Streak Artifact Reduction in Human-scale Dark-field CT Using 3D Gaussian Splatting

Objective – Functional imaging of the lung is enabled by measuring small-angle scattering at tissue interfaces using X-ray dark-field computed tomography (DFCT). However, image quality is typically limited by hardware constraints inherent to the setup. We propose a post-processing method based on the 3D Gaussian Splatting (3DGS) [2] method to improve DFCT image quality.

Motivation & Background – The clinical DFCT scanner enables attenuation- and small-angle scatter-based imaging of human-scale phantoms. Due to the scanner's vibrating Talbot-Lau grating interferometer, images suffer from inherent streak artifacts [1]. In this work, DFCT data is processed by re-purposing the 3DGS method, designed for rendering sparsely sampled X-ray attenuation data [2], and is compared against conventional filtering.

Methods – A ventilated ex vivo porcine lung sample placed inside an anthropomorphic Lungman phantom (Kyoto Kagaku, Tokyo, Japan), measured at 20 randomly selected table positions, and reconstructed with the filtered back-projection algorithm at the clinical DFCT setup [1] was utilized. Gaussian, bilateral, and total variation (TV) filters, and the re-purposed 3DGS model from [2] were explored for post-processing DFCT data. For each conventional filter, the hyperparameters were optimized via grid search, maximizing the structural similarity index between 3DGS and the filtered image on a global image-level. The contrast-to-noise ratio (CNR) and the full-width-at-half-maximum (FWHM) of manually-selected 20 × 20 pixel regions of lung tissue and air were calculated, as in Fig. 1.

Results – The resulting mean and standard deviation values are: for the reference scan (CNR = 2.44±0.93, FWHM = 40.25±11.32), Gaussian filter (CNR = 4.14±1.48, FWHM = 31.99±16.22), bilateral filter (CNR = 6.44±2.60, FWHM = 23.36±16.33), TV (CNR = 8.09±3.47, FWHM = 15.78±16.21), and 3DGS (CNR = 6.74±2.51, FWHM = 10.06±8.83).

Conclusion – These findings indicate that 3DGS outperforms conventional filtering in DFCT streak-reduction, preserving edge sharpness and a high CNR, a necessity for diagnostic accuracy in future clinical trials.

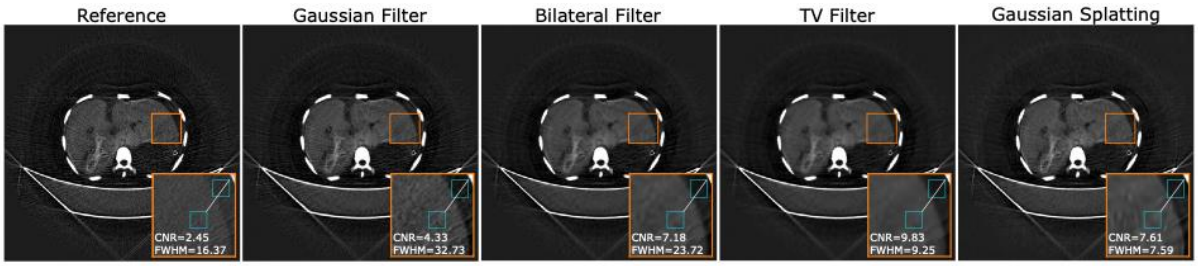

Fig. 1. Example axial DFCT slice, without (reference) and with streak-reduction post-processing. The CNR and FWHM values for the 20 × 20 pixel lung tissue and air regions (blue) are provided. The white line is used for pixel-wise FWHM calculation.

Refrences

[1] M. Viermetz et al., “Dark-field computed tomography reaches the human scale,” *PNAS,* vol. 119, 2022.

[2] R. Zha et al., “R²-gaussian: Rectifying radiative gaussian splatting for tomographic reconstruction,” *Advances in Neural Information Processing Systems*, vol. 37, 2024.