Theory and algorithms for phase-contrast CT

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Applications of x-ray computed tomography (CT) vary from medical and biological imaging to material research and industrial inspection. We briefly discuss the state of the art in conventional absorption-based CT and make a link to a new imaging technique: phase-contrast CT. This technique can be implemented at third generation synchrotron radiation sources or by using a microfocus x-ray tube. Unlike conventional absorption-based imaging, phase-contrast imaging uses the phase shifts in the x-ray beam rather than the differences in attenuation. Promising experimental results have been obtained by several research groups. At the same time, the lack of a mathematical theory comparable to that of conventional absorption-based CT limits the progress in this field. We suggest such a theory and prove a fundamental theorem that plays the same role for phase-contrast CT as the Fourier slice theorem does for absorption-based CT. The theory holds for both purely phase objects and the mixed phase and amplitude objects with weak absorption. In contrast to other methods, the suggested approach requires no intermediate steps of phase retrieval and provides exact quantitative reconstruction of the refractive index from intensity measurements. The fundamental theorem plays an important role in the derivation of the algorithms. In particular, the theorem establishes a straightforward relation between the 3D object function and its phase-contrast projections and allows us to derive reconstruction algorithms in the form of filtered backprojection (FBP). FBP is a relatively simple and fast image reconstruction algorithm. The latter makes it a suitable candidate for routine processing of huge volumes of high-resolution phase-contrast data. The filter function of the FBP algorithm can be derived in the Fourier and spatial domains. Depending on the type of phase-contrast measurements, different filter functions are suggested. For the measurements based on the scheme of in-line holography, a low-pass filter function has been derived (Ref. 1-2). The measurements based on using a grating interferometer require the filter function of the Hilbert transform. The reconstruction algorithms have been implemented in the commercially available software (Ref. 3). The results of application of the algorithms are discussed; a comparison with the conventional FBP algorithm is given.

References:

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