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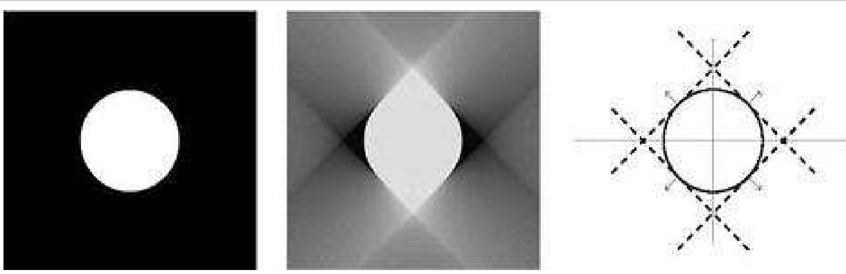
How to characterize and decrease artifacts in limited angle tomography using microlocal analysis

The filtered backprojection algorithm (FBP) in limited angle tomography reliably reconstructs only specific features of the original object and creates additional artifacts in the reconstruction. While the former is well understood mathematically, the added artifacts have not been studied very much in the literature. In our paper *Inverse Problems* 29125007 (http://iopscience.iop.org/0266-5611/29/12/125007/article) we mathematically explain why additional artifacts are created by the FBP and Lambda-CT algorithms for a limited angular range, and we derive an artifact reduction strategy using microlocal analysis.

The success of computed tomography has initiated the development of new imaging techniques in which the tomographic data are available only from a limited angular range. Typical examples of such modalities are digital breast tomosynthesis, dental tomography and electron microscopy. In these cases, the reconstruction problem is severely ill-posed, which results in serious instabilities in the reconstruction. The missing features and the artifacts we characterize are examples of this ill-posedness. Characterization of artifacts. By developing analytic expressions for the limited angle FBP and Lambda tomography algorithms, we characterize the added streak artifacts using microlocal analysis. We explain that artifacts might appear only along lines that are tangent to singularities of the original object. The orientations of the added streaks correspond to the ends of the limited angular range; see figure 1.



(http://images.iop.org/objects/jio/insights/4/1/1/Fig1.jpg)

Figure 1. Original image (left), its FBP reconstruction (middle), and an illustration of added singularities (right) for an angular range [-45°,45°]. The streak artifacts are located on lines that are tangent to singularities with directions +45° or -45°. (http://images.iop.org/objects/jio/insights/4/1/1/Fig1.jpg)

Reduction of artifacts. Limited angle data can be viewed as a hard truncation of full Radon data with respect to the angular variable. Thus, the hard truncation generates additional singularities in the sinogram which in turn are translated into additional singularities in the reconstruction. In our paper we prove that generation of additional artifacts is reduced by replacing the hard truncation with a smooth cutoff. We prove that, with the hard cutoff, the reconstruction operator is a singular pseudodifferential operator which adds artifacts, and this smooth cutoff creates a standard pseudodifferential operator, so it does not add artifacts. Because these results use microlocal analysis, they apply generally. Reconstructions are given in figure 2.

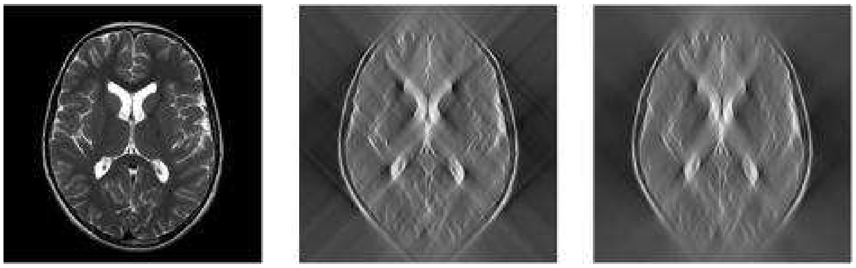

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Figure 2. Reconstruction from noisy Radon data (noise level = 1%) for an angular range [-45°,45°]. Original (left), FBP reconstruction (middle), and artifact reduced FBP reconstruction (right). (http://images.iop.org/objects/jio/insights/4/1/1/Fig2.jpg)


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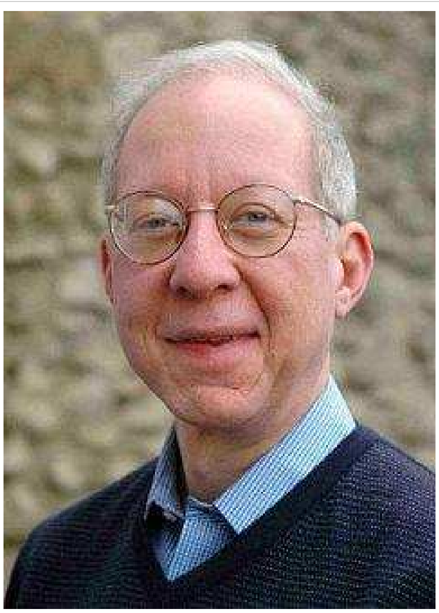
Jürgen Frikel (http://images.iop.org/objects/jio/insights/4/1/1/Auth1.jpg)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Eric Todd Quinto (http://images.iop.org/objects/jio/insights/4/1/1/Auth2.jpg)

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