TomoGAN: Low-Dose X-Ray Tomography with Generative Adversarial Networks

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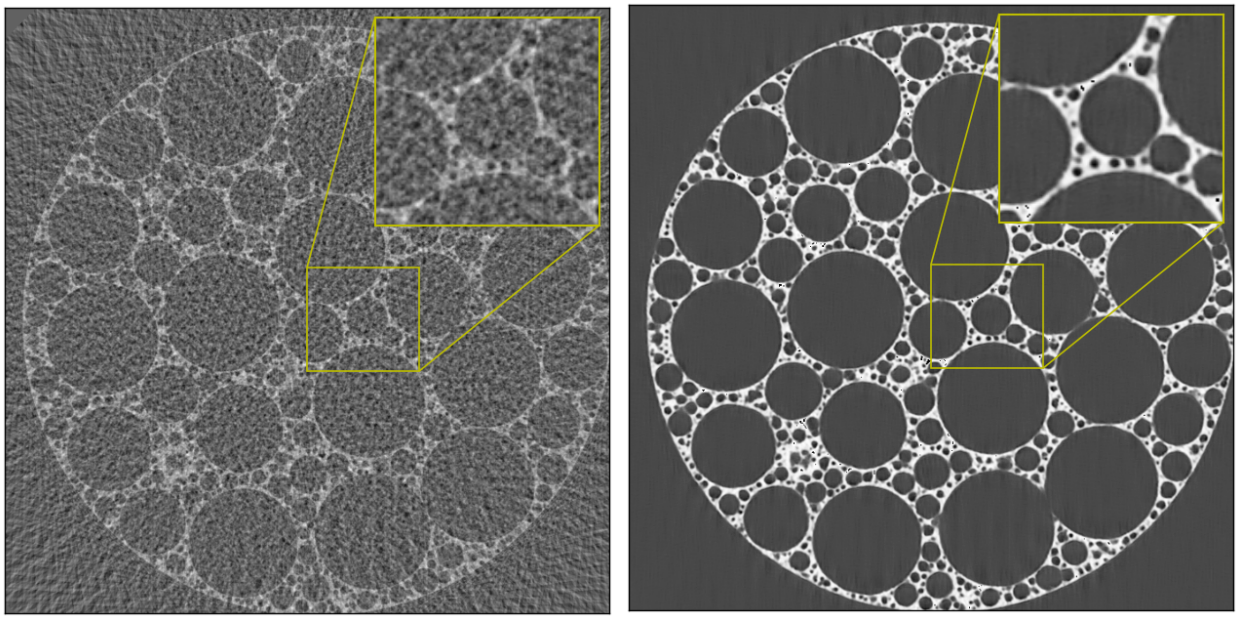
Abstract: Synchrotron-based x-ray tomography is a noninvasive imaging technique that allows for reconstructing the internal structure of materials at high spatial resolutions. Here we present TomoGAN, a novel denoising technique based on generative adversarial networks, for improving the quality of reconstructed images for low-dose imaging conditions, as at smaller length scales where higher radiation doses are required to resolve sample features. Our trained model, unlike other machine-learning-based solutions, is generic: it can be applied to many datasets collected at varying experimental conditions. We evaluate our approach in two photon-budget-limited experimental conditions: (1) sufficient number of low-dose projections (based on Nyquist sampling), and (2) insufficient or limited number of high-dose projections. In both cases, angular sampling is assumed to be isotropic, and the photon budget throughout the experiment is fixed based on the maximum allowable radiation dose. Evaluation with both simulated and experimental datasets shows that our approach can reduce noise in reconstructed images significantly, improving the structural similarity score for simulation and experimental data with ground truth from 0.18 to 0.9 and from 0.18 to 0.41, respectively. Furthermore, the quality of the reconstructed images with filtered back projection followed by our denoising approach exceeds that of reconstructions with simultaneous iterative reconstruction.



Two different reconstructions of a noisy simulated dataset, constructed by subsampling 64 projections from a 1,024-projection simulated dataset containing foam features in a 3D volume. On the left, the results of conventional reconstruction, which are highly noisy. On the right, those same results after denoising with TomoGAN; the features are much more visible. In these images and others that follow, an inset shows details of a representative feature.

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