Workshop on Future of Construction
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Efficient and Accurate 3D Reconstruction Based on LiDAR HBA

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Abstract

Reconstructing an accurate and consistent large-scale LiDAR point cloud map is crucial for robotics applications. The existing solution, pose graph optimization, though it is time-efficient, does not directly optimize the mapping consistency. LiDAR bundle adjustment (BA) has been recently proposed to resolve this issue; however, it is too time-consuming on large-scale maps. To mitigate this problem, we present a globally consistent and efficient mapping method, hierarchical bundle adjustment (HBA) suitable for large-scale maps. Our proposed work consists of a bottom-up BA and a top-down pose graph optimization, which combines the advantages of both methods. With the hierarchical design, we solve multiple BA problems with a much smaller Hessian matrix size than the original BA; with the pose graph optimization, we smoothly and efficiently update the LiDAR poses. The effectiveness and robustness of our proposed approach have been validated on multiple spatially and timely large-scale public spinning LiDAR datasets, i.e., KITTI, MulRan and Newer College, and self-collected solid-state LiDAR datasets under structured and unstructured scenes. With proper setups, we demonstrate our work could generate a globally consistent map with centimeter-level precision.

Scan to read our RA-L paper

Scan to try our code on GitHub

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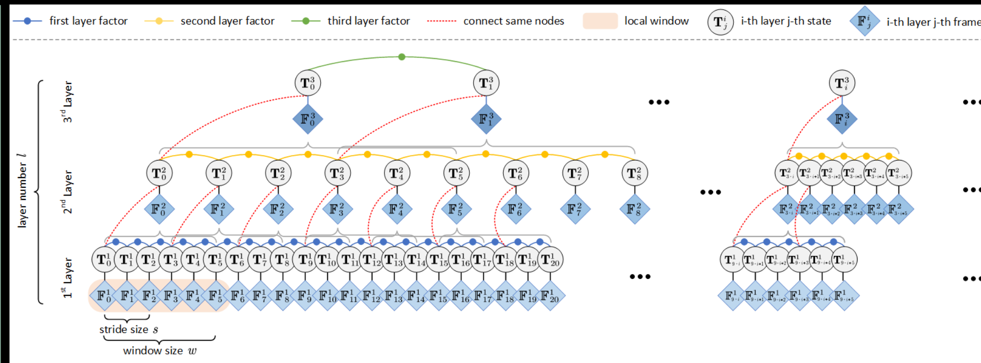
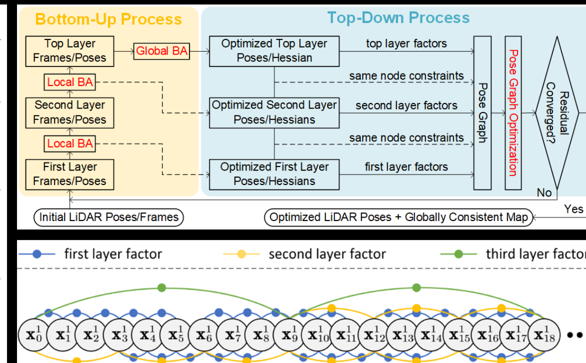
Methodology and Workflow

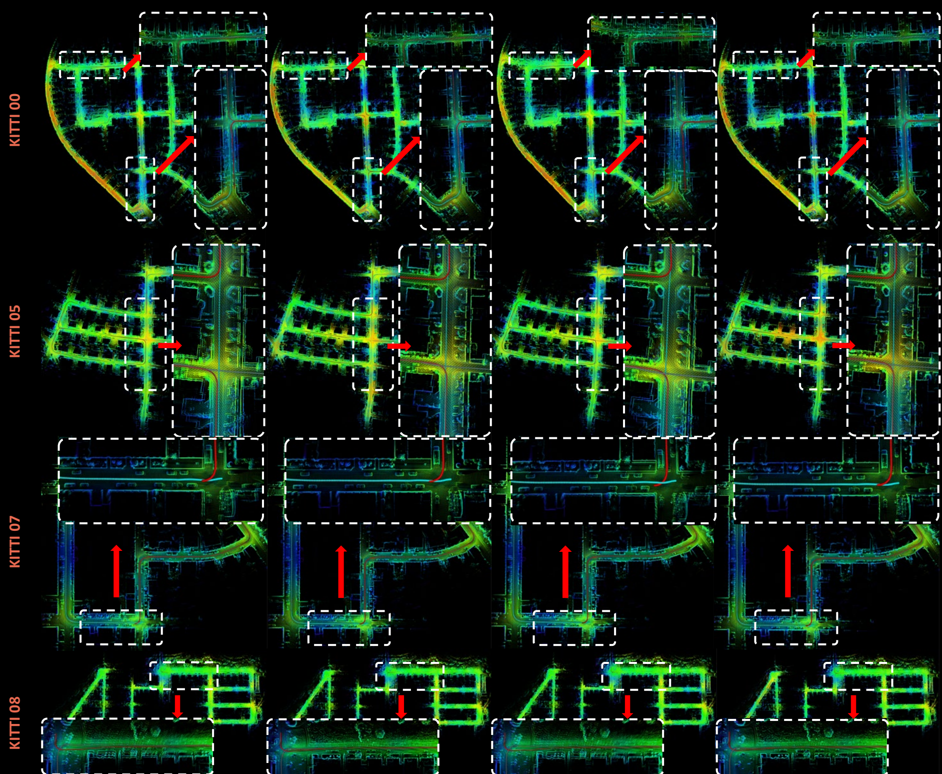


Pyramid structure of our HBA. In bottom-up process, frames within the same local window are optimized by BA to create a keyframe for the next layer. In top-down process, adjacent frames in the same layer are connected by factors obtained from the bottom-up BA.

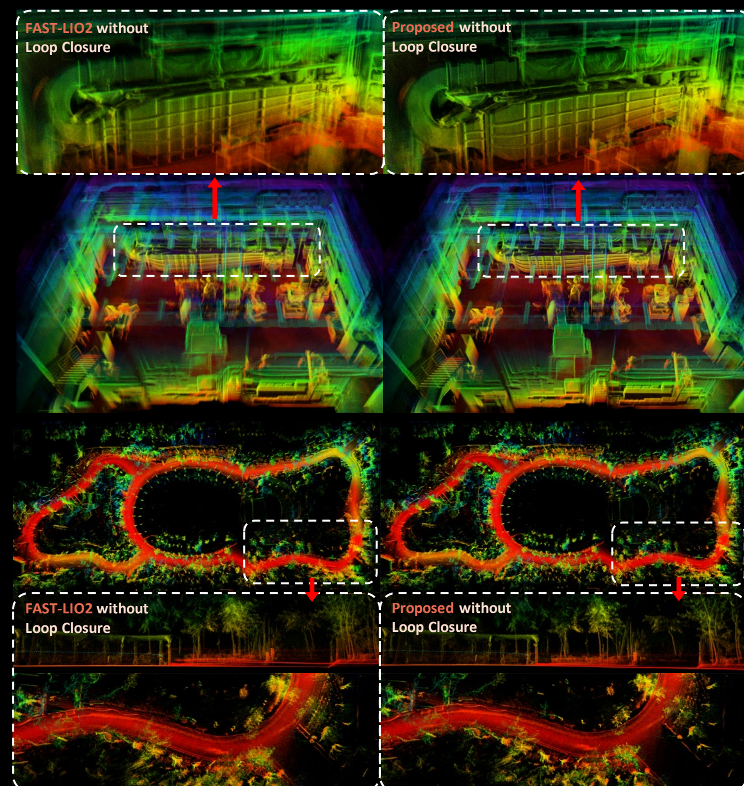


Top: system workflow. Bottom: final factor graph.

Experiment Results

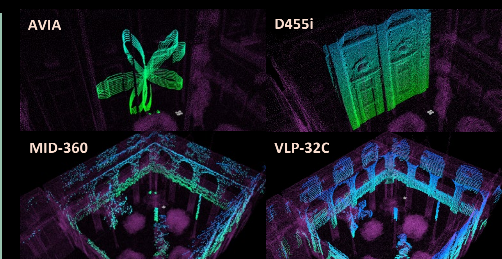


Closure of the gap on KITTI dataset using initial trajectories with and without loop closure. The main gaps are detailed by white dashed rectangles.



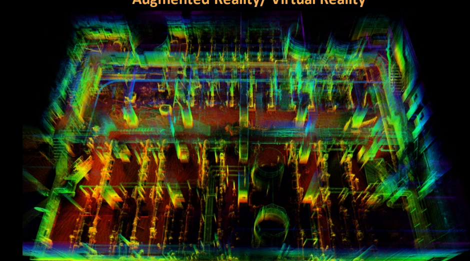
Refinement of point cloud map on self-collected solid-state LiDAR dataset. The initial trajectories are not loop closured. Top: cluttered indoor laboratory. Bottom: unstructured outdoor park.

Potential Applications



Robotics Simulator

Augmented Reality/ Virtual Reality



Building Information Model