



http://upload.wikimedia.org/wikipedia/commons/archive/d/da/20060904231838!Head_CT_scan.jpg



A

- Introduction

- *Computed Tomography*, CT for short (also referred to as CAT, for Computed Axial Tomography), utilizes X-ray technology and sophisticated computer software to create images of cross-sectional "slices" through the body.
- CT exams and CAT scanning provide a quick overview of pathologies/anatomy and enable rapid analysis and treatment plans.
- Tomography is a term that refers to the ability to view an anatomic section or slice through the body.
- Anatomic cross sections are most commonly referred to as transverse axial tomography.
- The CT scanner was developed by Godfrey Hounsfield in the late 1960s.
- This x-ray-based system created projection information of x-ray beams passed through the object from many points across the object and from many angles (projections).
- CT produces cross-sectional images and also has the ability to differentiate tissue densities, which creates an improvement in contrast resolution.

- Introduction

- The x-ray tube in a CT scanner is designed to produce a fan shaped beam of x-rays that is approximately as wide as your body.
- The x-ray tube on a CT scanner is more heavy duty than tubes used for standard film imaging since the unit rotates and they operate at slightly higher energies.
- Opposite the patient is an array of detectors that measure the intensity of the x-ray beam at points laterally across the patient's body.
- Modern CT scanners use solid state detectors that have very high efficiencies.
- Solid state detectors are made of a variety of materials that create a semiconductor junction similar to a transistor.
- Ultrafast ceramic detectors use rare earth elements such as silicon, germanium, cadmium, yttrium or gadolinium, which create a semiconducting p-n junction.
- Ceramic solid-detectors are very fast, can be extremely stable, and are produced to form an array of very small, efficient detectors that can cover a large area.

- The basics

- The x-rays are produced in a part of the ring and the ring is able to rotate around the patient.
- The target ring contains an array of detectors and is internally cooled to reduce electronic noise in the detectors and to cool the anode.
- The patient is put into the system using a precise high speed couch.





http://www.endocrinesurgery.ucla.edu/images/adm_tst_ct_scan.jpg



Computed Tomography - The basics



https://www.youtube.com/watch?v=pLajmU4TQuI



• The inner workings of a CT scanner.

https://radiopaedia.org/cases/internal-structure-of-ct-scanner?lang=us

- The basics of image formation



- The x-ray tube and detectors rotate around the patient and the couch moves into the machine.
- This produces a helical sweep pattern around the patient.
- The patient opening is about 70cm in diameter.
- The data acquired by the detectors with each slice is electronically stored and are mathematically manipulated to compute a cross-sectional slice of the body.
- Three-dimensional information can be obtained by comparing slices taken at different points along the body.
- Or the computer can create a 3D image by stacking together slices.
- As the detector rotates around many cross-sectional images are taken and after one complete orbit the couch moves forward incrementally.





https://maxfacts.uk/diagnosis/tests/ct-scans



- Here the x-ray tube and detector array makes many sweeps past the patient.
- The x-ray tube and detector array is capable of rotating around the axis of the patient.
- Each scan tries to determine the composition of each transverse cross section.

- The basics of image formation

- As the x-ray tube and detectors swing around an intensity profile mapping is created.
- This could also be written as an attenuation profile which is the incident intensity minus the transmitted intensity.
- This generates a set of NxN equations that will be solved simultaneously for /(x,y) in the image reconstruction system.





In a CT scan we measure the intensity of radiation. The attenuation coefficient, /, is easily determined if you have a homogeneous object. The incident intensity needs to be known and for inhomogeneous objects we need many scans to determine /(x,y).

- The basics of image formation

- *Pixel* picture element a 2D square shade of gray.
- *Voxel* volume element a 3D volume of gray.
- This is a result of a computer averaging of the attenuation coefficients across a small volume of material. This gives depth information.
- Each voxel is about 1mm on a side and is as thick as 2 – 10mm depending on the depth of the scanning x-ray beam.





- The basics of image formation



The detectors see the forward projected x-rays and measure the intensity, given that the x-ray intensity without the body present is known.

The intensity I_i written as sum of attenuation coefficients along a given x-ray path.

This generates a shade of gray and a number associated with this shade.

Then the detector changes angles and the process repeats.

The images are reconstructed by a method called *back projection*, or tracing backwards along the x-rays forward path to reconstruct the image and calculating the absorption due to a localized region.

This a mathematically tedious process but is handled easily with computers.



- The top scan we see that there are lighter and darker regions somewhere in it, but we don't know whether the light/dark regions are high, low, or in the middle. In other words, we know where the light region is horizontally but not vertically.
- So, by stretching it out we're kind of saying, "We don't know where the light spot is vertically, so for now give it *all* vertical values!"
- Now do a vertical scan and now we've taken the light/ dark spots whose location we know vertically and "smeared" it out across all horizontal positions.
- You can see where the light areas cross and it gets even more light there and we can start to form an image.
- By "adding" more shadows, medium light lines would eventually disappear, and we'd have a more complete and higher resolution image.

What are the four x-ray "attenuation" coefficients?

In other words, what numbers do we put in each of the 4 boxes, which represent my 4pixel image?

The projections are shown for four different scan angles.



- Hounsfield Units or CT numbers

- CT numbers (or *Hounsfield units*) represent the percent difference between the x-ray attenuation coefficient for a voxel and that of water multiplied by a constant.
- Water has a CT number of zero and the numbers can be positive or negative depending on the absorption coefficient.
- This is how we assign a shade of gray, and 1000 is just a scaling factor set by the CT manufacturer.



$$CT # = \left(\frac{M_{structure} - M_{water}}{M_{water}}\right) \times 1000$$

Computed Tomography - Image Quality



Number of Pixels

- In images *a* and *b* we have an 80 x 80 images matrix and you can easily see the discrete pixels.
- In images *c* and *d* we have a 1024 x 1024 image matrix. Here the individual pixels are not seen and the image quality increases.

Computed Tomography - Image Quality

- •*Contrast Resolution* The ability to differentiate between different tissue densities in the image
- *High Contrast* Ability to see small objects and details that have high density difference compared with background.

- These have very high-density differences from one another.

- Ability to see a small, dense lesion in lung tissue and to see objects where bone and soft tissue are adjacent

• *Low Contrast* - Ability to visualize objects that have very little difference in density from one another.

- Better when there is very low noise and for visualizing soft-tissue lesions within the liver.

- Low contrast scans can differentiate gray matter from white matter in the brain.





- Imaging artifacts

- Artifacts can degrade image quality and affect the perceptibility of detail.
- Includes
 - Streaks due to patient motion, metal, noise, mechanical failure.
 - Rings and bands due to bad detector channels.
 - Shading can occur due to incomplete projections.



Streaks



Rings and bands



Shading

- Advantages & Disadvantages

Advantages:

- Desired image detail is obtained
- Fast image rendering
- Filters may sharpen or smooth reconstructed images
- Raw data may be reconstructed post-acquisition with a variety of filters

Disadvantages

- Multiple reconstructions may be required if significant detail is required from areas of the study that contain bone and soft tissue
- Need for quality detectors and computer software
- X-ray exposure