Image restoration by Wiener deconvolution in limited-view computed tomography

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In many applications of computed tomography, we cannot acquire the projection data at all angles evenly spaced over 360°. In such cases, the computed tomography images reconstructed using a limited number of projections, measured over a narrow angle range, are characterized by approximately elliptical distortion along the view angles used and poor contrast at angles not used (anisotropic resolution). This systematic geometric distortion is caused by the 2-D point spread function of the reconstruction process. In this paper, we show that such geometric distortion and other artifacts introduced in the reconstruction process can be reduced substantially by deconvolution performed via Wiener filtering using *a priori* knowledge derived from the given projections. The 2-D system transfer function used in the deconvolution is obtained from the reconstruction of a test image by the same reconstruction algorithm which has been used for reconstructing the unknown object.

I. Introduction

Reconstruction tomography from a limited number of projections is of vital interest. In many applications of computed tomography (CT), the projection data from only a small number of viewing angles are available. Images reconstructed from a limited number of projections using the conventional image reconstruction algorithms, which are designed for 360° coverage of viewing angles, suffer from a systematic geometric distortion and severe streaking artifacts.

Recently, several image reconstruction and image restoration algorithms have been investigated for limited-view reconstruction tomography. Several investigators have suggested various iterative techniques in Fourier space to estimate the missing projection data for limited-view image reconstruction.[1–6] The use of *a priori* information from the available projections, as constraints to reduce the streaking artifacts, has been strongly recommended and found quite helpful to achieve better reconstruction.[3–10] Various methods for extrapolating the available data into the missing information region have been used.[2,4,9,10] These methods are primarily based on the algorithms suggested by Gerchberg[7] and Papoulis[8] for extrapolation in the Fourier domain by imposing the space limiting constraints on the object in the spatial domain. Inouye[6] and Peres[11] have proposed orthogonal expansion algorithms for the narrow angle limited-view problems. Other methods include use of an optical feedback system[12] solving a set of simultaneous equations,[13] the maximum entropy,[14–17] and the Baysian approach.[18] A review of the limited-view reconstruction algorithms can be found in our paper published in this issue.[19] In practice most of these algorithms are computationally complex and time-consuming. Moreover, the solutions are sensitive to errors in the data and numerical inaccuracies. They do remove some artifacts in the limited-view reconstructions but do not perform well if the number of known projections is very small.

We proposed a simple method of removing the geometrical distortion in our previous paper[20] by geometric deconvolution. There deconvolution was performed via inverse filtering using 1-D projections instead of the 2-D image. The results, however, were noisy. Also, the method required a second reconstruction process.

The geometric distortion and streaking artifacts are due to the 2-D point spread function of the reconstruction process for the given set of projection angles.[21] We have the following problem: Given a distorted reconstruction, compute a distortion-free and noise-free reconstruction of the image. In other words, deconvolve the geometric distortion and artifacts.[22] Klug and Crowther[23] and King *et al.*[24] have pointed out the possibility of application of the Wiener filter in image reconstruction from projections but have not explained how it may be implemented in limited-view reconstruction tomography. If we restrict ourselves to a linear reconstruction algorithm, the problem reduces to that of estimating the point spread function of the

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