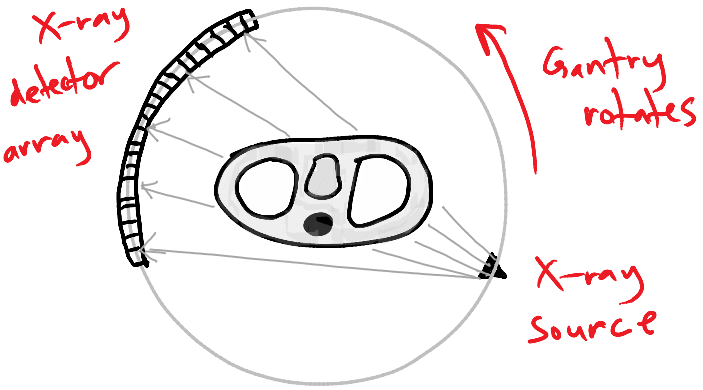
Computed Tomography (CT)

L13

Goal: To find out how CT works, and how it is used (its pros & cons).

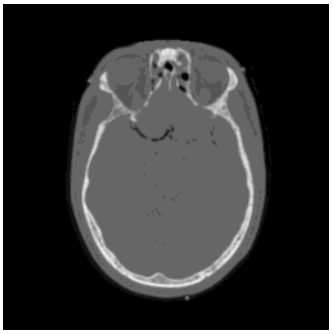
Also known as CAT (computer assisted/aided tomog.).

The idea is to resolve a single slice of an object using many x-ray projections.

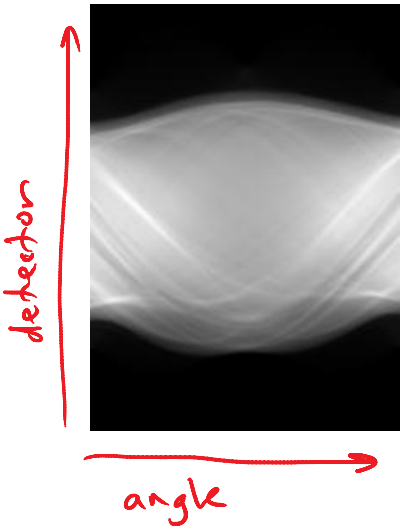


As the gantry rotates, the scanner collects a 1D x-ray at each angle.

Anatomy



Radon Transform



Properties of CT

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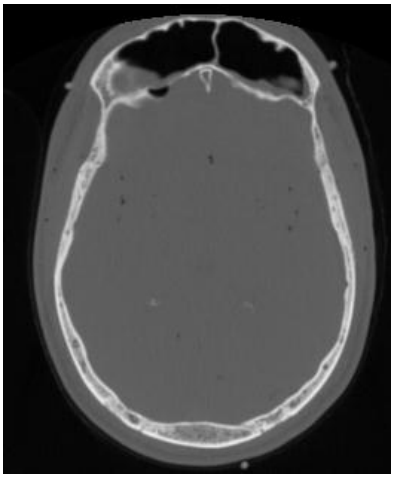
Some things to consider when choosing an imaging modality.

Contrast

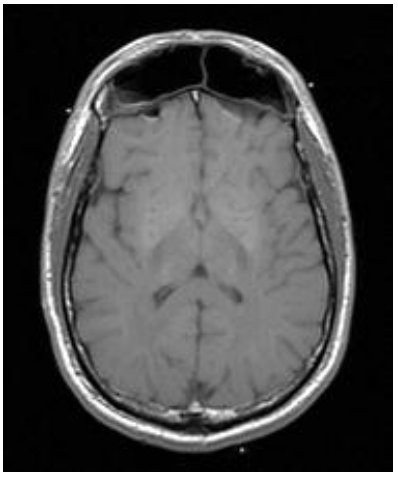
CT is great for distinguishing bone from soft tissue, but not too good for distinguishing soft tissues apart.

CT



vs.

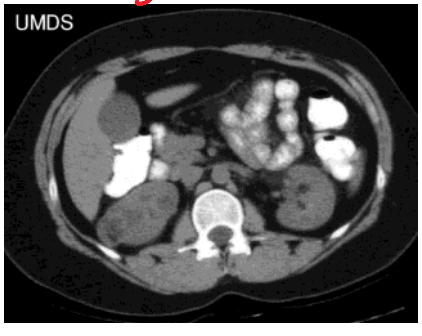
MRI



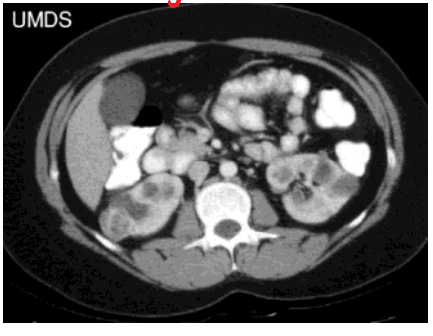
Contrast Agents

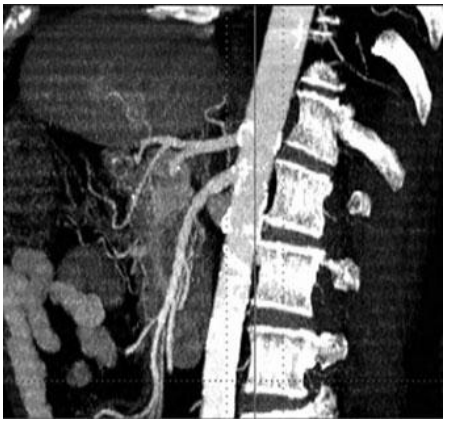
Substances can be introduced to the body to add contrast. These are called contrast agents. They are especially useful for visualizing vasculature (arteries & veins).

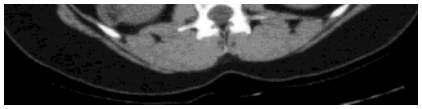
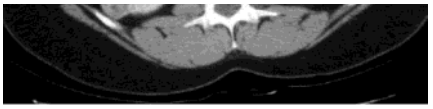
Without contrast agent



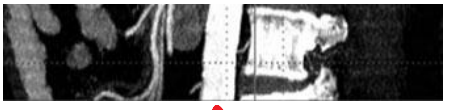
With contrast agent





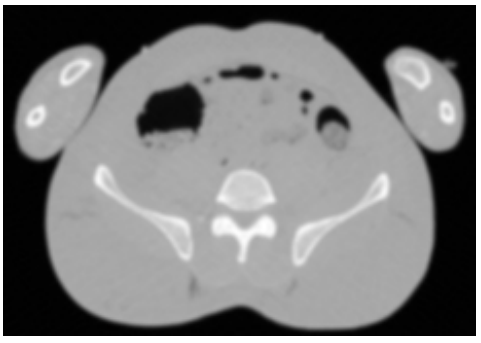
http://www.radiology.co.uk/radiological-cases



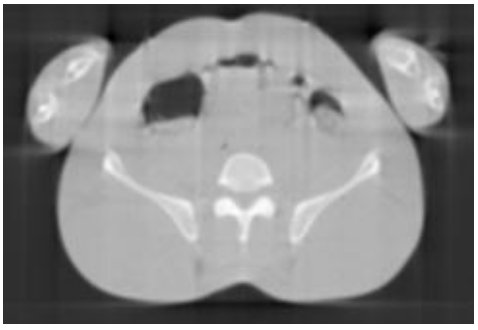
Aorta shows up as bright as bone

Motion Artifacts

It takes a few seconds to acquire one slice of CT data. If the patient moves during that acquisition, the resulting Radon transform will be inconsistent, and the reconstructed image will contain errors.



Motion-free

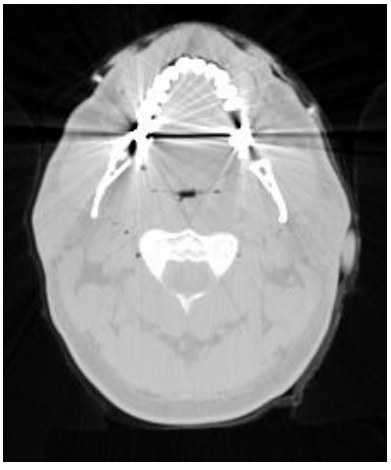


Patient moved 3° half-way through the scan

If the patient motion is known, a lot of the artifacts can be corrected during the reconstruction. There are also some automatic methods that try to sharpen the image by guessing the motion.

Dense Object Shadowing

Highly radio-opaque objects in the field of view do not fit the model assumed by the imaging & reconstruction process. These include metal objects like dental fillings, bullets, artificial joints, etc.



bullets, artificial joints, etc. [redacted]

Ionizing Radiation

X-rays are a form of ionizing radiation. Ionizing radiation is radiation with high enough energy that electrons can be ejected out of their orbitals, creating ions. These ions, in large numbers, can cause tissue damage & damage DNA.

For these reasons, we actively limit the amount of ionizing radiation a person gets (the government keeps track of all your x-rays, CT scans, etc, and sets yearly & lifetime limits).

These dose issues are factored in when a doctor orders a CT scan for a patient.

Recall: risk vs. benefit

Speed

The speed of a CT scan is really only limited by how fast the x-ray source can be moved, and by x-ray flux. After all, the x-rays themselves move at the speed of light.

So, although patient motion can be an issue, CT is among the best for speed.

Quantitative

The intensity values are in Hounsfield units, which is an absolute intensity scale.

Recall: $H_{air} = -1000$ HU $H_{water} = 0$ HU

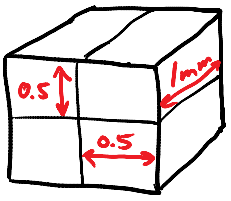
This helps when processing the images. For example,

This helps when processing the images. For example, we know the range for bones, so we can do a pretty good job of deciphering which voxels are bone without even looking at the image.

Resolution

CT scanners designed for human diagnostic imaging are generally capable of producing images with voxels of size 0.5mm x 0.5mm x 1mm.

Typical image size is 512 x 512 pixels.



Tradeoffs

We could achieve higher resolution & higher signal-to-noise ratio (SNR) if we could increase the x-ray dose. So CT scans are carefully designed with all 3 factors in mind to minimize the dose, while still acquiring images that serve their diagnostic purpose.