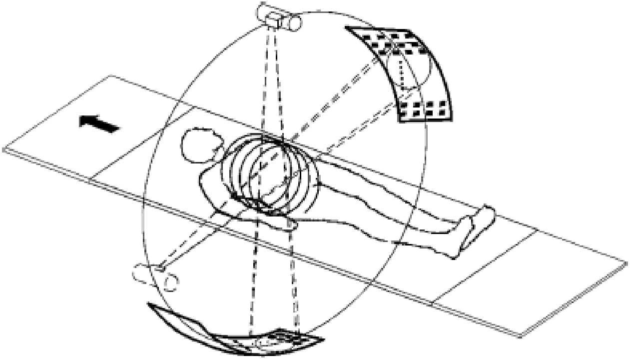
CTs of the 4^{th} generation (1978)



Last developments

1. The projection system has a spiral movement around the patient (1989): a detectors sect in a circular section (*Single-slice Spiral Computed Tomography*), SSCT.
2. There are between 8 and 34 detectors rows $\rightarrow$ it is possible to obtain four slices simultaneously (1998): (*Multi-slice Spiral Computed Tomography*), MSCT.
3. The *Cone Beam Spiral Tomography*, CBST (2002) permits the simultaneous acquisition up to 256 slices: the combination of the cone beam and the spiral movement of the projection system goes to a very important reduction in the scanning time and the resolution (up to 0.23 mm).

Last developments



The movement of the projection system respect to the patient in a CBST.