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RGB-D/CT Registration for Preemptive Patient Pose Alignment in Longitudinal CT Scans

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Introduction

Longitudinal CT scanning is essential for monitoring treatment responses, yet its precision is compromised by inconsistent patient positioning between sessions. Current post-hoc image registration corrects these inconsistencies after acquisition, but remains computationally intensive, error-prone, and limited by the magnitude of initial pose discrepancy. This work proposes a paradigm shift: addressing variability at its source by aligning the patient's pose before the follow-up scan to complement post-hoc registration.

Methods

A top-mounted RGB-D camera acquires a surface image of the patient immediately before the follow-up scan. The surface is extracted from the prior CT-scan using the Marching Cubes algorithm and segmented into torso and limbs. The RGB-D point cloud is segmented using 2D skeleton keypoints projected into 3D. Registration has two stages: the CT torso mesh is converted to a 2.5D point cloud via Poisson disk sampling and Hidden Point Removal, then aligned to the RGB-D torso through PCA-based coarse matching and point-to-plane ICP refinement. After this anchoring, each CT segment undergoes independent coarse and refined alignment to its RGB-D counterpart. Correction vectors, defined as the displacement between the torso-anchored ideal limb position and the current registered position, are projected onto the 2D RGB image via a pinhole camera model, providing intuitive visual pose guidance for clinical staff.

Results

Validated on an anthropomorphic whole-body-phantom across three poses, torso anchoring achieves an average centroid error of 2.69cm and PCA angle error of 3.46° over repeated iterations. Limb surface registration yields mean point-to-surface errors between 1.61cm and 1.84cm with high repeatability. The visual guidance successfully communicates the required direction of postural adjustment.

Conclusion

This proof-of-concept demonstrates the feasibility of proactive, pre-scan patient pose alignment using RGB-D/CT registration. By reducing initial pose discrepancy before acquisition, the approach has the potential to improve raw data quality and reduce the burden on subsequent post-hoc registration.

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