Real-Time Dynamic 3D CBCT Reconstruction from Two Projections using Latent Information of Past Time Steps

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Abstract

Interventional tools guided by fluoroscopy have limited depth information, but 3D image guidance or 4D interventional guidance can overcome this limitation. An algorithm for the 3D reconstruction of interventional material from only two newly acquired X-ray images was proposed by Vöth et al. [1]. A 3D U-net called the deep tool reconstruction (DTR) transforms backprojections into 3D reconstructions of the interventional material. In this study, we improve the temporal information utilization by providing the reconstructions of previous time steps as additional inputs to the DTR. This leads to an increase in the Dice coefficient from 71.21% to 76.84% on a simulated guidewire dataset.

Purpose

This paper builds on Eulig et al.'s [2] research to enhance the 3D reconstruction of guidewires from X-ray projections. Addressing the limitations of previous methods that demanded extensive technology and incurred higher costs, Vöth et al. [1] refined the approach, reducing hardware requirements and minimizing dose exposure. The focus is on the DTR component, with a novel strategy leveraging backprojections and reconstructions from previous time steps to predict the current 3D reconstruction. The proposed approach aims to surpass prior work through comprehensive experiments by achieving a higher dice similarity coefficient (DSC) and delivering superior reconstruction images. This innovation promises more efficient and cost-effective 3D guidewire reconstruction, marking a significant advancement in the field.

Methods

This paper introduces a novel pipeline for guidewire reconstruction, emphasizing the utilization of temporal information, as depicted in Figure 1. The methodology extends the two-projections-based DTR model [1], aiming to evaluate DTR performance by incorporating the outputs of previous time steps' reconstructions as inputs to the DTR alongside their respective backprojections. Several experiments, employing a similar methodology demonstrate the potential for enhanced guidewire reconstruction. The proposed approach focuses on the DTR task, refining it by integrating reconstructions from previous time steps with backprojection pairs. This task, akin to the two-projections-based DTR algorithm [1], is formulated as a segmentation problem. For a fair comparison, a dataset was generated through simulated forward projections of 40,000 guidewire scenes at 16 time steps, aligning with the parameters of the two-projections-based DTR algorithm [1]. A standard 3D U-Net with five stages was employed for experiments.

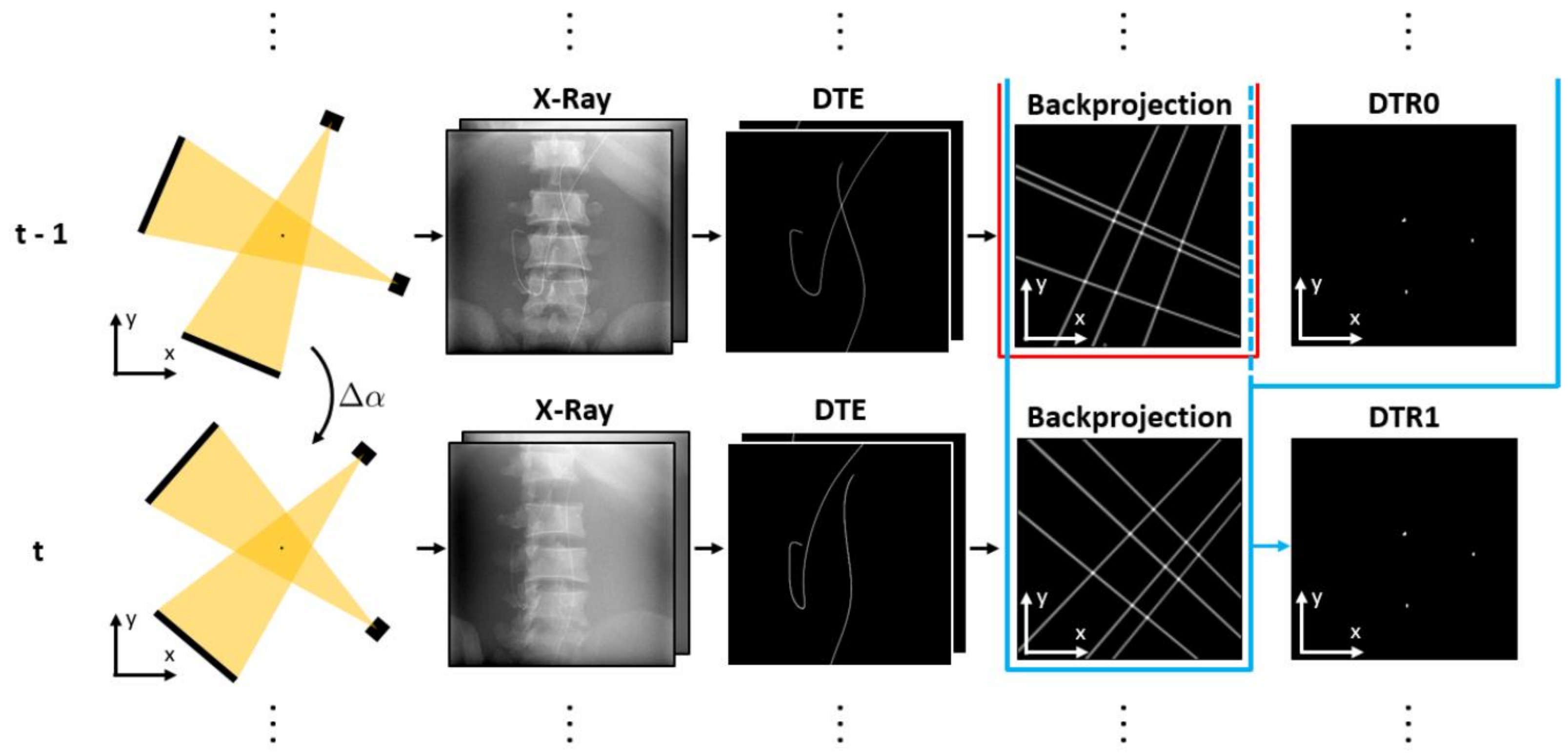

Figure 2: 3D reconstructions that are obtained from different models.

The baseline model's results were reproduced for reference, and three new experiments were conducted, exploring potential improvements in reconstruction accuracy. The DTR+PrevRecons, DTR+PrevOwnRecons, and DTR+PrevGTs models were developed and tested, with detailed methodology and setups provided. This comprehensive analysis aims to advance guidewire reconstruction techniques, offering insights into the efficacy of the proposed approach compared to established methods.

Results

Training baseline and variant models with diverse reconstructions yielded DSC on the test set: 71.21%, 73.28%, 73.69%, 76.84% for baseline, DTR+PrevRecons, DTR+PrevOwnRecons, and DTR+PrevGTs models, respectively. The DSC improvements showcase the significance of incorporating DTR outputs from previous time steps. Evaluation on the unseen test set reaffirms the efficacy of the proposed methodology.

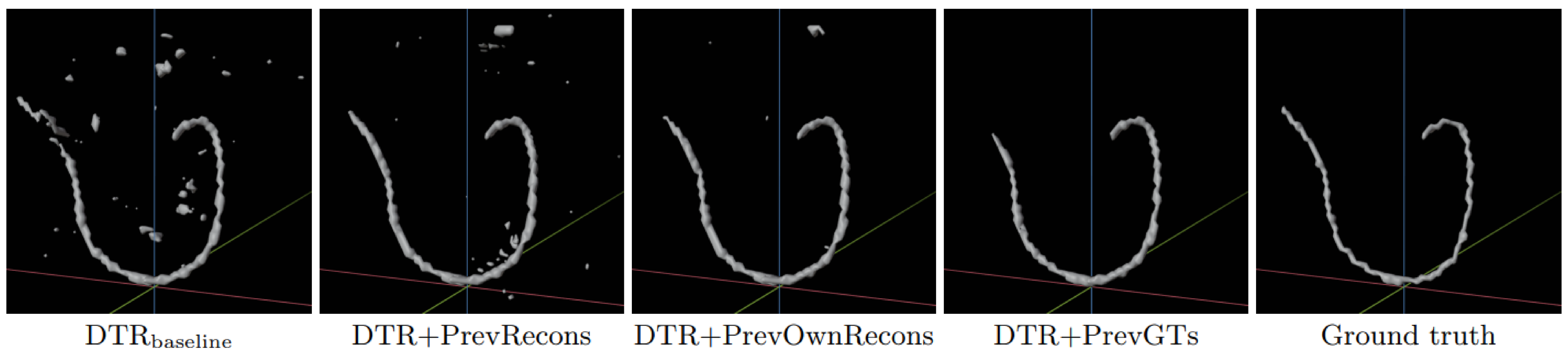

Figure 2: 3D reconstructions that are obtained from different models.

Conclusion

The results highlight the potential for enhanced accuracy and dose efficiency in 3D guidewire reconstruction, contributing to safer and more effective interventional procedures.

[1] Vöth, Kachelrieß et al., Med. Phys., Vol. 50, No. 9, pp. 5312-5330, 2023.
[2] Eulig, Kachelrieß et al., Med. Phys., Vol. 48, No. 10, pp. 5837–5850, 2021.

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