Edge Device-Optimized LiDAR SLAM for Real-Time and Robust Localization in Dynamic Environments

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ION GNSS+ 2025
D6: Alternative Technologies for GNSS-Denied Environments – Optical Approaches

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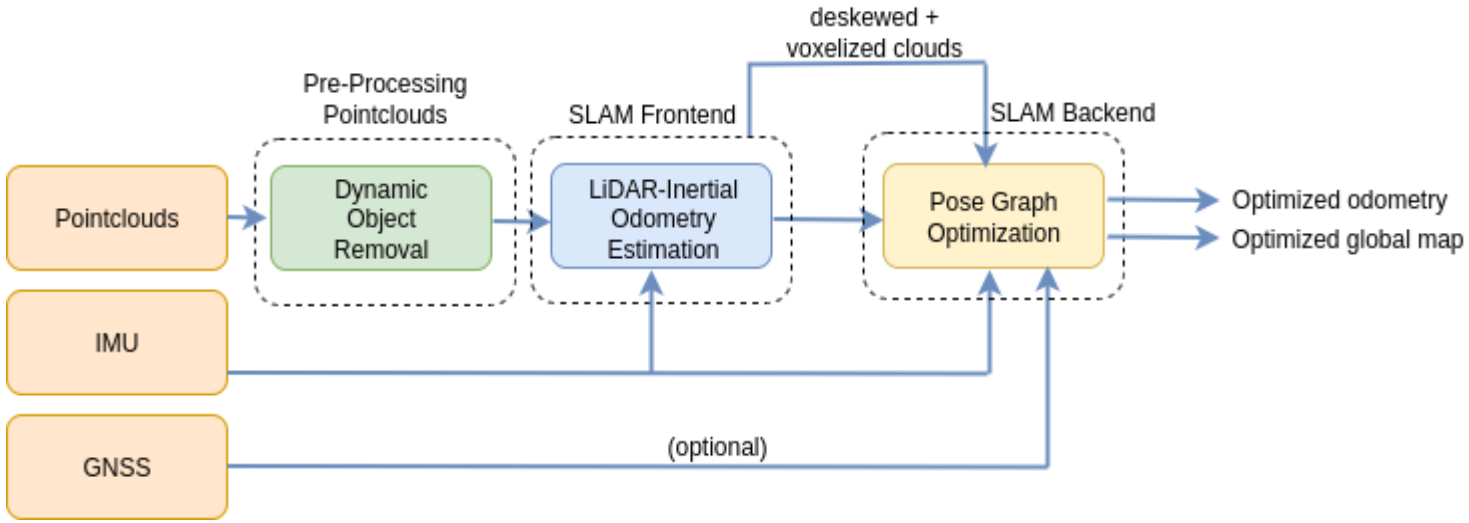
DREAM Project

- DREAM aims to address the stringent requirements of **ADAS** systems in challenging urban environments by developing advanced AI solutions.
- **AI** techniques to detect **spoofing**, **multipath** and NLOS situations and ensuring correct **ambiguity resolution**
- For improved localization in GNSS-denied scenarios, AI-driven methods will be applied for **IMU calibration and denoising**, as well as **LiDAR/Visual SLAM** (enhance with AI-based moving objects removal)
- It also features **3D bounding boxes** for object detection and **geo-referenced maps** supporting LiDAR/Visual localization and improving situational awareness.

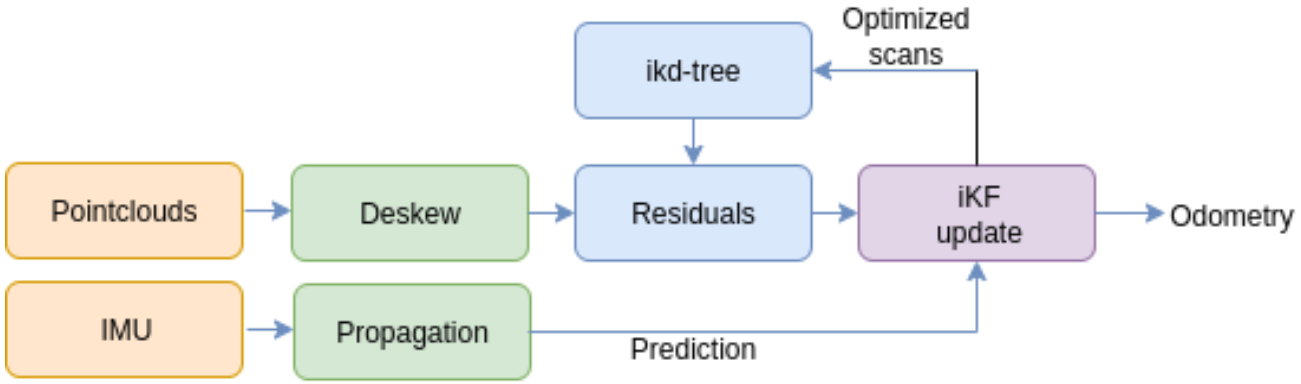
LiDAR SLAM – Online

- **Dynamic object removal** for improved odometry estimation and cleaner map generation
- **LIO estimation frontend** where the LiDAR and IMU measurements are tightly coupled for a robust odometry estimation and compensate pointclouds for motion distortion
- **Factor graph backend** to optimize the odometry with IMU integration, scan-to-map, and loop closure factors

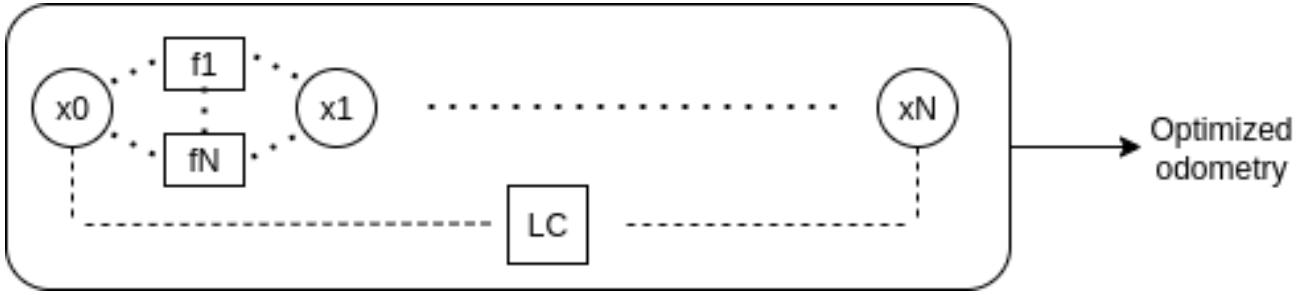


Frontend + Backend

- **Frontend** is a FAST-LIO* based pipeline which subscribes (ROS2) to LiDAR and IMU topics to estimate odometry



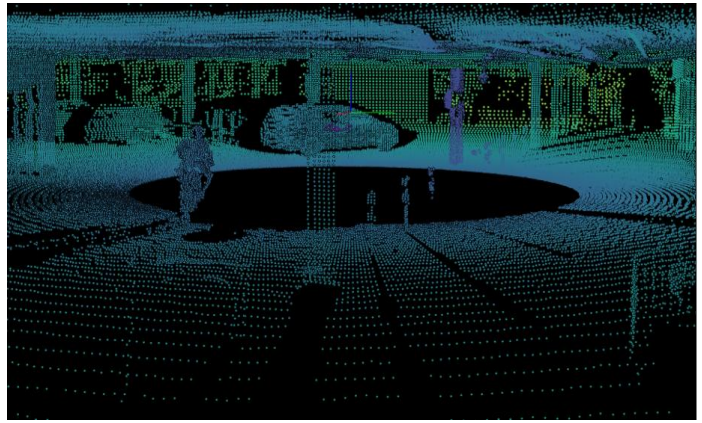
- **Factor graph backend** is used to optimize the odometry with IMU integration, relative pose, and loop closure factors

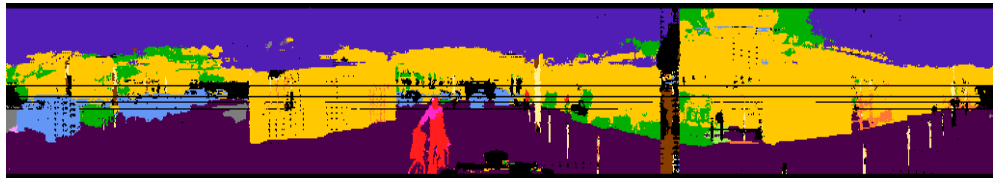


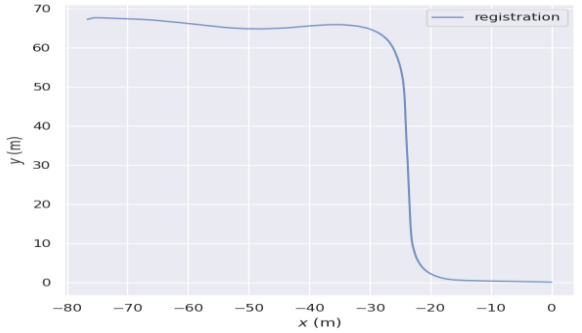
*W. Xu, Y. Cai, D. He, J. Lin and F. Zhang, "FAST-LIO2: Fast Direct LiDAR-Inertial Odometry"

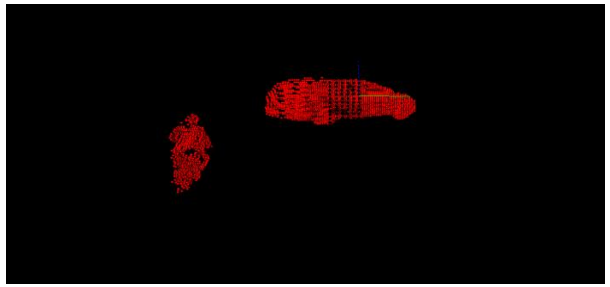
Dynamic Object Removal

- **Static scenes** help in understanding the surrounding geometries better thereby estimating odometry with minimal drift over time
- **Semantic segmentation** of the deskewed pointclouds is used to filter out possible dynamic objects such as cars, trucks, pedestrians etc. (~12 ms at 55.6 % mIoU)
- **Robust ICP** estimates transformation between adjacent clouds using covariances estimated with KNN. Best of point-to-point and point-to-plane on a smaller covariance subset (~16 ms at a registration score of ~0.2)
- **Temporal consistency** of voxel points over N frames help determine dynamic objects (~20 ms at 65 % IoU)









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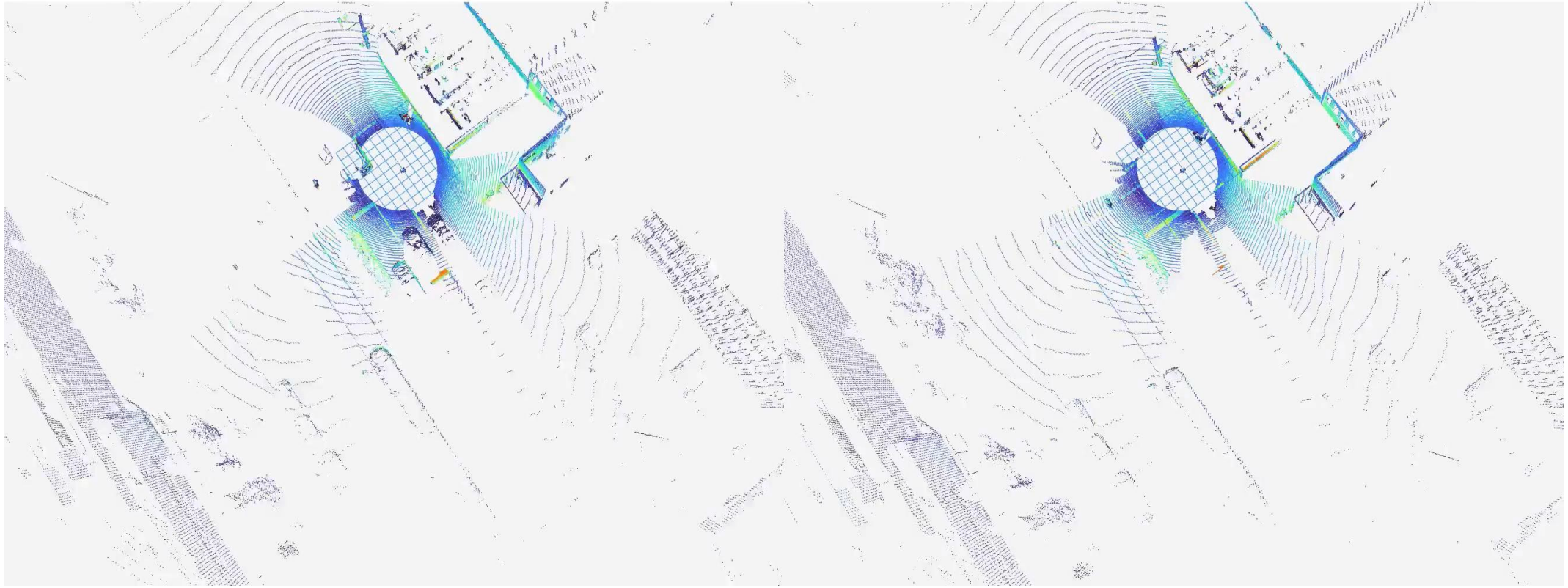
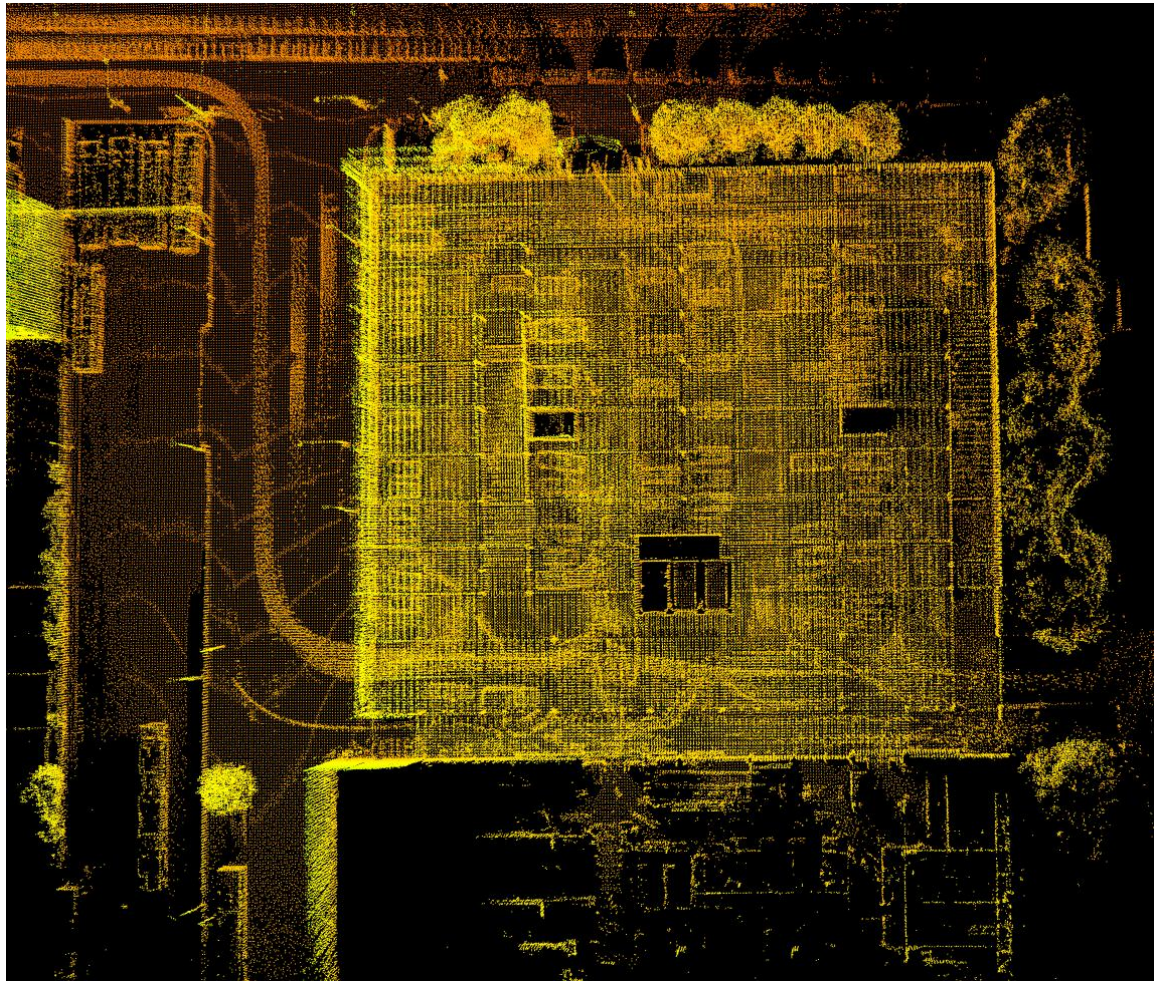
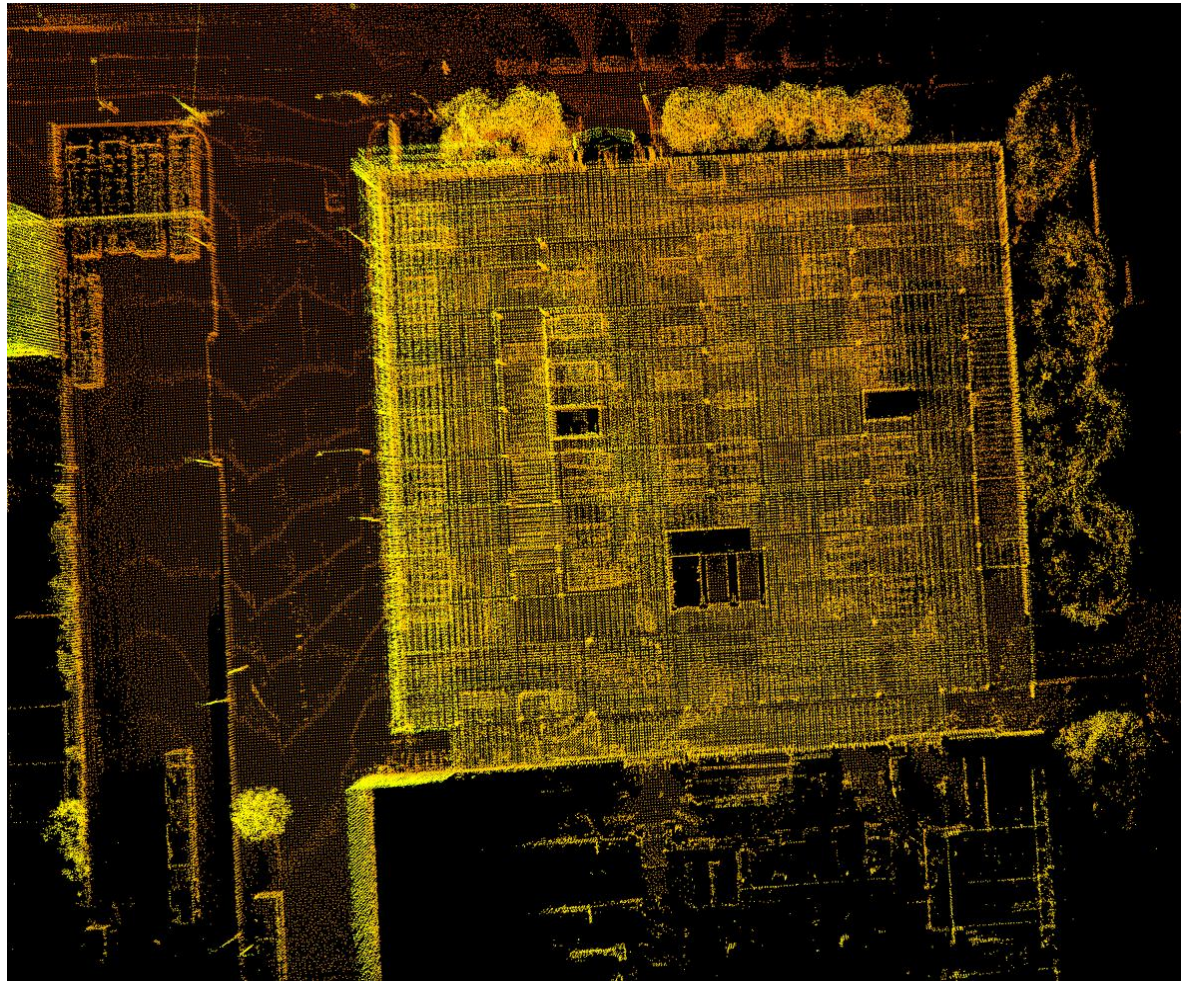
Dynamic Object Removal



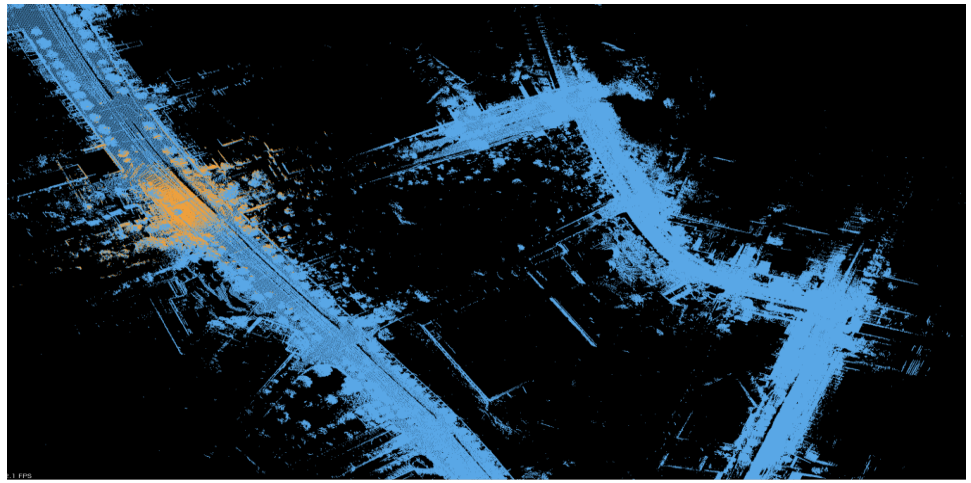
Optimized Global Map

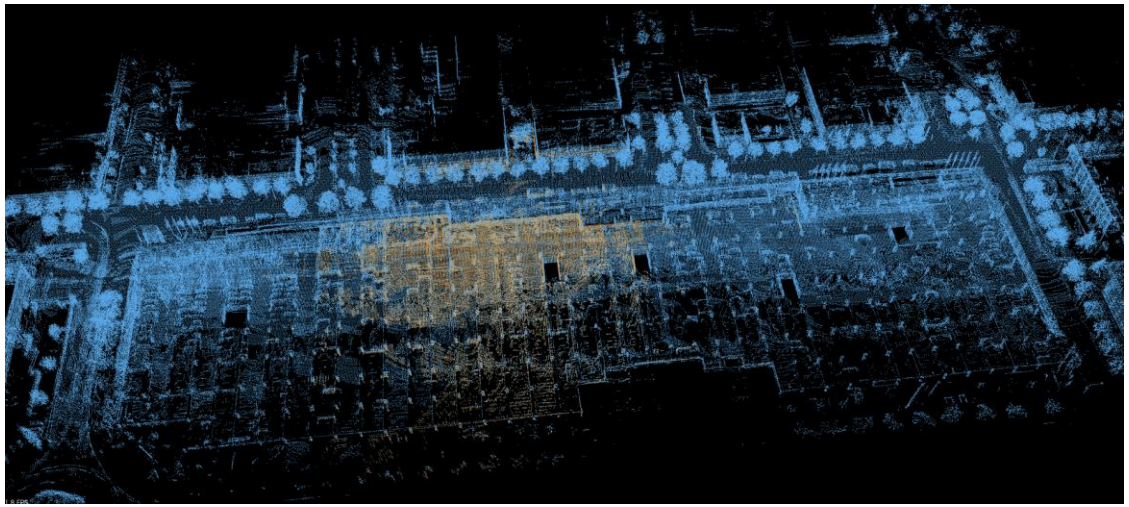




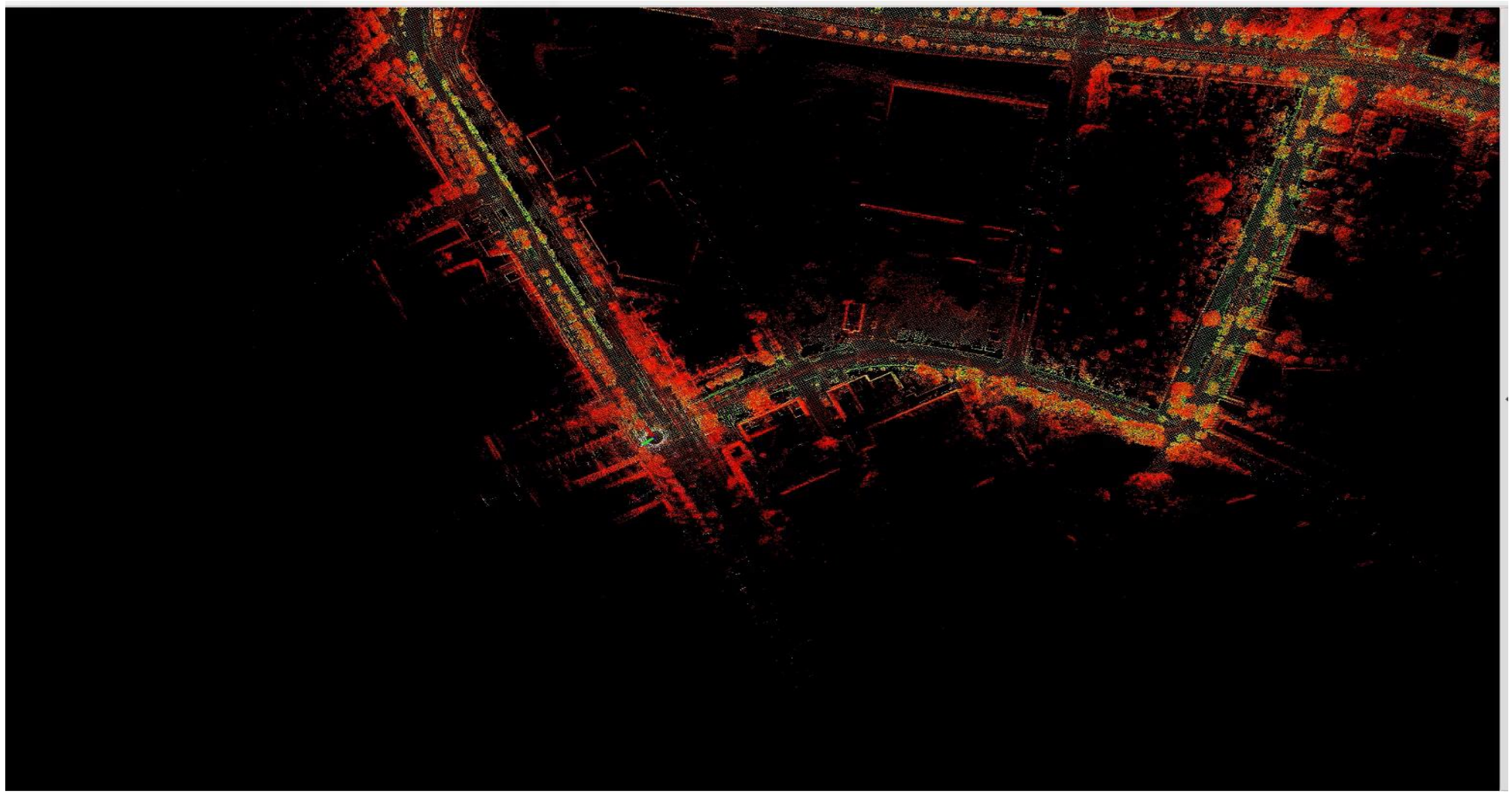
Scan to Map Global Registration for Re-Localization

- Re-Localization provides a **drift free odometry**
- Global initialization is critical for **positional awareness** within the global map
- Voxelized input pointclouds + voxelized global map + **Fast Point Feature Histogram Descriptors** → Global Init Estimate
- Global Init Estimate + Loop Closure with surrounding keyframes → **Optimized Global Init**
- Segmented global map coupled with multi-threading provides quick estimation → ~6 s for a 4 km wide map
- **Scan-to-Submap registration** then helps estimate odometry





Real-Time Re-Localization



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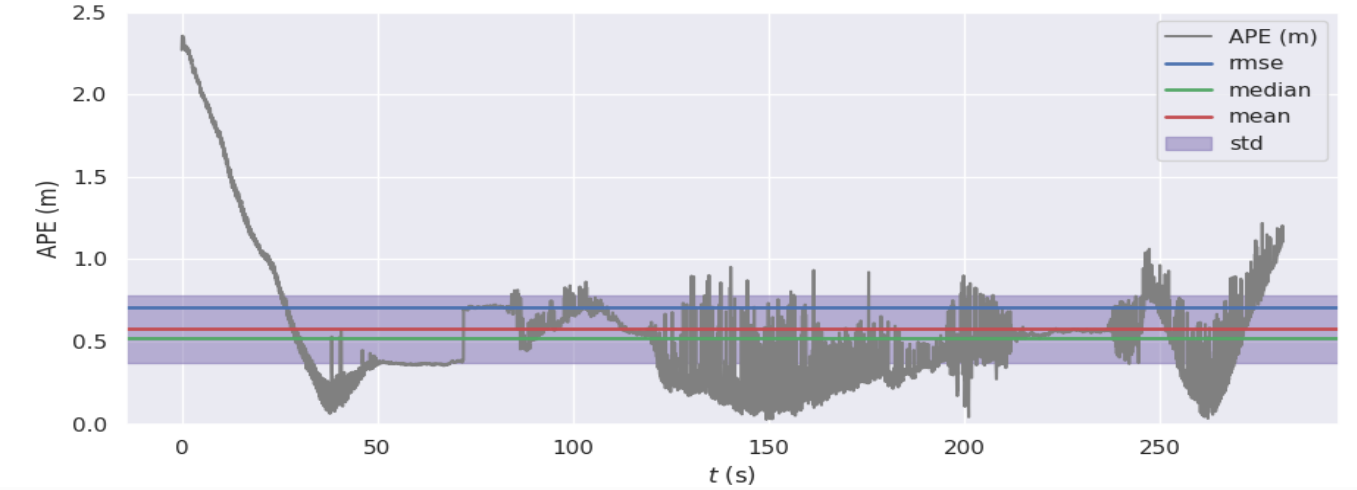
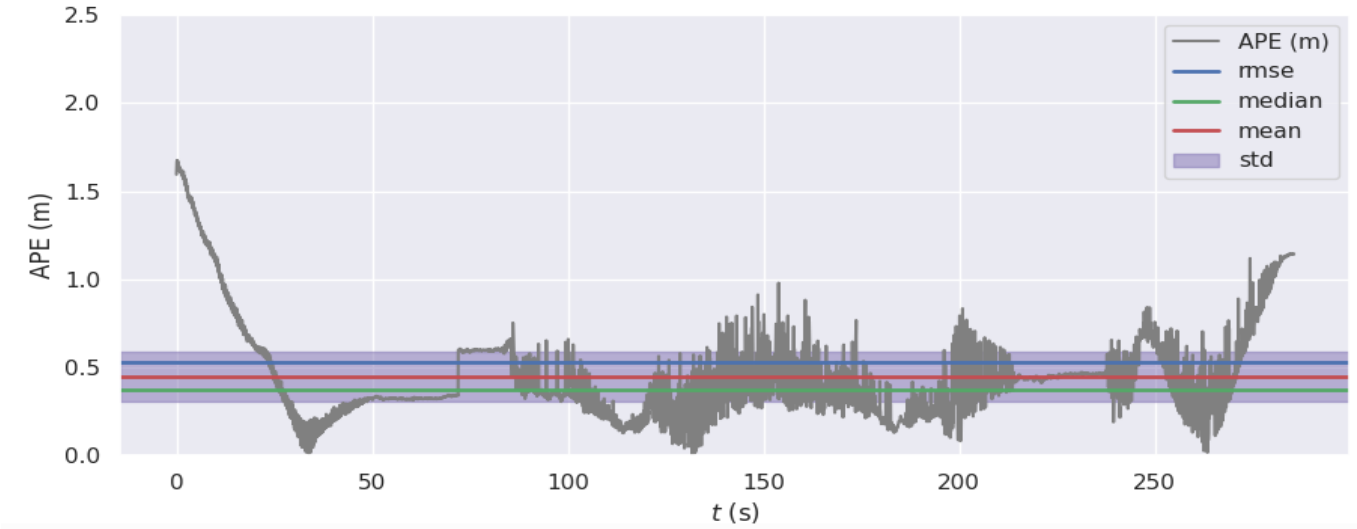
Odometry Benchmark

- RMSE of ~0.7 m with raw scans

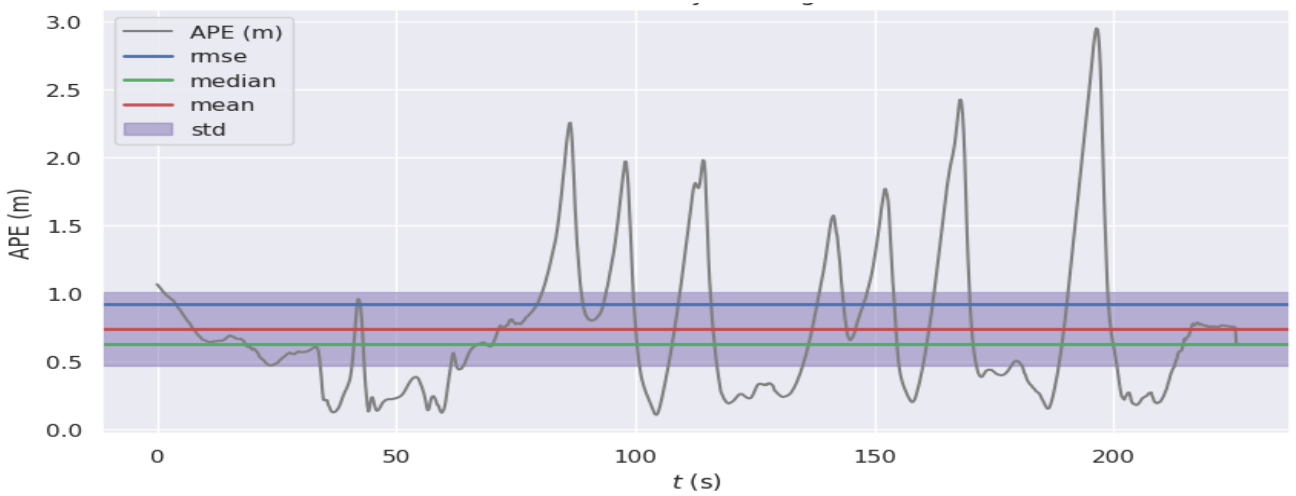


- RMSE of ~0.5 m with cleaned scans

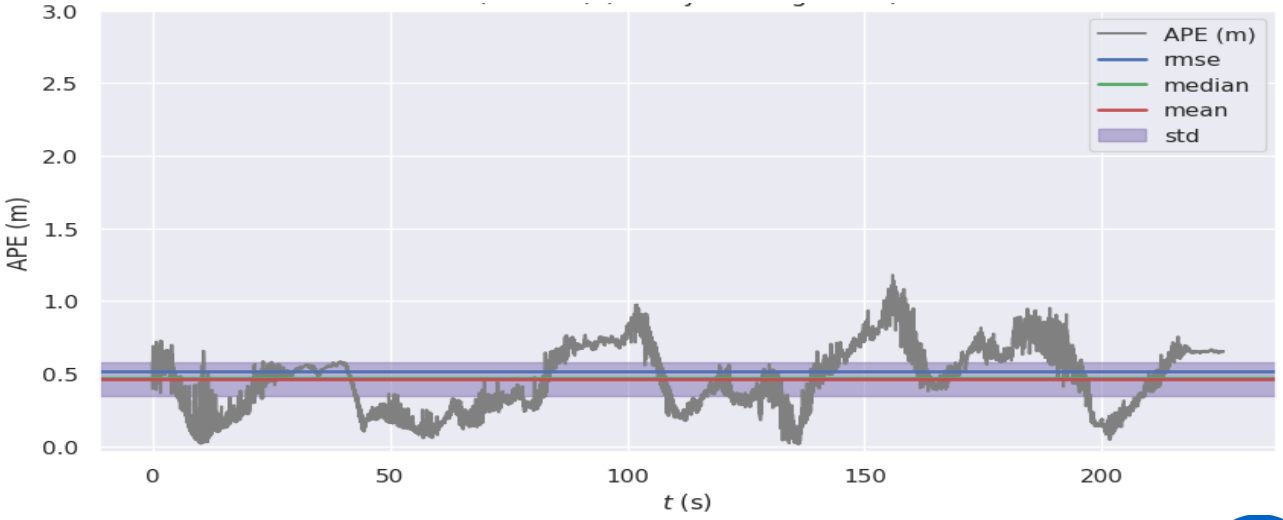


Improvements in Central Filter with LiDAR SLAM

- GNSS + IMU solution shows an RMSE of ~1 m indoors



- Central filter performance improves indoors with an RMSE of ~0.5 m with the fusion of LIO



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Summary

- We propose a **real-time capable** dynamic object segmentation pipeline to extract static geometries from a scene
- We demonstrate that dynamic object removal **reduces drift** in the estimated odometry.
- We demonstrate that fusing our LiDAR-Inertial Odometry into our central filter helps improve its performance, especially in **GNSS-denied environments**
- We demonstrate a **robust global registration** algorithm coupled with **re-localization** to mitigate drift in the estimated odometry

Contact & Project Information

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DREAM Project

- Funded by the EUSPA as part of the Fundamental Elements Programme
- Contract number: EUSPA/GRANT/03/2022.
- https://dream-project-eu.com/