2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

3D Reconstruction of Bone Structure from Multi-View X-Ray Images Using Planar Markers

Pragyan Shrestha, Chun Xie, Hidehiko Shishido, Yuichi Yoshii, Itaru Kitahara

***Abstract*— This paper proposes a method to reconstruct bone structure from multi-view x ray images by estimating camera poses using planar markers. A calibration plane with five embedded fiducial markers is attached to the target object. Projection images are taken by rotating the target object such that the markers remain in the field of view. The pose estimation pipeline followed by simultaneous algebraic reconstruction technique enabled reconstructing the bone structure from the projection images alone. We conduct a C-arm fluoroscopy experiment with a bone phantom for qualitative evaluation of the reconstructed image.**

***Clinical Relevance*— The proposed method focuses on image reconstruction using conventional C-arm fluoroscopy devices. Intra-operative image reconstruction with such devices would be beneficial in terms of initial cost required.**

I. Introduction

Orthopedic surgeries such as osteosynthesis and osteotomies benefit from intra-operative x-ray imaging. A computed tomography (CT) scan prior to the surgery could be used to plan and simulate the fracture reduction, while intra-operative x-ray images are used as guidance for positioning implants or cutting bones during the operation [1]. However, the perception of depth is lost in x-ray images. This work addresses the issue by introducing a pose estimation pipeline for 3D reconstruction in multi view X-ray imaging setting.

II. Proposed Methods

The calibration plane is an acrylic plate of 2mm thickness with five lead fiducials of 5mm diameter embedded in a parallelogram pattern. The markers are identified in each frame of the projection images taken in half circle trajectory. The geometry of acquisition system is computed using homograph decomposition [2]. The final reconstruction method is SART [3]. An overview of the imaging scheme is illustrated in Fig. 1. The method is qualitatively evaluated on real data acquired from a C-arm fluoroscopy of a fractured bone phantom. The phantom is positioned in the middle of a turning chair and rotated slightly over 360 degrees by hand. The resolution of the reconstructed voxel is 512×512×512voxels, 128mm×128mm×128mm in size. The resolution of the projection image is 1024pixel×1024pixel with actual size 21.5 mm×21.5mm.

III. Results

The reprojection error of the marker points was 3.63+/-1.74 pixels. Analyzing the frame wise error, we find forward facing frames to drastically degrade the accuracy of the pose estimation. The reconstructed image and the ground truth image for c-arm acquisition is shown in Fig. 2. While the general shape of the bone can be observed, it remains difficult to extract refined mesh from the volume due to discrepancy in the reconstruction geometry and artefacts due to noise in projection images.

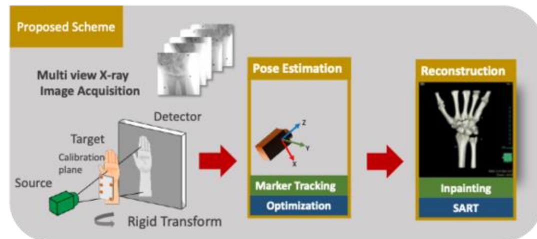

Figure 1. Our proposed scheme for 3D reconstruction of bone structure.

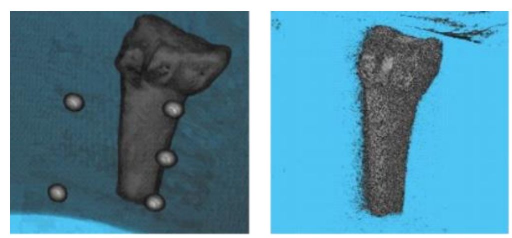

Figure 2. Ground truth phantom (Left) and reconstructed bone (Right).

IV. Discussions&conclusions

The proposed method finds its potential application in intra operative imaging settings. Intra-operative reconstruction scans can be performed with conventional C-arm fluoroscopy devices. It remains future work to improve the reconstruction quality by optimizing the pose estimation as well as adopting sparse tomography techniques.

References

[1] Y. Yoshii, T. Kusakabe, K. Akita, W. L. Tung, and T. Ishii, "Reproducibility of three dimensional digital preoperative planning for the osteosynthesis of distal radius fractures.," *J. Orthop. Res. Off. Publ. Orthop. Res. Soc.*, vol. 35, no. 12, pp. 2646–2651, Dec. 2017, doi: 10.1002/jor.23578.

[2] Z. Zhang, "A flexible new technique for camera calibration," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 22, no. 11, pp. 1330–1334, Nov. 2000, doi: 10.1109/34.888718.

[3] A. H. Andersen and A. C. Kak, "Simultaneous Algebraic Reconstruction Technique (SART): A superior implementation of the ART algorithm," *Ultrason. Imaging*, vol. 6, no. 1, pp. 81–94, 1984, doi: https://doi.org/10.1016/0161-7346(84)90008-7.