Using deep learning to reduce the radiation damage induced by X-ray microscopy

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During the last decade, the new generation synchrotron facilities with ultra-high brilliance x-ray sources have enabled 3D imaging at the nanoscale [1]. However, the radiation damage is the limiting factor for imaging biological tissues and dose-sensitive materials at nanoscales. There is an inherent trade-off between signal-to-noise ratio (SNR) and beam damage when imaging at the nanoscale, because of the radiation dose absorbed by the sample scales inversely with the resolution. It is often challenging to improve the quality of the X-ray images by optimizing the scan setup, and sometimes is far beyond the capability for current hardware. Computational methods are good options to address these problems. Traditional image post-processing has limited use for most of the X-ray imaging applications, because of the high complexity and variability of the structural features in samples. The deep convolutional neural network (CNN), which is a feature-based image analyzing method [2], is an alternative to traditional methods. It has great potential to appropriately model complex imaging problems, as we recently demonstrated, e.g. for accurate calibration of X-ray imaging techniques [3].

We will present a CNN method for enhancing low-dose images collected from a small number of high-dose measurements. We validated our methods on measurements acquired at the transmission X-ray microscopy instrument at the 32-ID beamline of Advanced Photon Source [4]. Short-exposure-time projections that were enhanced with CNN showed SNR comparable to long-exposure-time projections. They also showed improved noise suppression and more structural information in reconstructions than conventional acquisitions followed-by a post-processing step for image enhancement. We evaluated this approach using simulated samples and further validated it with experimental tomography data from a radiation sensitive mouse brain. It reduced the total exposure time by more than 10-folds without compromising image quality. We demonstrated that automated algorithms can reliably trace brain structures, such as vessels or neuronal tracts, in this low-dose setting with CNN. With the same principle, the proposed method was also evaluated for low-dose imaging of biological cells using X-ray fluorescence microscopy measurements.

References

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