SparseBeads data: benchmarking sparsity-regularized computed tomography

Sparsity regularization (SR) such as total variation (TV) minimization allows accurate image reconstruction in x-ray computed tomography (CT) from fewer projections than analytical methods. Exactly how few projections suffice and how this number may depend on the image remain poorly understood. Compressive sensing connects the critical number of projections to the image sparsity, but does not cover CT, however empirical results suggest a similar connection. The present work establishes for real CT data a connection between gradient sparsity and the sufficient number of projections for accurate TV-regularized reconstruction. A collection of 48 x-ray CT datasets called SparseBeads was designed for benchmarking SR reconstruction algorithms. Beadpacks comprising glass beads of five different sizes as well as mixtures were scanned in a micro-CT scanner to provide structured datasets with variable image sparsity levels, number of projections and noise levels to allow the systematic assessment of parameters affecting performance of SR reconstruction algorithms. Using the SparseBeads data, TV-regularized reconstruction quality was assessed as a function of numbers of projections and gradient sparsity. The critical number of projections for satisfactory TV-regularized reconstruction increased almost linearly with the gradient sparsity. This establishes a quantitative guideline from which one may predict how few projections to acquire based on expected sample sparsity level as an aid in planning of dose- or time-critical experiments. The results are expected to hold for samples of similar characteristics, i.e. consisting of few, distinct phases with relatively simple structure. Such cases are plentiful in porous media, composite materials, foams, as well as non-destructive testing and metrology. For samples of other characteristics the proposed methodology may be used to investigate similar relations.

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