EPiC Series in Health Sciences
Volume 8, 2026, Pages 143–146
Proceedings of The 25th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Metal Artifact Avoidance: Improved CBCT Image Quality through Tilted C-Arm 3D Scans

Maximilian Rohleder[1,2], Joshua Scheuplein[1,2], Andreas Maier[1], and Björn Kreher[2]

[1] Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
[2] Siemens Healthineers AG, Forchheim, Germany
Maximilian.Rohleder@siemens-healthineers.com

Abstract

Metal artifacts degrade cone-beam computed tomography (CBCT) image quality, particularly in spine surgeries involving pedicle screws. This paper introduces a deep learning-enabled Metal Artifact Avoidance (MAA) workflow that optimizes C-arm trajectories to minimize artifacts during CBCT acquisition. The workflow incorporates real-time visualization for trajectory verification and user adjustment. Evaluations on cadaveric specimens demonstrate that MAA-guided tilted scans reduce artifacts and enhance the visibility of critical anatomical structures compared to standard scans. This approach provides a straightforward solution for achieving task-specific, artifact-minimized imaging in challenging surgical scenarios.

1 Introduction

Intraoperative 3D imaging with cone-beam CT (CBCT) is increasingly used in spine surgery for its ability to improve the assessment of implant positioning, particularly in procedures involving pedicle screw fixation. However, metal implants can severely degrade image quality with artifacts like streaks and distortions, complicating the evaluation of screw positioning [1].

Conventional Metal Artifact Reduction (MAR) methods, such as the fsMAR technique [3], have been effective in reducing minor artifacts but fail in cases with pronounced distortions. Recent studies have demonstrated that modifying the CBCT acquisition trajectory, such as tilting the C-Arm scanner, can enhance image quality and improve clinical assessability in spine surgery [1]. This trajectory optimization approach focuses on acquiring better initial data rather than relying solely on post-processing corrections.

The field of trajectory optimization has seen rapid advancements. A review by Hatamikia et al. [2] outlines state-of-the-art methods, including the scout-view-based approach introduced by Wu et al. [6], which predicts artifact-minimizing trajectories based on metal segmented in coarse reconstructions. Rohleder et al. [5] extend this approach with an interactive system that guides users using visual overlays. Recently, an object-based optimization algorithm was proposed, enabling trajectory predictions for individual objects and computing globally optimal solutions [4].

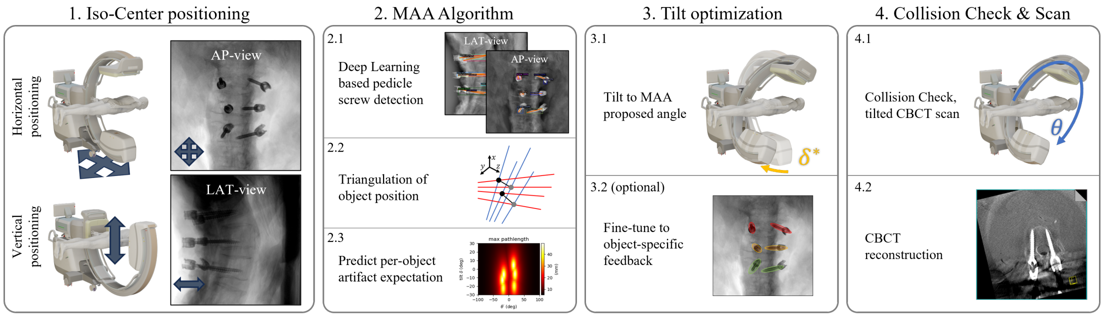

Figure 1: **The MAA workflow.** First, the mobile C-Arm system is positioned relative to the patient. For accurate selection of the volume of interest, at least one anterior-posterior is used for horizontal adjustment, and at least one lateral view is used for vertical fine-positioning (1). Once these so-called scout views are acquired, the MAA algorithm detects metallic objects (2.1), triangulates their 3D position using the calibrated system geometry (2.2) and finally computes object-specific quality predictions for possible tilted scans ranging from $\delta \in [-30°, 30°]$. The tilt angle minimizing artifacts for all detected objects is suggested (2.2), and a detailed overview is shown to allow for procedure specific adaptions. Finally, a collision check is performed and 3D scan is acquired in the tilted gantry position (4.1 & 4.2).

In this study, we build upon these advances by presenting a novel workflow that integrates a deep learning-enabled MAA method. Our contributions include detailing a deep learning-based workflow for artifact avoidance, proposing a visualization scheme for fast trajectory verification and user correction, and demonstrating the method's efficacy through evaluation on cadaver data.

2 Materials and Methods

The proposed MAA-guided 3D imaging workflow (see Figure 1) begins with positioning of the mobile C-Arm system. This is crucial for ensuring the reconstructed volume — 160^3mm — is centered around the anatomical region of interest. First, an anterior-posterior (AP) scout view is acquired for horizontal adjustment of the isocenter, followed by a lateral (LAT) view to align vertically with the anatomy of interest. Internally, we store the most recent LAT and AP views and use them as prior knowledge for trajectory optimization.

The second step involves an object-specific MAA algorithm, which predicts artifact severity for various tilt angles, typically constrained to $\pm 30°$ to avoid collisions with the patient or operating table. Metallic objects are detected in the scout views using a pre-trained Faster R-CNN deep learning model, trained specifically to recognize pedicle screws. Detected screws are parametrically represented by their head and tip keypoints, forming line segments.

The 3D positions of the metallic objects are triangulated from two sets of detected 2D objects and the associated projection matrices. Object correspondence is established geometrically by applying a 5 mm distance threshold between backprojected rays. Modelling each object with an ellipsoidal shape, a predictive artifact metric is calculated based on the X-ray intersection lengths. The predicted artifact severity is adjusted to account for underlying physical phenomena using the spectral shift model described in [6].

As shown in Figure 1, the algorithm determines a globally optimal tilt angle by averaging

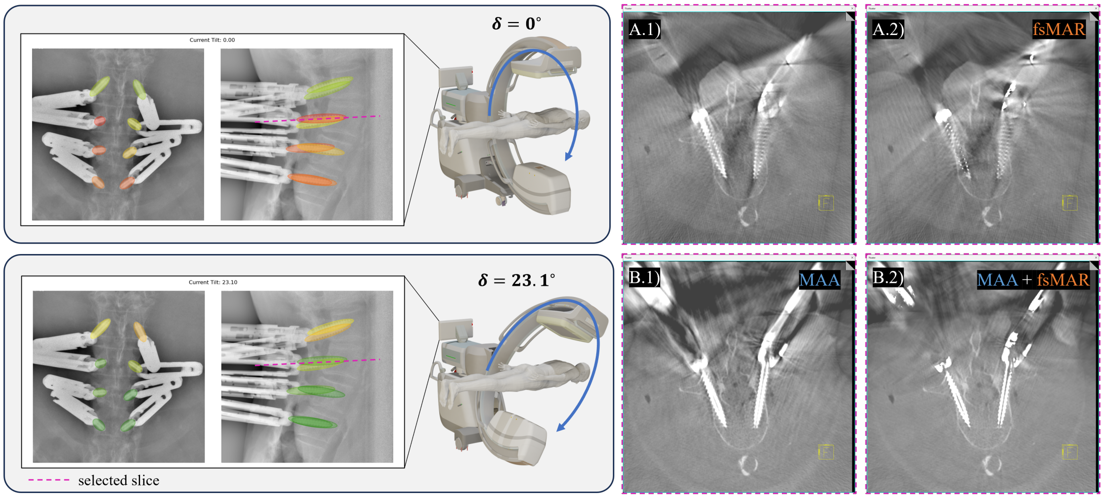

Figure 2: **Qualitative comparison of MAA and MAR effects on image quality.** Top row: standard position (no tilt), unprocessed (A.1) vs. fsMAR-processed (A.2). Bottom row: tilted scan at $\delta = 23.1°$ (determined using MAA), unprocessed (B.1) vs. fsMAR-processed (B.2).

artifact predictions across objects, presenting this to the user through an interactive interface. During manual tilt adjustments, graphical feedback overlays scout views, color-coding objects to indicate artifact severity (green for minimal, red for severe), enabling validation and refinement of the suggested trajectory. After confirming the tilt configuration via collision checks, the final 3D scan is performed and reconstructed.

3 Experimental Results

In this experimental study we seek to demonstrate the magnitude of artifact reduction achievable with the proposed MAA method and compare it with the readily available MAR algorithm on the Cios Spin mobile C-Arm System, Siemens Healthineers, Erlangen, Germany. A cadaveric human specimen is instrumented in the Lumbar spine, vertebrae L1 through L4, with pedicle screws of length 45mm and thickness 6.5mm (L1-L3) and 7.5mm (L4). Scans are acquired in a standard (non-tilted) position and with tilt angles ranging from $-30°$ to $30°$. For comparative analysis, scans were reconstructed with and without MAR post-processing, using the frequency split MAR method [3].

Figure 2 compares the four reconstruction scenarios: standard (non-tilted) and tilted ($\delta = 23.1°$) scans, each processed with and without fsMAR. The standard scan without MAR (A.1) exhibited pronounced streak artifacts and obscured anatomical details around the pedicle screws, hindering the assessment of cortical surfaces and screw placement. Applying fsMAR to the standard scan (A.2) yields little improvement, with the metallic screws remaining distorted and the surrounding anatomy still obscured. These results highlight the limitations of MAR when faced with severe artifacts.

In contrast, the tilted scan selected via MAA guidance significantly reduced artifacts in both unprocessed (B.1) and fsMAR-processed (B.2) reconstructions. The cortical surfaces and pedicle screws were clearly discernible, enabling more reliable clinical assessment of screw stability and potential breaches. Clear improvement with fsMAR in B.2 compared to B.1 is not evident but may be subject to user preference.

4 Discussion and Conclusion

The results demonstrate the efficacy of MAA-guided imaging in visibly improving CBCT image quality in pedicle screw fixation. The proposed method combines automated deep learning-based object detection with user-verified trajectory optimization, providing an intuitive and effective system for artifact avoidance. This explainable AI approach is expected to enhance workflow efficiency while fostering user trust through real-time feedback and verification.

Empirical findings suggest that larger tilt angles generally reduce artifacts in pedicle screw fixation procedures [1], though the extent of improvement depends on implant orientation relative to the scanner [4]. By enabling tailored trajectory adjustments, the MAA workflow aims to balance artifact reduction with practical feasibility, ensuring consistent improvements across varying implant orientations. Future work will focus on validating this approach on larger datasets and integrating it into clinical workflows for broader applicability.

References

[1] M. Fikuart, B. Bullert, S. Y. Vetter, J. Franke, P. A. Gruetzner, and B. Swartman. Effect of the cone-beam ct acquisition trajectory on image quality in spine surgery: experimental cadaver study. *The Spine Journal*, 25:154–164, 1 2025.

[2] S. Hatamikia, A. Biguri, G. Herl, G. Kronreif, T. Reynolds, J. Kettenbach, T. Russ, A. Tersol, A. Maier, M. Figl, J. H. Siewerdsen, and W. Birkfellner. Source-detector trajectory optimization in cone-beam computed tomography: a comprehensive review on today's state-of-the-art. *Phys Med Biol*, 67(16):16TR03, 8 2022.

[3] E. Meyer, R. Raupach, M. Lell, B. Schmidt, and M. Kachelrieß. Frequency split metal artifact reduction (FSMAR) in computed tomography. *Med Phys*, 39(4):1904–1916, 2012.

[4] M. Rohleder, A. Maier, and B. Kreher. Parametric-MAA: Fast, Object-Centric Avoidance of Metal Artifacts for Intraoperative CBCT. *Int J Comput Assist Radiol Surg*, 20(7), 5 2025 (in press).

[5] M. Rohleder, M. Thies, S. Riedl, B. Bullert, J. Gierse, M. Privalov, E. Mandelka, S. Vetter, A. Maier, and B. Kreher. An interactive task-based method for the avoidance of metal artifacts in CBCT. *Int J Comput Assist Radiol Surg*, 19(7):1399–1407, 5 2024.

[6] P. Wu, N. Sheth, A. Sisniega, A. Uneri, R. Han, R. Vijayan, P. Vagdargi, B. Kreher, H. Kunze, G. Kleinszig, S. Vogt, S. F. Lo, N. Theodore, and J. H. Siewerdsen. C-arm orbits for metal artifact avoidance (MAA) in cone-beam CT. *Phys Med Biol*, 65(16), 8 2020.