# Joint reconstruction of multi-modal tomography data using total generalized variation

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Electron tomography has seen major progress over the last years with the development of new reconstruction algorithms using sparsity constraints, such as total-variation (TV) minimization [1], and with the development of analytical tomography, where EELS or EDXS signals are reconstructed in three dimensions [2]. In particular in the case of analytical tomography the usage advanced reconstruction algorithms is essential, as quantity and quality of acquired data is strongly limited by beam damage and/or acquisition time [3].

For TV minimization reconstruction and its application in analytical tomography, we can currently identify two major limitations. First, TV minimization is based on sparsity of the image (or volume) gradient, and thereby enforces sharp interfaces between different regions in the reconstruction. Continuous changes inside the sample, caused for example by diffusion at interfaces, typically lead to staircasing artifacts in the reconstruction. Second, each signal is usually reconstructed independently of all other signals, even though different signals can be strongly correlated and should be therefore combined to better recover features inside the sample.

In this work we overcome these limitations. We introduce the concept of total generalized variation (TGV) [4]. TGV extends TV by using also higher order derivatives, thereby favoring not only sharp, but also gradual interfaces in the reconstruction. A first study of TGV for two-dimensional electron tomography was carried out in [5]. Here, we utilize TGV for the reconstruction of three-dimensional single- and multi-channel data sets.Fig. 1 shows a comparison between a three-dimensional TV and a TGV reconstruction of the same slice, where it can be seen that TGV removes staircase artifacts present in the TV reconstruction. Second, we link different reconstructions, by combining the regularization terms of the individual reconstructions [6,7]. This joint regularization favors co-localization of interface and transition regions in the different reconstructions, thereby transferring morphological information between different reconstructions [8]. Fig. 2 compares separate and joint reconstructions of HAADF STEM and EDXS data.

This work introduces total-generalized variation to electron tomography for reconstruction of single datasets as well as for joint reconstruction of data acquired in a multi-modal tomography experiment, such as EELS or EDXS tomography. These approaches widen the applicability of sparse recovery, lifting the constraint of sharp interfaces, and significantly improving the spatial resolution in multi-modal tomography experiments.

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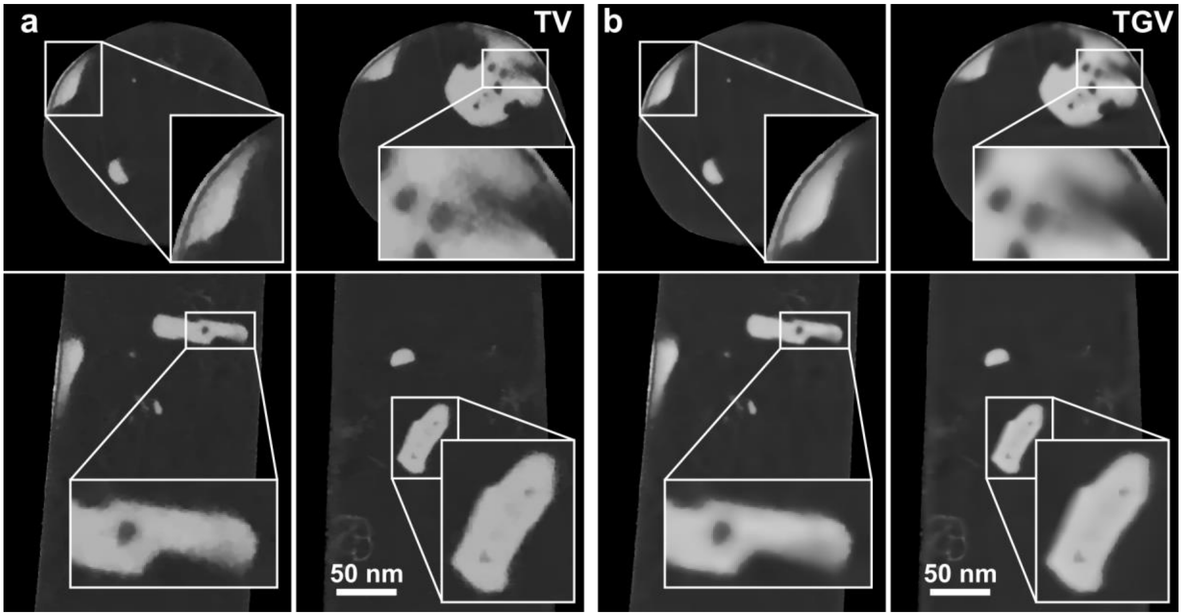


Fig. 1 Slices through (a) TV and (b) TGV reconstructions of the same sample

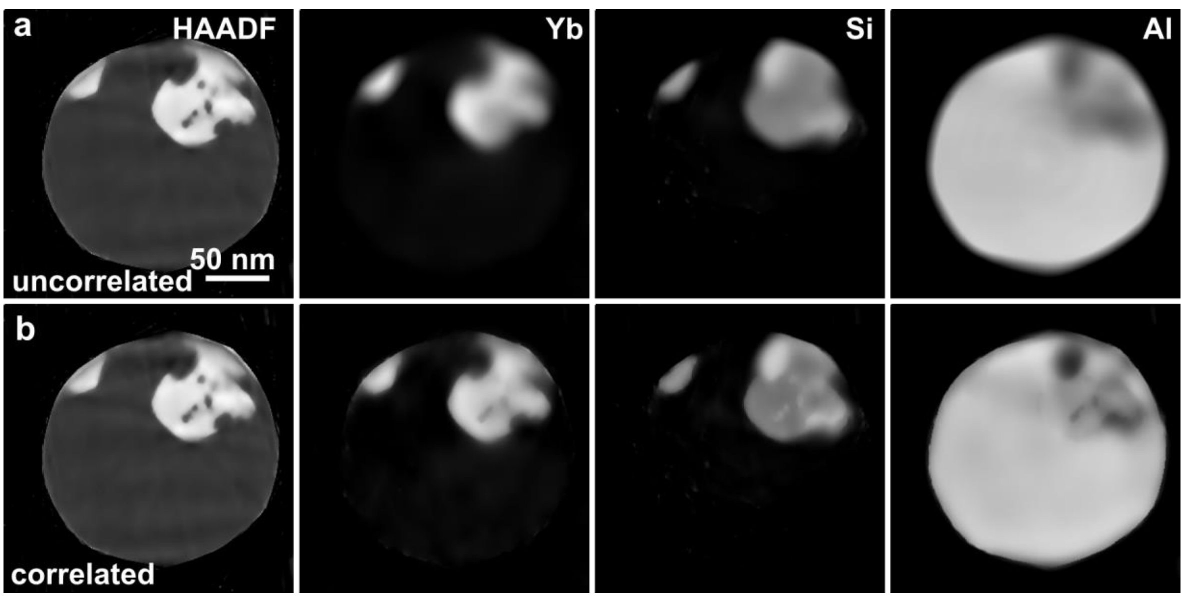


Fig. 2 Slice through (a) an uncorrelated and (b) a joint reconstruction of the HAADF STEM signal and EDXS elemental maps for Ytterbium, Silicon and Aluminum.