Robust Sparse-view Dark-field CT with 3D Gaussian Splatting

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IEEE ISBI 2026

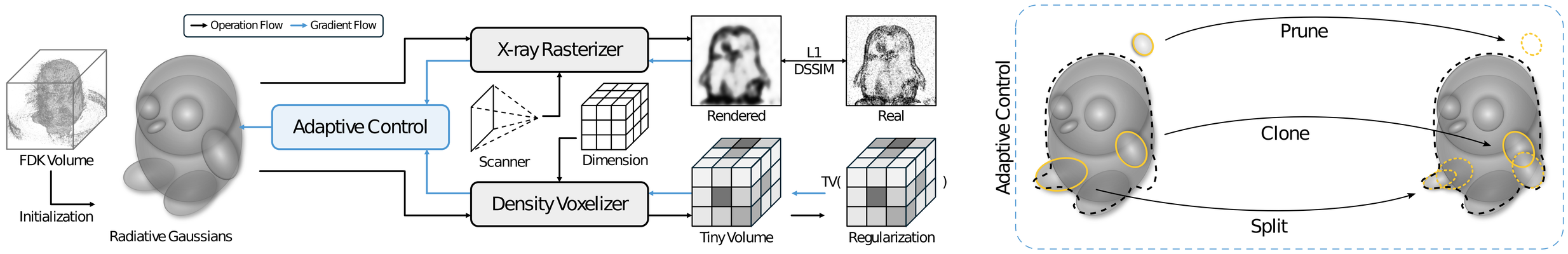
Poster No.

INTRODUCTION

- Streak artifacts constitute a major challenge in X-ray **dark-field computed tomography** (**DFCT**).
- Convolutional neural networks have shown promising results for **streak reduction**, but rely on limited ground truth data [1].
- In contrast to post-processing approaches, this work aims to prevent streak formation at the reconstruction stage using **3D Gaussian splatting** (**3DGS**) [2].

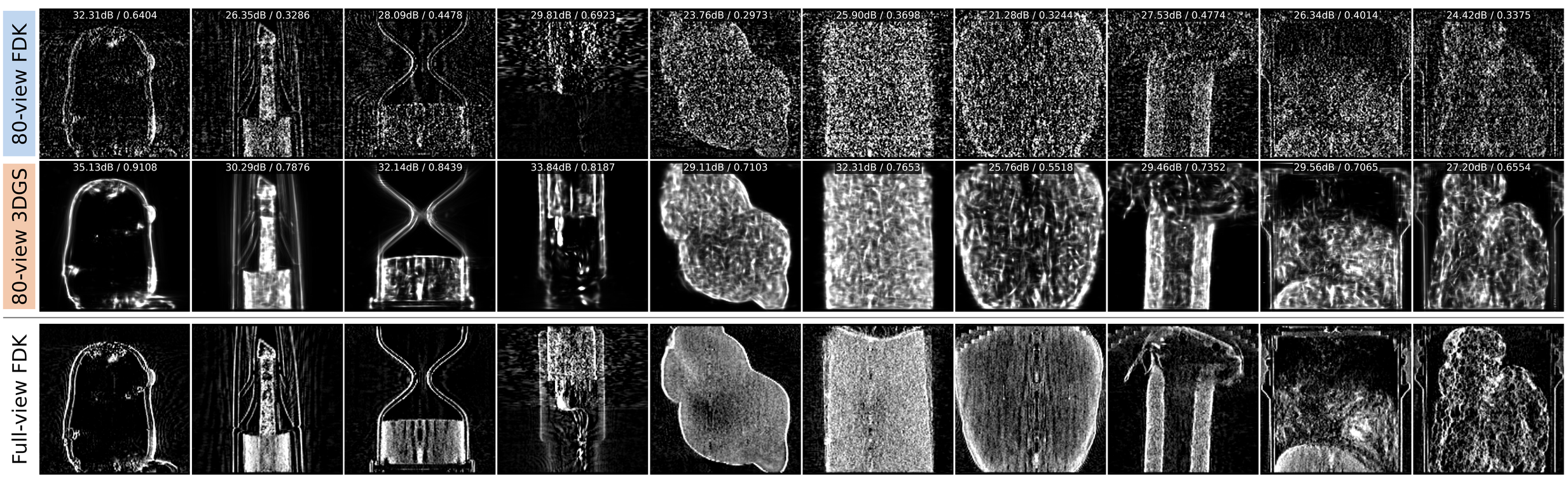
METHODS

- Dataset containing sets of grating-based DFCT projections scanned at varying sparsity levels for $n = 17$ samples.
- Sparse-view reconstruction with 3DGS compared to Feldkamp–Davis–Kress (FDK).
- Evaluation based on 3D Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) with respect to the full-view (2324 projections) FDK reconstruction.



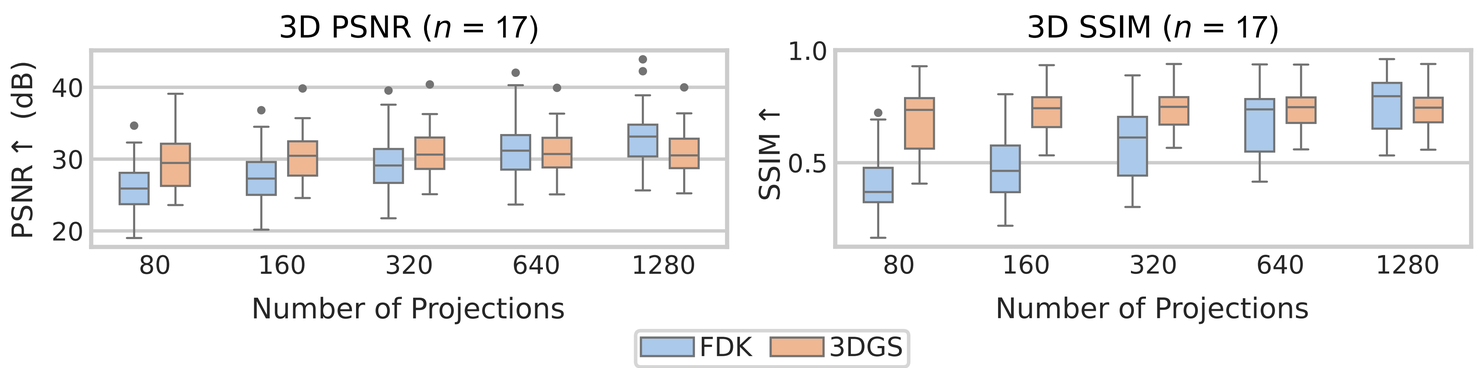
Training pipeline for DFCT reconstruction with 3DGS based on the R^2-Gaussian implementation [2]. Gaussians are initalized by sampling from a preliminary FDK reconstruction. The volume is forward-projected using a view-invariant rasterizer, and loss computed per L1 and structural dissimilarity (DSSIM) relative to the true projection. The voxelized volume is queried efficiently via tiny volumes and regularized with Total Variation (TV). Adaptive control constrains Gaussians to enhance the object representation.

RESULTS



Lateral slice of 80-view reconstructions using FDK and 3DGS, including volumetric PSNR and SSIM values relatve to the full-view FDK as approximate ground truth. Sparse-view FDK suffers from noise and streaks. 3DGS recovers smooth, continuous structures and maintains geometric integrity.

- 3DGS enables robust DFCT reconstruction within minutes suppressing noise and streak artifacts.
- Largest benefit is observed for ultra-sparse conditions and for samples particularly susceptible to thickness- or metal-induced artifacts.
- PSNR and SSIM indicate systematic image quality enhancement across all samples and sparsity levels, saturating for increasing numbers of projections.



3DGS-based DFCT reconstruction yields substantially increased PSNR and SSIM. For larger projection numbers, quantification of image quality is limited by residual imperfections in the full-view FDK reference.

CONCLUSION

- 3DGS demonstrates superior performance for **reconstructing sparse-view DFCT** scans compared to FDK.
- Our findings underscore the potential of 3DGS to **enable streak-free DFCT reconstruction** on a controlled per-instance basis.

REFERENCES

[1] T. Kumschier et al., "Streak artefact removal in x-ray dark-field computed tomography using a convolutional neural network," *Med Phys*, 2024.

[2] R. Zha et al., "R²-gaussian: Rectifying radiative gaussian splatting for tomographic reconstruction," *NeurIPS*, 2024.

ACKNOWLEDGEMENTS

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Financial support through the European Research Council (ERC Synergy Grant SmartX, SyG 101167328), and the Free State of Bavaria under the Excellence Strategy of the Federal Government and the States, as well as by the Technical University of Munich – Institute for Advanced Study.

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Bayerisches Staatsministerium für Wissenschaft und Kunst

Federal Ministry of Education and Research