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Deep Generative Phase Reconstruction for X-Ray Holography

Recovering phase information from intensity-only measurements is a central challenge in many imaging modalities, including coherent diffraction imaging, lensless X-ray holography, and medical imaging. Accurate phase retrieval is essential for reconstructing the underlying structure of samples in these fields, but traditional methods often rely on iterative solvers with strong prior assumptions, sensitivity to noise, and significant computational costs. These limitations hinder scalability and robustness, particularly in high-throughput experimental settings.

We present a machine learning-based approach for fast and accurate phase imaging using Conditional Wavelet Flow (cWF), a deep generative model built on normalizing flows. cWF learns a multiscale representation of complex-valued phase information from intensity-only measurements, effectively capturing both fine and global structures without requiring iterative refinement. The wavelet-based architecture allows for efficient memory usage and parallelized training on high-resolution data.
To assess cWF's applicability in real-world imaging pipelines, we evaluate its performance against standard and deep learning-based phase retrieval methods. Reconstruction quality is assessed based on accuracy, inference time, robustness to noise, and generalization across diverse imaging conditions.

Our results on near-field X-ray holography datasets demonstrate that cWF produces accurate, high-resolution phase reconstructions at a fraction of the computational cost. This work highlights the potential of deep generative models for accelerating and improving phase imaging, while also providing a structured evaluation framework for their integration into imaging pipelines.

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