

Structured Loss Amplification for U-Net-based Dark-field CT Noise and Streak Reduction

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I. INTRODUCTION

Streak artifacts remain a substantial challenge for the clinical translation of human-scale dark-field computed tomography (DFCT) [1]. Supervised learning approaches using U-Nets have shown promise in artifact suppression, but typically do not incorporate domain-specific information into the training objective [2]. In this work, we introduce a structured loss formulation encoding prior knowledge by selectively amplifying relevant pixel regions for noise and streak reduction.

II. METHODS

A conventional 2D U-Net was trained on axial DFCT slices, whereby higher-quality multi-rotation reconstructions served as ground truth (GT). Structured amplification consisted in boosting individual pixels of the loss map (squared error between prediction and GT) with purposefully designed weights in real and frequency space, penalizing discrepancies in central image regions and fine structural details, respectively. Amplification strategies were analyzed systematically with an ablation study. Performance was quantified via median contrast-to-noise ratio (CNR) and full-width-at-half-maximum (FWHM) of the line spread function at the air-tissue interface across test predictions from ten trained models for each configuration.

III. RESULTS AND CONCLUSION

Using amplified U-Nets, image quality is notably enhanced, mitigating residual noise and streaks that are still visible in the baseline model prediction (trained with the unmodified L_2 loss), as shown in Fig. 1. Spatio-frequency amplification enhances CNR by 33% ($\text{CNR} = 2.52 \pm 0.37$, $n = 10$) compared to baseline ($\text{CNR} = 1.89 \pm 0.58$) at similar image resolution. Additionally, variance is reduced across repeated trainings, suggesting improved robustness of the amplified models. These results demonstrate the utility of structured

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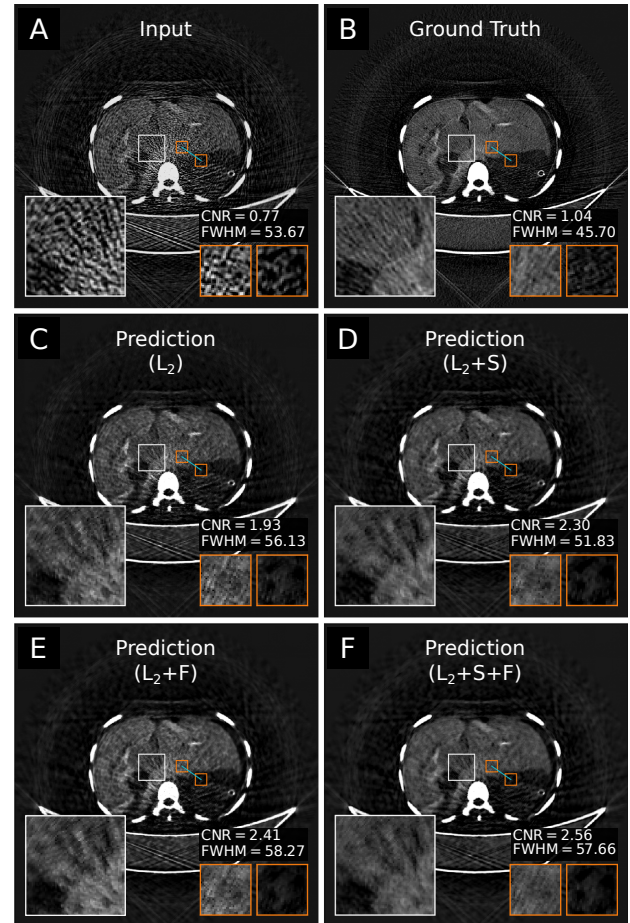


Fig. 1. Impact of structured loss amplification on U-Net-based DFCT noise and streak reduction for a test slice of ventilated ex vivo porcine lungs inside of a thorax phantom. The inset highlights details within an artifact-prone region. Inference tested on a single-rotation slice (A). Multi-rotation reconstruction of the same slice shown as GT reference (B). Predictions retrieved using the baseline (C), spatially amplified (D), frequency-amplified (E), and combined spatio-frequency-amplified model (F). Out of each set ($n = 10$) of model predictions per configuration, we show the one closest in CNR to the respective set median. Regions of interest (orange) and line profiles (cyan) for CNR and FWHM computation are indicated.

loss amplification to achieve substantially improved noise and streak suppression in human-scale DFCT.

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