Advanced reconstruction algorithms for electron tomography: from comparison to combination

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During the last decade, electron tomography has evolved into a standard technique for 3D characterization in material science. The reconstruction of a 3D volume out of its 2D projections is typically carried out using a weighted backprojection (WBP) or an iterative reconstruction algorithm. The simultaneous iterative reconstruction technique (SIRT) is nowadays widely used. However, it is known that a 3D reconstruction obtained by SIRT might suffer from so-called “missing wedge” artefacts whenever projections from a full tilt range cannot be acquired. Recently, several alternative reconstruction algorithms have been developed that reduce these artefacts. These algorithms exploit additional knowledge about the original object during the reconstruction.

The discrete algebraic reconstruction technique (DART) uses prior knowledge concerning the discrete number of grey levels of the reconstructed object [1,2]. Beside reduction of artefacts, this algorithm has the additional advantage that segmentation is already carried out during the reconstruction, leading to a more straightforward quantification of the reconstruction. A different kind of prior knowledge is exploited when using total variation minimization (TVM) based reconstruction algorithms [3,4]. Here, it is assumed that the object that needs to be reconstructed has a sparse gradient at the nanometer scale. This is a useful assumption because, for objects at the nanoscale, it is often valid to assume that boundaries between different compounds are sharp, leading to a sparse gradient of the object. During the reconstruction algorithm, a regularization parameter $\mu$ is used that determines the sparsity of the final reconstruction:

$$\hat{x} = \arg\min_x \left[ TV(x) + \frac{\mu}{2} \|Ax - b\|^2_2 \right]$$

In this minimization, $x$ represents the reconstructed object, the matrix $A$ corresponds to the projection matrix and the vector $b$ to the measured projections. For comparison, a SIRT, TVM and DART reconstruction of a cluster of PbSe/CdSe core/shell particles, are presented in figure 1 [5]. Missing wedge artefacts that are present in the SIRT reconstruction, are reduced both in the TVM and the DART reconstruction, but the DART reconstruction has the advantage that the result is already segmented. However, a correct estimation of the grey levels is required for the DART reconstruction. This estimate can be conveniently acquired from the grey level histogram of a TVM reconstruction. As can be seen from figure 2, it is impossible to determine the correct grey levels using the histograms of the SIRT reconstruction. On the other hand, this SIRT reconstruction can be used to estimate the regularization parameter $\mu$, required for TVM. The resulting grey level histogram of the TVM reconstruction yields the correct grey levels that are needed as an input for a DART reconstruction. This approach is illustrated by the flowchart in figure 2d. [6]

References

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Figure 1. Visualizations of reconstructions of cluster of core/shell nanoparticles with an average diameter of 9 nm. Figures a, b and c show a 3D rendering of the SIRT, TVM and DART reconstructions respectively. Slices through the SIRT reconstruction (d and g) show an elongation in the direction of the missing wedge. This elongation is reduced in both the slices through the TVM (e and h) and the DART (f and i) reconstructions.

Figure 2. Grey level histograms of the SIRT (a), TVM (b) and DART (c) reconstruction and (d) flowchart of tomographic reconstruction algorithms. This scheme indicates that the result of one reconstruction algorithm can provide the required input for the following reconstruction.