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Non-local Prior Modeling for Tomographic Reconstruction of Bright Field Transmission Electron Microscopy Images.

Suhas Sreehari[1], S. V. Venkatakrishnan[2], Jeffrey P. Simmons[3], Lawrence F. Drummy[3] and Charles A. Bouman[1].

[1.] Electrical and Computer Engineering, Purdue University, West Lafayette, IN, USA.
[2.] Lawrence Berkeley National Laboratory, Berkeley, CA, USA.
[3.] Air Force Research Laboratory, Dayton, OH, USA.

Many important imaging problems in materials and biological sciences involve reconstruction of images that contain several repeating non-local structures. The presence of similar/identical particles or structures in images gives rise to enormous redundancy. Model-based iterative reconstruction (MBIR) is a powerful reconstruction framework that could – in principle – exploit such redundancies [1]. This is normally done through the selection of a log prior probability term that is part of the cost function used to compute the maximum a posteriori (MAP) estimate of the unknown. However, in practice, determining such a log prior probability term that accounts for the similarity between non-local particles or structures in the image is quite a challenging task. The open question of how to capture this non-local redundancy brings our attention to the advances made in the area of denoising algorithms. Non-local, patch-based denoising algorithms like BM3D and non-local means (NLM) are known to capture non-local similarities in images. However, since these denoising algorithms are not explicitly formulated as solutions to optimization problems, it is unclear as to how to use them in the MBIR framework.

In this paper, we formulate a solution to the tomographic reconstruction of bright field transmission electron microscopy (TEM) images. Bright field electron tomography has a reliable solution within the MBIR framework [2], however it does not support non-local prior modeling. To open up MBIR to advanced prior modeling techniques, we make use of a novel framework we call "plug&play priors" [3]. The plug&play technique is an application of the alternating directions method of multipliers (ADMM) [4], wherein we split the state variable into two variables, and solve two smaller optimization problems with the additional constraint that the two split variables be equal to each other. In doing so, plug&play effectively decouples the log likelihood term (based on the data) from the log prior probability term. We then define two operators – the inversion operator (based just on the data) and the denoising operator (based just on the prior model) – that are applied sequentially until convergence. We specifically use 3D non-local means (NLM) as the prior model in the plug&play framework, and we showcase high quality tomographic reconstructions of two real datasets of aluminum spheres and ferritin structures. In all the results, we observe that smear artifacts are visibly suppressed, and that edges are preserved. NLM-based reconstructions are also sharper than reconstructions that use the standard qGGMRF [1] as prior model [5].

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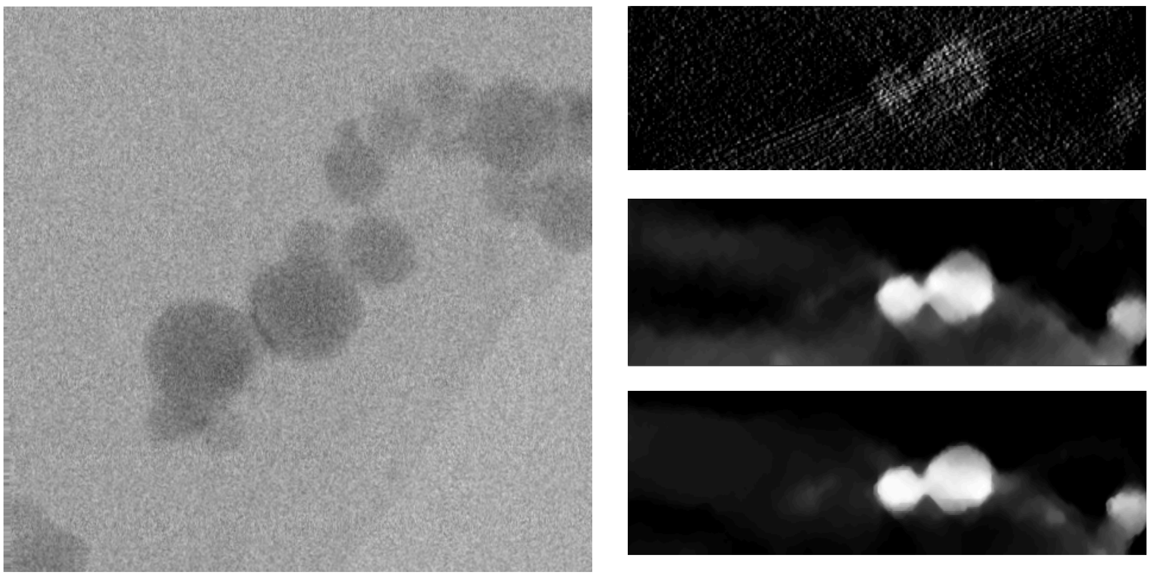

Figure 1. (Clockwise from left) 0° tilt of the aluminum spheres bright field dataset; filtered backprojection reconstruction; qGGMRF reconstruction; 3D NLM reconstruction – all of slice #307 of the dataset.

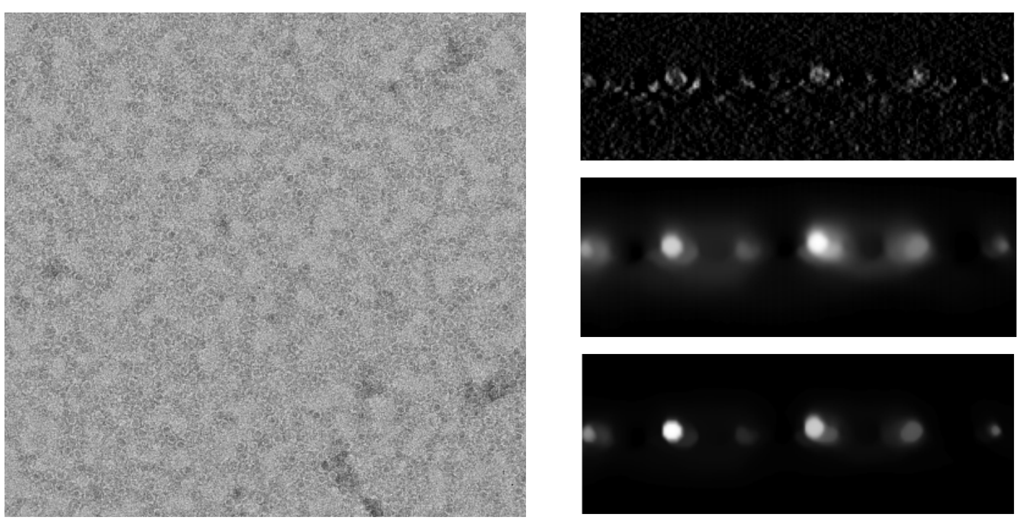

Figure 2. (Clockwise from left) Contrast-stretched version of the 0° tilt of the ferritin structures bright field dataset; filtered backprojection reconstruction; qGGMRF reconstruction; 3D NLM reconstruction – all of slice #1149 of the dataset.