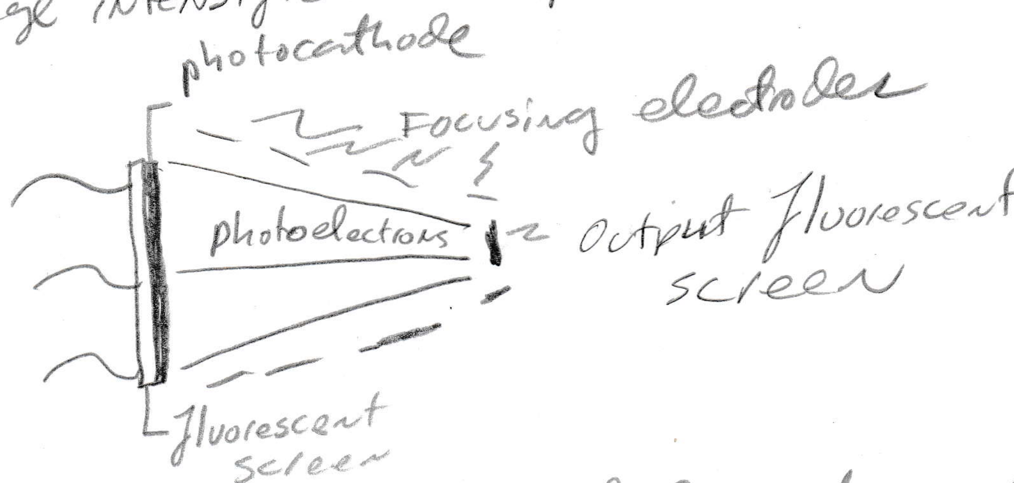
Today: X-rays

Fluoroscopy

Real-time x-ray imaging for motion

Example use: follow catheter motion in cardiac catherization techniques

* Usually uses fluorescent material to convert x-ray to visible light
* An image intensifier is often used



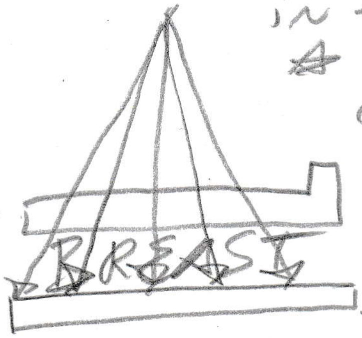
photoelectrons are accelerated & focused onto output fluorescent screen

Brightness can be increased by a factor of 1000 to 5000 by using an intesifier

* Requires higher continuous radiation than typical still-shot x-ray images ⇒ higher radiation dose

Mammography

* Can detect 80% of all breast cancer
* Exams use specially designed systems
  * * Breast compressed to D-shape several cm thick : * Can use lower energy X-rays in thinned breast ⇒ Better contrast * Better spatial resolution (less blur due to motion & detector can be very close) * Fewer scattered X-rays * Less overlap of different tissues



  * * X-rays passed through compressed breast onto image receptor
* In a few percent of all cases, more investigation is warranted
  * * Additional high-resolution mamogram

    AND/OR

  * * High resolution ultrasound [to distinguish between cysts & solid tumors]
* Millions of women are screened each year ⇒ X-ray dose needs to be kept to minimum

Digital Radiography

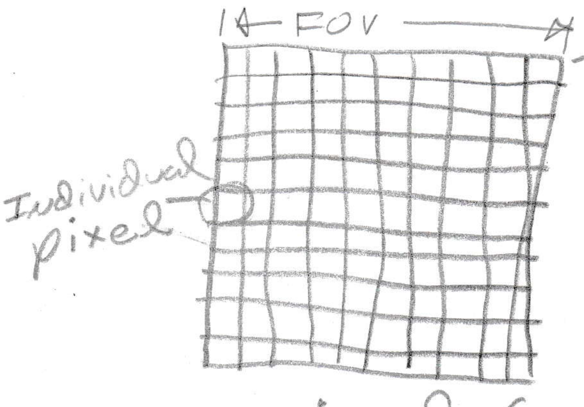
* Digital detectors have large dynamic range & allows differentiation of tissue with subtle differences in contrast

Digital subtraction radiography

1) Take x-ray
2) Add contrasting agent & take 2nd x-ray
3) Subtract 1st x-ray

* Subtraction improves contrast
* Removes distracting images of bones & other absorbers that may hide information

Digital data



2-d image broken into an xy-grid. Each element of the grid has a gray-scale value associated with it. Each element of the grid is called a pixel (picture element).

FOV ≡ field of view

Binary & Decimal

Decimal [Base 10]

1 2 3 4
- 4 — ones place (10^0)
- 3 — Tens place (10^1)
- 2 — Hundreds place (10^2)
- 1 — Thousands place (10^3)

$$1234 = 1*10^3 + 2*10^2 + 3*10^1 + 4*10^0$$
$$= 1*1000 + 2*100 + 3*10 + 4*1$$

We need 10 kind of characters { 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 }

Binary [Base 2]

10011010010
- 2^0 place
- 2^1 place
- 2^2 place
- 2^3 place
- 2^4 place
- 2^5 place
- 2^6 place
- 2^7 place
- 2^8 place
- 2^9 place
- 2^{10} place

$2^0 = 1$
$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$
$2^7 = 128$
$2^8 = 256$
$2^9 = 512$
$2^{10} = 1024$

so $10011010010 = 1*1024 + 0*512 + 0*256 + 1*128 + 1*64 + 0*32 + 1*16 + 0*8 + 0*4 + 1*2 + 0*1 = 1024 + 128 + 64 + 16 + 2$

$= 1152 + 80 + 2 = 1234$

If we had 8 binary digits we could have all numbers between

00000000 and 11111111

Note

$$\begin{array}{r} 011111111 \\ +\ 000000001 \\ \hline =100000000 \end{array} = 2^8 = \underbrace{256}_{\text{Decimal}}$$

So $11111111 = \underbrace{255}_{\text{Decimal}}$

This means that 00000000 to 11111111 is the same as 0 to 255 and that is 256 numbers in total [Note: zero is a number]

This means that 8 bits [binary digits] can encode 256 numbers from 0 to 255

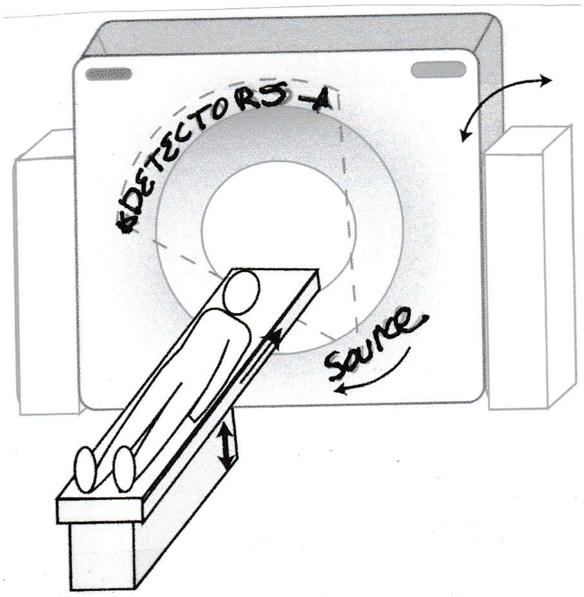
<u>Gray-scale</u>

For 8-bit gray-scale : 0-white, 255-Black } 256 shades (2^8)

12-bit gray-scale : 0-white, 4095-Black } 4096 shades (2^{12})

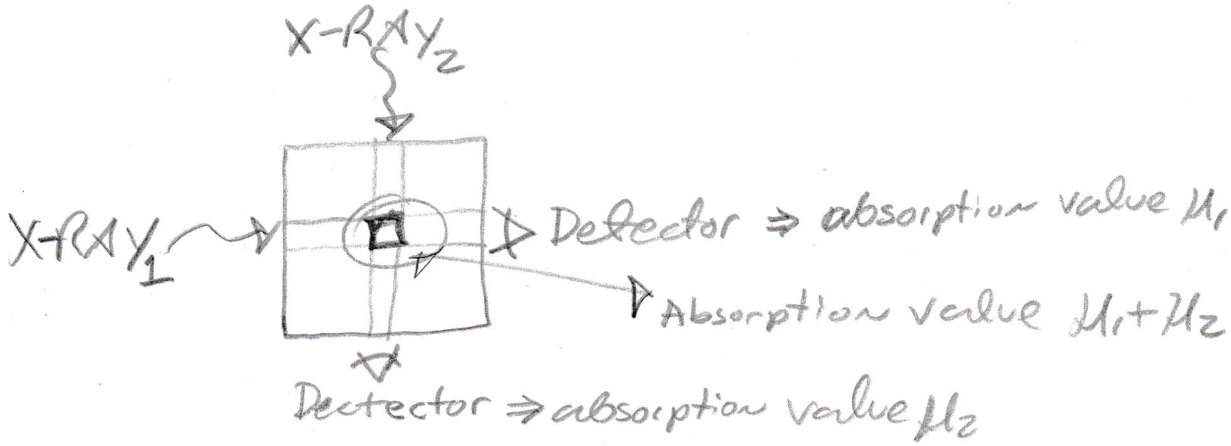
14-bit gray-scale : 0-white, 16,383-Black } 16,384 shades (2^{14})

Computed Tomography ≡ CT



X-ray source & Detector array rotate about patient. This records a single slice of X-ray data. After a slice of data has been taken, the patient can be translated through the machine and another slice of data taken.

Simplified data reconstruction



CT-scan [Continued]

previously we had a pixel [picture element]
now we have a voxel [volume element]

* Voxel side can be smaller than 1/3 mm

* An axial image [single slice] is typically
512x512 voxels or 1024x1024 voxels
⇒ 260,000 or over 1 million voxels per
slice [respectively]

$$\text{CT number} \equiv \left(\frac{\mu_{tissue} - \mu_{water}}{\mu_{WATER}}\right) * 1000$$

Small variations in CT number can be
easily measured and displayed

* Skip Section 5.11