Application of Missing Wedge Inpainting in Material Science

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Tilt-based electron tomography volumes are reconstructed based on acquired projections from different directions. A limited number of projections leads to elongation artifacts along the electron beam direction in the reconstructions, called missing wedge artifacts, which are also visible as a missing wedge in the Fourier domain. Such errors impede meaningful and correct interpretations of investigated samples. We proposed to use exemplar-based inpainting [1] known from image processing for restoration tasks. As a proof-of-concept we applied our method to an artificial dataset and showed its applicability [2]. Now, we collected a real dataset to validate the use of our method in a real world setup [3].

The powder of the 1 wt.% Au/TiO_2 catalyst was directly dispersed on copper grid with carbon support film. A FEI Titan 80-300 microscope operated at an acceleration voltage of 300 kV in STEM mode was used to acquire the projections. We took projections from -76° to 76°. For evaluation purposes we used the projections from -62° to 62° as incomplete dataset. The remaining projections were used for comparing inpainting results against ground truth, as depicted in Figure 1.

We assessed reconstruction quality with the full-width at half-maximum (FWHM) of the point spread function based on all colloidal gold particles contained in the dataset, which provides a measure for particles sizes. FWHM of the reconstruction from the incomplete dataset was 11.2±3.5 pixels, whereas FWHM of the reconstructed particles based on the inpainted dataset was 9.9±2.6 pixels. A paired two-tailed t-test was conducted to ensure statistical significance (p-value = $3 \cdot 10^{-5}$). A comparison of some reconstructed particles is shown in Figure 2. Furthermore, we measured the average particle size based on the projection at 0°, which delivers the real sizes of the particles as 8.8±2.6 pixels. The approximated particles sizes with FWHM of the inpainted data reconstruction were closer to the real sizes, which indicates the practical usefulness of our approach.

Our method acts as preprocessing before a subsequent tomographic reconstruction and helps to reduce elongation artifacts along the xz-direction. Main concern of this preprocessing are performance limitations and the introduction of other artifacts, which must be kept in mind when applying the method. However, comparing the original reconstructions of the incomplete data and the inpainted reconstructions should help to prevent wrong conclusions due to introduced artifacts. Maybe it is even possible to fuse the two reconstructions as kind of a regularization.

The conducted experiments show that out method worked well for datasets with small equidistant tilt angle steps of around 1° and a tilt range that includes at least -60° to 60° projections. Further research has to be performed to improve runtime performance on bigger datasets and to get a better understanding of the influence of inpainted projections on reconstructed volumes [4].

References:

[1] A Criminisi et al., IEEE Transaction on Image Processing **13** (2004), p. 1200.
[2] P Trampert et al., Microscopy and Microanalysis **22** (2016), p. 554.
[3] P Trampert et al., Ultramicroscopy **191** (2018), p. 1.
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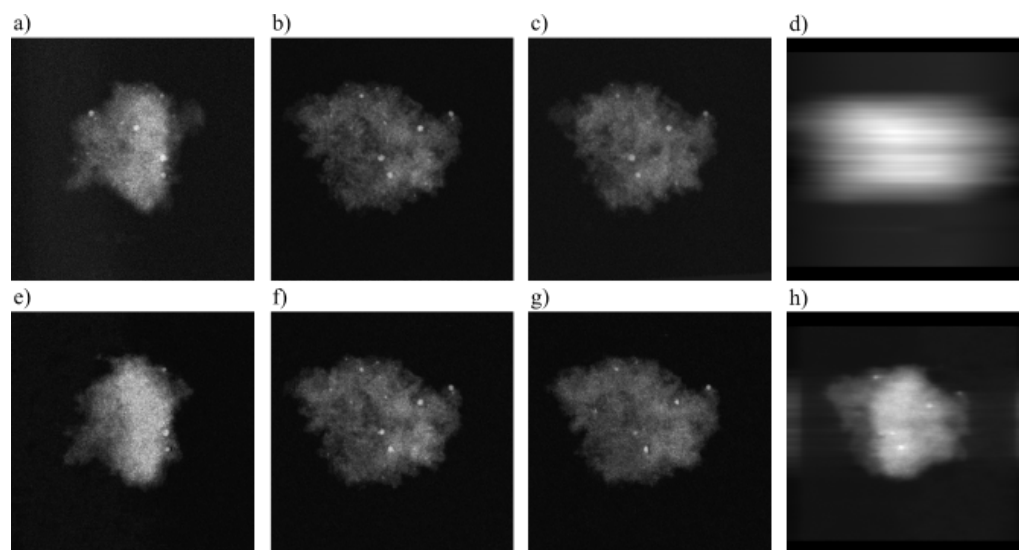
Figure 1. Depicted are projections at angles a),e) 76°, b),f) -63°, c),g) -70°, and d),h) -90°. The upper row shows original projections from the catalyst data. The lower row shows artificial projections that were generated by exemplar-based inpainting. The projections at -90° are based on virtual projections from reconstructions from the incomplete data (d) and from the inpainted data (h).
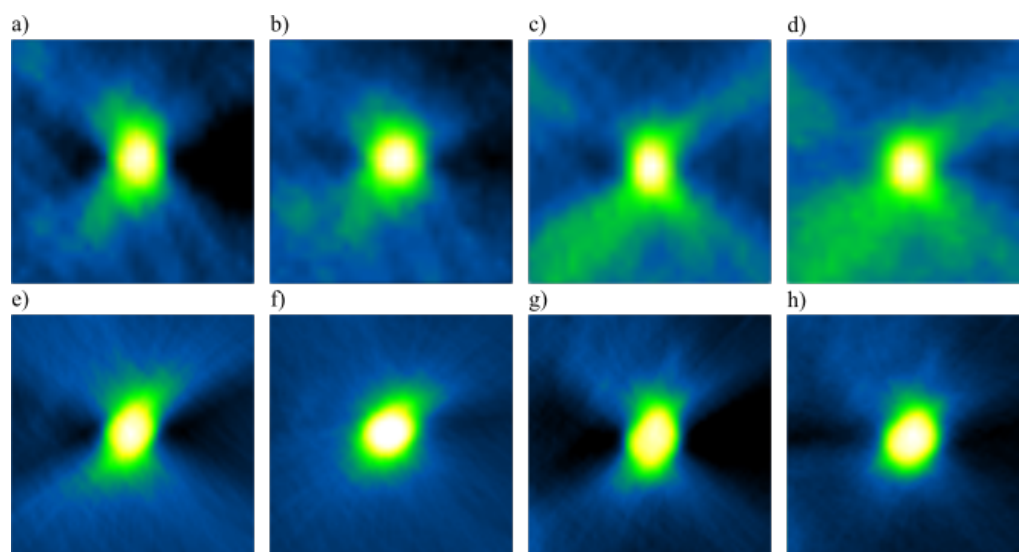
Figure 2. Comparison of reconstructed particles. The upper row shows reconstructions from the incomplete data. The lower row shows corresponding particle reconstructions from the inpainted dataset.