Deep Neural Network for Iterative Image Reconstruction with Application to Fast Environmental Transmission Electron Tomography

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Image reconstruction in electron tomography (ET) is considered as an ill-posed inverse problem due to missing wedge; hence, reconstructed volumes suffer from severe artifacts when using classical reconstruction algorithms. Recently, reconstruction algorithms based on compressive sensing (CS) have been used in ET to reduce missing wedge artifacts. Although CS-based methods suppress artifacts and can highly improve image quality in many cases, they have high computational cost and face the challenge of choosing best tuning parameters.

In recent years, the field of machine learning has gained a lot of attention to solve inverse problems. Deep learning based methods for image reconstruction from limited data have been explored recently [1] and achieved state-of-the art performance with high computational speed [2]. Most of these techniques are based on first using filtered-back projection (FBP) method for fast reconstruction of low quality images and then training a neural network to correct the obtained artifacts. An alternative network named Neural Network-Filtered Backprojection (NN-FBP) [1] has been developed to deal with limited-view computed tomography (CT). This high-efficient approach can be viewed as a sum of several FBP operations with custom filters that are learned in the neural network. NN-FBP was applied in electron tomography to study the 3D shape of nanoparticles [3]. The obtained results showed improvements over SIRT algorithm. Another approach to solve ill-posed inverse problems is to unroll the iterative optimization algorithm into the neural network architecture. A recent work has made progress in this direction by a partially learned gradient descent that improves tomographic reconstruction quality [4].

Inspired by [4] and based on FISTA-TV [5] that is an optimization algorithm for tomographic reconstruction with Total Variation (TV) regularization, we propose here reformulating FISTA-TV to a deep neural network. In other words, this learned iterative scheme is similar to classical TV regularization, but uses a deep neural network that is trained (on data) to find an optimal set of parameters in each iteration for a best update of the image. There are two advantages of this learned scheme: i) faster convergence and thus reduced time complexity and ii) better accuracy where the network is trained to minimize the mean square error of reconstruction.

We apply our proposed approach to fast environmental transmission electron tomography. In this context, a tilt series was acquired on a catalytic system studied under environmental gas and high temperature conditions. A rapid continuous rotation of the goniometer was performed to highly accelerate the data acquisition and images were recorded with the Gatan Oneview camera in the 2K x 2K binning mode at 100 fps installed on an environmental transmission electron microscope (ETEM) Titan 80-300 KeV. Due to the fast rotation of the sample, noise and motion blur effects occur in many projections. However, we have showed in another study that TV-regularization is robust to noisy and blurred data. Therefore, we aim to validate the improved reconstruction results and better performance of our proposed deep neural network using these experimental data.

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