AbstractID: 11939 Title: Dual Energy Imaging with Dual Source Systems

The first investigations of dual energy methods for CT were made by Alvarez and Macovski in 1976. They demonstrated that using a conventional X-ray source having a broad energy spectrum, one can still separate the attenuation coefficient into the contributions from the photoelectric effect and Compton scattering. Thereafter, several applications were reported utilizing dual energy CT, focusing primarily on lung, liver and tissue characterization. However, all of the approaches were limited in some manner and not able to be used routinely in clinical practice. The primary limitation was that data for the different tube voltages were acquired at two different times.

In the 1980s, it was possible to acquire dual energy data nearly simultaneously using a modified commercial CT system (Siemens DR scanner). During the rotation of the tube-detector pair, the tube voltage was switched quickly for each detector reading between the high and low settings so that two sets of raw data (projections) were acquired nearly simultaneously at two different tube voltages. Unfortunately, the only practically and routine used Dual Energy application was bone densitometry, and this was not sufficient to let this system survive. The main limitation of the tube voltage switching approach of the DR scanner was that a) the delivered dose of the low kV readings was – compared to the dose delivered by high kV reading - too low, b) the necessary adaptation (increase) of the tube current at low kV was not adequately possible, and c) the impact on image quality due to the switching between high and low kV was too big.

The technical limitations of the DR system were overcome with the introduction of the first dual source system in 2006. In contrast to a single source system, dual source CT systems have two separate tube/detector pairs that are mounted orthogonally on the rotating slip ring. This design provides the flexibility to adjust not only the tube voltage but also the tube current for both tube/detector pairs and allows simultaneous data acquisition. Although the raw projection data do not match identically because of the 90 degree offset between both systems, reconstructed images – although measured at different tube position - are acquired at exactly the same time. This is true for regular spiral or sequential scans and also for the gated scans used in cardiac examinations. Data from both tube/detector pairs are reconstructed separately into two different image stacks. Image-based post processing then is used to extract the dual energy information.

In 2008 an even improved version of the established Dual Source CT system was introduced – the SOMATOM Definition Flash (Siemens Healthcare, Germany). The main changes are that the limited FOV of the second tube-detector system was extended so that nearly all of the relevant anatomy fits into the FOV of the second system. In addition, a so called ‘selective photon shield’ was added to the high kV beam. This additional filtration (tin pre-filtration) improves the dual energy separation significantly. The overlap of both spectra is minimized and therefore the Dual Energy separation e.g. of bone and iodine is increased by nearly a factor of 2; noise in dual energy post-processed data, e.g. virtual non-contrast images, reduced significantly.

Dual energy data from dual source systems are typically prost-processed using image-based DE methods.

Some of the DE techniques focus on the ability to separate two materials based on their CT-values at high and low kV. For this purpose, pixel data are put into a 80-140-kV diagram. Pixels containing a certain material (e.g. calcium or iodine) in different concentrations or at different densities are on a straight line. Drawing a separation line for example between the lines for calcium and iodine allows separating both materials in the 80-140-kV diagram and therefore also in the DE CT images. This technique is for example used for applications like bone removal or lung vessels. A similar principle applies to the differentiation of a vessel lumen filled with iodinated blood and calcified plaques.

Other image based Dual Energy methods focus on the quantification of iodine distribution in tissue. This allows, for example, the visualization of perfusion defects in the parenchyma in the case of a pulmonary embolism by displaying the iodine concentration of the different areas of the lungs. Another possible application might be the visualization of pure iodine enhancement in abdominal organs like the kidneys. In this case, additional information about the pure enhancement might be helpful for the differential diagnosis between a hemorrhagic cyst and a renal cell carcinoma. The basic method for post-processing in those cases is the so called three material decomposition. As a first step, three material/tissue types are defined that are of interest and are found in a certain anatomical area. In the liver region, this might be, for example, “soft tissue”, “fat” and “iodine”. Based on values from literature or clinical experience, these materials are drawn into an 80-140-kV diagram, where they span a triangle. To evaluate a certain area of interest, the respective CT values in the 80 and 140 kV image are plotted into the existing diagram. Projecting this point onto the line between “fat” and “soft tissue” allows the calculation of true iodine enhancement in the region of interest.

By applying this method to the whole field of view, an image showing true enhancement can be calculated. In addition to that, the image showing true enhancement can be subtracted from the weighted sum of the low and high voltage image and by doing so a “virtual” non-contrast image be calculated.

Base on the above mentioned techniques in total 12 dedicated dual energy post-processing applications are available for DE images from dual source systems. In addition, special visualization techniques like ‘optimum contrasts’ and ‘monoenergetic’ are available. Due to the recent improvements with the second version of a Dual Source CT system even more applications can be expected in the near future.