

Recent advances in CT scanner technologies have generated a great deal of interest in dual energy CT. The basic research on the fundamental principles, however, dates back to the 1970's, and that work was based in part on the earlier work on x-ray absorptiometry. The purpose of this presentation is to discuss the basic physics principles of multi-energy x-ray methods for material characterization, and the strengths and limitations of the techniques and the various implementations.

As single energy CT images cannot possibly fully characterize materials. At best it is an image of the linear attenuation coefficient as a function of energy, and it is well known that this does not uniquely identify the tissue. The x-ray attenuation of materials with different atomic numbers has different energy dependence, and the concept behind multi-energy imaging is to measure the x-ray attenuation properties at different energies to more fully characterize the material. At first glance one might assume that measurements at N energies would enable the separation of the object into N component materials. However, an important limitation to the ability of x-ray attenuation measurements to fully characterize materials is the fact that in the diagnostic energy range the attenuation of all materials is dominated by Compton scattering and photoelectric absorption, and, unless there is an absorption edge in the energy range used, these x-ray interaction mechanisms have the same energy dependence for all materials. Under these conditions, there are really only two "basis functions" and multi-energy CT essentially measures the effective atomic number and the electron density of the material. This leaves us with considerable residual ambiguity as to what the materials are. Also, measurement noise limits the ability to measure small changes in atomic number.

The main requirement for dual energy CT is to measure projection data using two x-ray spectra. There are several implementations available. These include systems that obtain measurements at multiple kVp and/or filtration. There are also methods in which the x-ray energy discrimination is performed at the detector. These include layered detectors and photon counting systems with the energy analysis. These various approaches to obtaining energy dependent measurements have different dose efficiency and different sensitivity to subject motion.

There are two main ways to process the multi-energy data. The simplest method reconstructs CT images from the data as if it were a single spectrum and performs the multi-energy analysis on the values in the reconstructed images. The energy dependent processing can alternatively be applied to the measured projections prior to reconstruction. This latter method is somewhat more complicated but provides additional benefits, such as an implicit beam hardening correction.

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