Deep learning for advanced 3D and 4D X-ray image reconstruction

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The rapid development of high-brilliance X-ray sources, including diffraction-limited storage rings and X-ray free-electron lasers, is enabling X-ray imaging at unprecedented spatial and temporal resolution. At the same time, these facilities generate increasingly large, high-dimensional, and often highly undersampled datasets, creating major challenges for image reconstruction, analysis, and real-time data processing. Recent advances in artificial intelligence and deep learning are opening new opportunities to address these challenges and to fully exploit the capabilities of next-generation X-ray sources.

In this talk, I will provide an introduction to deep learning and its growing role in X-ray imaging, with a special focus on 3D/4D X-ray image reconstruction. I will first present an overview of modern neural network architectures, ranging from simple multilayer perceptrons and convolutional neural networks to advanced frameworks for 3D and 4D image reconstruction, and outline how these approaches address imaging problems across different spatial and temporal dimensions. Then, I will focus on physics-informed and self-supervised learning methods developed for sparse-view 3D/4D reconstruction in X-ray Multi-Projection Imaging (XMPI) [1–5]. By integrating physical imaging models with data-driven priors, these methods enable high-quality reconstructions from sparse, noisy, and limited-angle measurements while reducing acquisition requirements. We will also discuss the practical trade-offs encountered in real-world implementations and demonstrate how learning-based methods offer the potential to explore and understand the structure and dynamics of various samples.

References

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