Reconstruction methods for combined HAADF-STEM and EDS tomography

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Propositions accompanying the thesis

"Reconstruction Methods for Combined HAADF-STEM and EDS Tomography"

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1. Under the thin-film assumption, a HAADF-STEM projection image of an electron microscopy sample can be modeled as a weighted sum of the linear projection of all chemical elements:

$$\mathbf{p}^h = \sum_{e=1}^{k} z^e \mathbf{W}\mathbf{x}^e. \tag{1}$$

The EDS projection image for a specific element e can then be modeled as:

$$\mathbf{p}^e = \zeta^e \mathbf{W}\, \mathbf{x}^e. \tag{2}$$

Based on these models, it is possible to compute element-specific reconstructions from the HAADF-STEM and EDS projection images simultaneously. For the definition of these symbols, refer to Equation 2.3 and Equation 2.5.

(Chapter 2)

2. Prior knowledge about common edges between the EDS and HAADF-STEM volumes can be exploited in the reconstruction algorithm using total nuclear variation (TNV) regularization. By regularizing the reconstruction problem using TNV, parallel and anti-parallel gradients of the two images are prioritized.

(Chapter 3)

3. Applying sophisticated tomographic reconstruction algorithms can compensate for certain limitations of the available data. Each such algorithm typically addresses only one particular aspect of the reconstruction problem. By combining multiple algorithms in one reconstruction process, it is possible to address the limitations in a more comprehensive manner.

(Chapter 4)

4. The nonlinear damping effect in HAADF-STEM data can be modeled by an exponential relationship (see Eq.5.2 in Chapter 5). Assuming that the sample has a small number of uniform materials, the parameters of the exponential relationship can be determined by minimizing the following objective function:

$$\mathscr{C}(I_0, p_b, \boldsymbol{\mu}, \mathbf{S}) = \| \mathbf{p} - I_0(1 - \exp(-\mathbf{W}\sum_{e=1}^{k} \mu_e \mathbf{s}_e)) - p_b \|_2^2 . \quad (3)$$

   For the definition of these symbols, refer to Equation 5.4.

   (Chapter 5)

5. The approaches for combining HAADF-STEM and EDS tomography presented in this thesis can be adapted to work with a combination of HAADF-STEM and Electron Energy Loss Spectroscopy (EELS) data in a straightforward manner, as EELS also yields projection images that are element-specific.

6. Combining the HAADF-STEM and EDS imaging modalities can also be performed by fusing the HAADF-STEM and EDS reconstruction images in a post-processing step. The advantage of combining the modalities in the reconstruction step is that the result is optimized for consistency with the measured microscopy data.

7. The quality of tomography images may be enhanced by either improving the quality the projection data, or using advanced reconstruction algorithms. Optimal results are only obtained if both aspects are jointly optimized.

8. Tuning the parameters of tomographic reconstruction algorithms often relies on subjectively observing the reconstruction results for different parameter values. The difficulty of parameter tuning is one of the major limitations of many advanced reconstruction algorithms.

9. When writing a scientific article, a pitfall is to neglect explaining assumptions that are known to the authors but not obvious to readers with different backgrounds.

10. Exploring scientific interests can facilitate developing new industrial technologies. Publishing and applying research results are both important for the success of a research project.