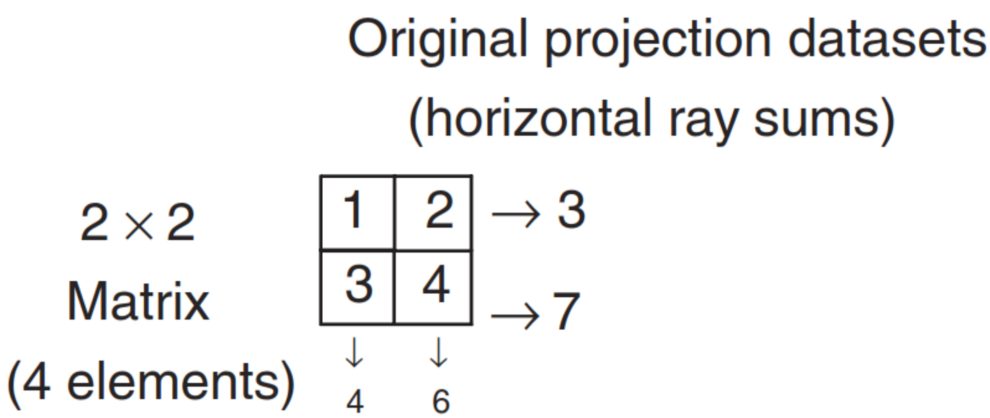
- **Iterative reconstruction**

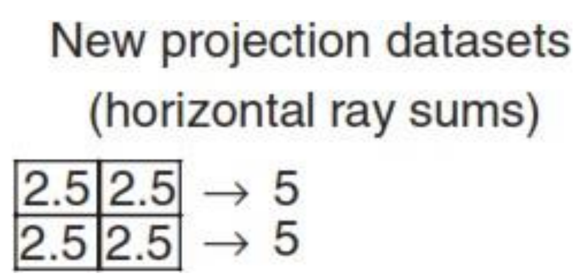
Another approach to image reconstruction is based on iterative techniques. Iteration is defined as a procedure in which repetition of a sequence of operations results in values successively closer to a desired result. Said another way, iteration is a computational, mathematical procedure in which a cycle of operations is repeated, often, to approximate the desired result more closel .

“An iterative reconstrution starts with an assumption (for example, that all points in the matrix have the same value) and compares this assumption with measured values, makes corrections to bring the two into agreement, and then repeats this process over and over until the assumed and measured values are the same or within accept- able limits”.

Consider the following numeric illustration:



1. Initial estimate: Compute the average of four elements and assign it to each pixel, that is, 1 + 2 + 3 + 4 = 10; 10/4 = 2.5



2. First correction for error (original horizontal ray sums minus the new horizontal ray sums divided by 2) = (3 − 5)/2 and (7 − 5)/2 = −2/2 and 2/2 = −1.0 and 1.0

3. Second estimate:

(2.5 – 1) 1.5	(2.5 – 1) 1.5
(2.5 – 1) 3.5	(2.5 – 1) 3.5

4. The second correction for error (original vertical ray sums minus new vertical ray sums divided by 2) = (4 − 5)/2 and (6 − 5)/2 = −1.0/2 and +1.0/2 = −0.5 and +0.5:

(1.5 – 0.5) 1	(1.5 – 0.5) 2
(3.5 – 0.5) 3	(3.5 – 0.5) 4

1.5	1.5
3.5	3.5
↓	↓
5	5

New projection datase
(vertical ray sums)

The final matrix solution is thus $\longrightarrow$

1	2
3	4

In this technique, repeated estimations of the x ray photon counts that would be acquired in each projection are calculated , and compares them with the actual measured counts (*forward projection*) acquired by the scanner's detector array. At each step, the ratio of estimated to actual x ray counts is used to formulate a correction factor that is used to create the next estimate (*back projecting the ratio*).

This process is repeated over and over again resulting in movement of the estimated x ray photon count distribution ever closer to the actual, measured photon count distribution, Fig. 1.

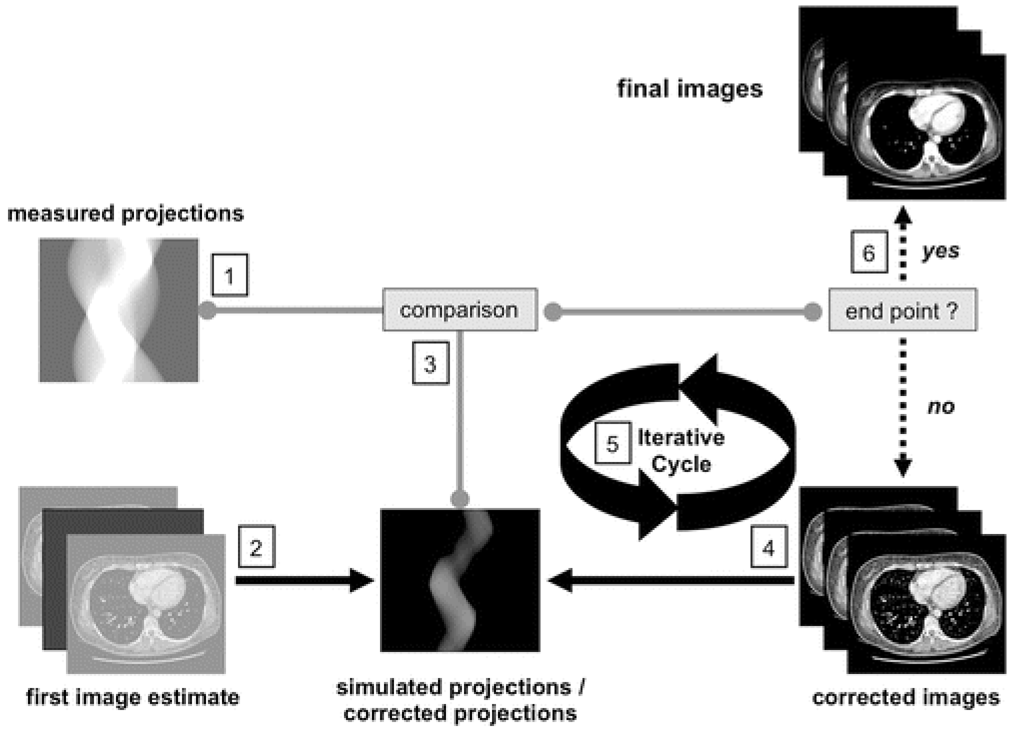


Fig. 1: Iterative reconstruction techniques used in CT.

Today, iterative reconstruction algorithms have resurfaced because of the availability of high-speed computing. The primary advantages of iterative image reconstruction algorithms are to reduce image noise and minimize the higher radiation dose inherent in the filtered back-projection algorithm.

CT image quality

Because CT images are composed of discrete pixel values, image quality is some what easier to characterize and quantitate.

A number of methods are available for CT image quality is dependent on:

- ❖ Image contrast,
- ❖ Spatial resolution,
- ❖ Noise
- ❖ Artifacts

Depending on the diagnostic task, these factors interact to determine sensitivity; the ability to perceive low & high contrast structures to yield a diagnostic CT image and the visibility of details.

➥ *Image contrast*

The ability to distinguish one soft tissue from another without regard for size or shape is called **contrast resolution**. This is an area in which multislice helical CT excels. CT image contrast depends on subject contrast and display contrast . Display contrast is arbitrary and based on the windowing parameters (window level & window width selected).

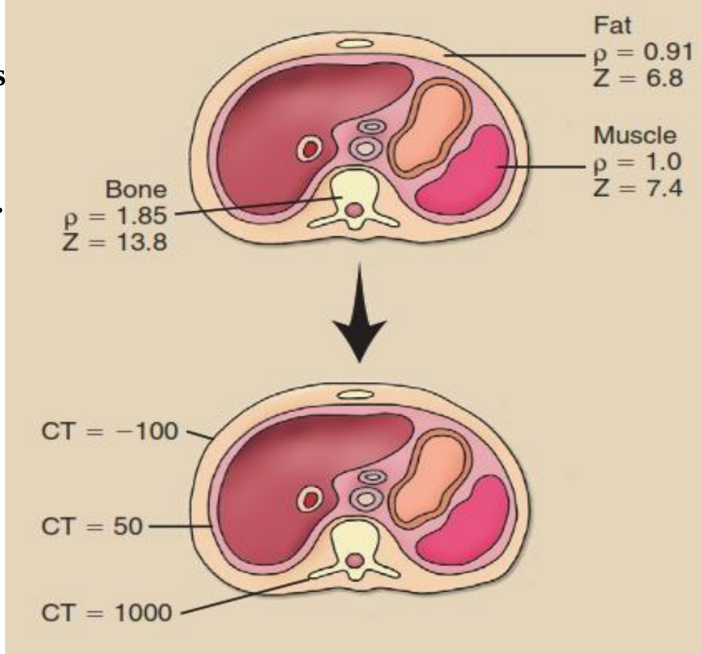
As in radiography, CT subject contrast is determined by differential attenuation: that is, differences in x-ray attenuation by absorption or scattering in different types of tissue and thus resulting in differences in the intensity of the x-rays ultimately reaching the detectors. Because of the high peak kilovoltage and relatively high beam filtration (beam hardness) used in CT, most of the radiological events in CT are Compton scatter events which differ in intensity based on differences in tissue electron density (electrons/ cm^3), which in turn are due primarily to differences in physical density

thus, subject soft-tissue contrast in CT comes mainly from differences in physical density. That the small differences in soft-tissue density can be visualized on CT is due to the nature of the image (a 2-dimensional image of a 2-dimensional slice). However, these differences may be mapped to large differences in grey levels (grey scale) through windowing which makes CT visualization of various tissues possible.

For more explainaton:

The absorption of x-rays in tissue is characterized bythe x-ray linear attenuation coefficient. This coefficient, as we have seen, is afunction of x-ray energy and the atomic number of the tissue. In CT, absorption of x-rays by the patient is determined also by the mass density of the body part.Consider the situation outlined in Figure (1), a fat–muscle–bone structure.Not only are the atomic numbers somewhat different (Z = 6.8, 7.4, and 13.8,respectively), but the mass densities are different (r = 0.91, 1.0, and 1.85g/cm3, respectively). Although these differences are measurable, they are notimaged well on conventional radiography.

Fig. (1): No large differences are noted in mass density and effectiveatomic number among tissues, but the differences are greatly amplified by computed tomography imaging.



The CT imaging system is able to amplify these differences in subject contrast so the image contrast is high. The range of CT numbers for these tissues is approximately −100, 50, and 1000, respectively. This amplified contrast scale allows CT to better resolve adjacent structures that are similar in composition. The contrast resolution provided by CT is considerably better than that available in radiography principally because of the scatter radiation rejection of the prepatient and predetector collimators. The ability to image low-contrast objects with CT is limited by the size and uniformity of the object and by the ***noise of the system***.

Factors influencing contrast:

- **Noise:** a higher noise will obscure any contrast between objects
- **Tube current:** a higher tube current reduces the noise in the image
- **Inherent tissue properties:** the difference in the linear attenuation coefficient of adjacent imaged objects will determine the contrast between those objects
- **Beam kilovoltage:** a higher beam energy will generally reduce the contrast between objects
- **Use of contrast media**

➥ *CT Spatial Resolution*

Spatial resolution in CT, as in other modalities, is the ability to distinguish small, closely spaced objects on an image.
Characteristics of the CT imaging system that contribute to such image degradation include collimation, detector size , mechanical and electrical gantry control, and the reconstruction algorithm.

Factors affecting spatial resolusion

If one images a regular geometric structure that has a sharp interface, the image at the interface will be some- what blurred. The degree of blurring is a measure of the spatial resolution of the system and is controlled by a number of factors.

➤ ***Focal spot***

Spatial resolution is determined by x ray tube focal-spot size as well as blurring occurring in the image detector. focal-spot size is a contributor to spatial resolution (smaller focal spot size equals better spatial resolution).

➤ ***Detectors size***

The size of the detector measurements (referred to as aperture size and represents sampling size) and the detector spacing (spacing of measurements) are the predominant factors that determining a CT scanner's spatial resolution.

The smaller the detector measurement capability and the closer the detector spacing, the better the spatial resolution. This concept is known as ***sampling***.

Detectors must be the same size or smaller than the imaged object in order to resolve it. In addition, detectors must be close together to resolve objects that are near to each other. Further, the detectors must be properly aligned. Improper alignment may result in less resolving power than would be predicted by detector size and spacing alone.

➤ ***Pixel size***

Spatial resolution is a function of pixel size: The smaller the pixel size, the better is the spatial resolution. CT imaging systems allow reconstruction of images after imaging followed by post processing tasks; this is a powerful way to affect spatial resolution.

- ***Voxel size***

The displayed spatial resolution may also be affected by the image reconstruction or by the voxel size on the computer screen. For example, it is possible that the voxel size on the computer matrix is too large to resolve an object that is theoretically resolvable based on the sampling characteristics. This limitation may be overcome by reducing the scanned field of view which will have the effect of yielding smaller voxels. For example, if the matrix size is 512 voxels by 512 voxels and the scanned field of view is a 50 cm diameter, the voxel sizewill be 50 cm/512 pixels or approximately 0.1 cm by 0.1 cm by 0.1 cm. However, if the scanned field of view is reduced to 25 cm then the resulting voxel size willbe 0.5 cm by 0.5 cm by 0.5 cm.

- ***Number of projections***

Larger number of projections gives finer resolution (up to a point).

- ***Detector slice thickness***

The above discussion applies mainly to x and y axis spatial resolution. Z axis spatial resolution (head to toe) depends on the image thickness which in turn depends on the length of the individual detector in the z axis. In addition, z axis resolution depends on the reconstruction interval (degree of overlap of z axis image slices) **Overlapping samples** .Acquiring the data using overlapping slicescan improve Z-sensitivity. This is achieved by using a low spiral pitch e.g. pitch<1.

Thinner slice thicknesses also allow better spatial resolution. Anatomy that does not lie totally within a slice thickness may not be resolved, an artifact called *partial volume.*