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비정형 환경 내 지도 작성과 자율주행을 위한 GNSS-라이다-관성 상태 추정 시스템

Tightly-Coupled GNSS-LiDAR-Inertial State Estimator for Mapping and Autonomous Driving

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Motivation

Why use GNSS (Global Navigation Satellite System) with LIO (LiDAR-Inertial Odometry)?

- GNSS provide absolute position, which can allevate long-term drift of state estimator.

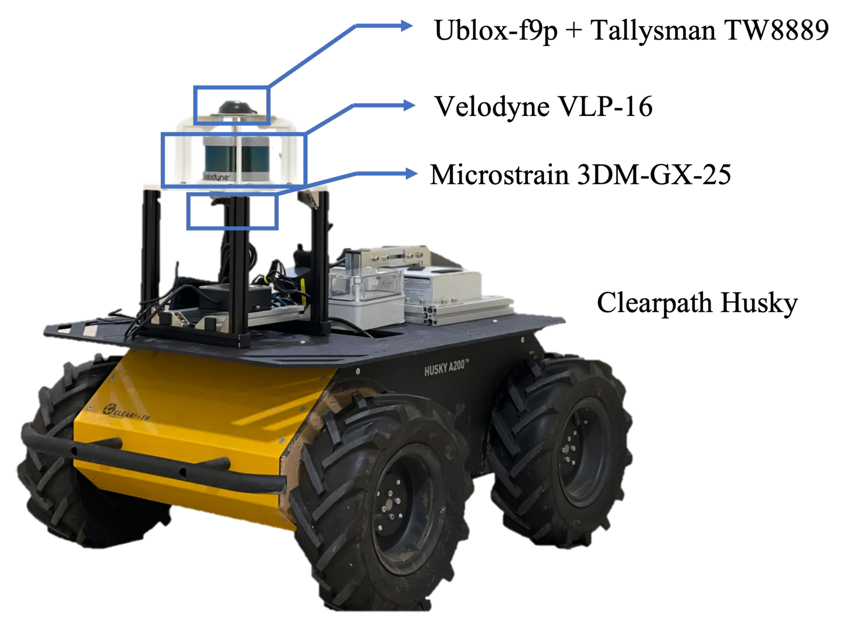
Why tightly-coupled GNSS factor?

- GNSS PVT fix position have high uncertainty in z-axis.
- LIO state estimator cannot minimize z-axis error with loosely-coupled approach.
- Tightly-coupling raw GNSS measurements
  → mitigate slowly-drifting z-axis error by jointly optimizing a factor graph.

Why should we handle NLOS (Non-Line-of-sight) signal?

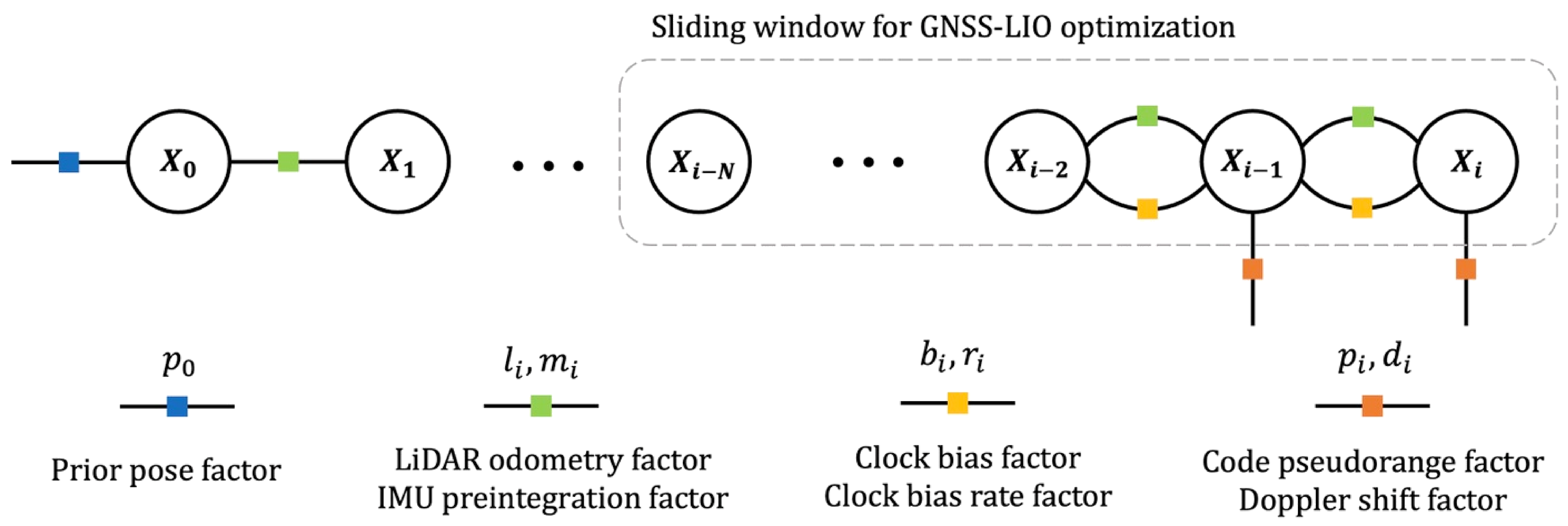
- NLOS satellites can affect the accuracy of raw GNSS pseudorange measurement.
- With accurate LiDAR pointcloud submap, we can check if the measurement is in NLOS.

Hardware

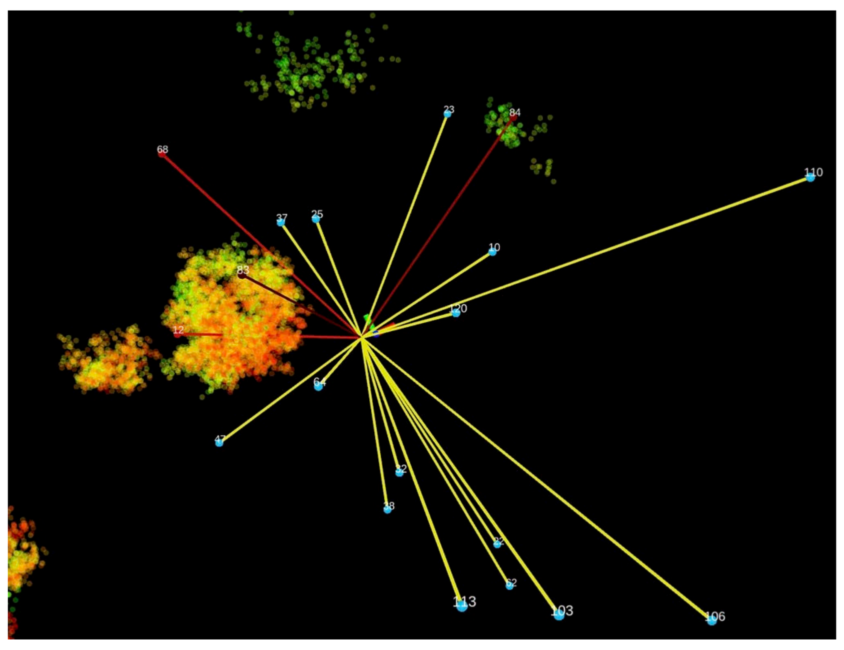


- GNSS-LiDAR-Inertial system mounted on UGV.
- Tested autonomous driving with estimated states. (video QR →)

Method

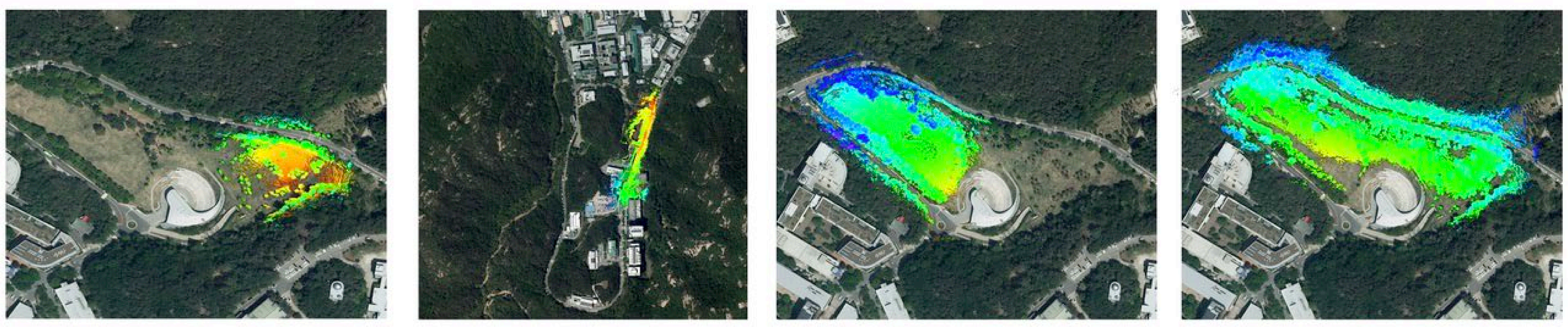


- Used GNSS raw measurement factors + clock factors with LiDAR, IMU factors
- Sliding window-based 3-step coarse-to-fine GNSS initialization

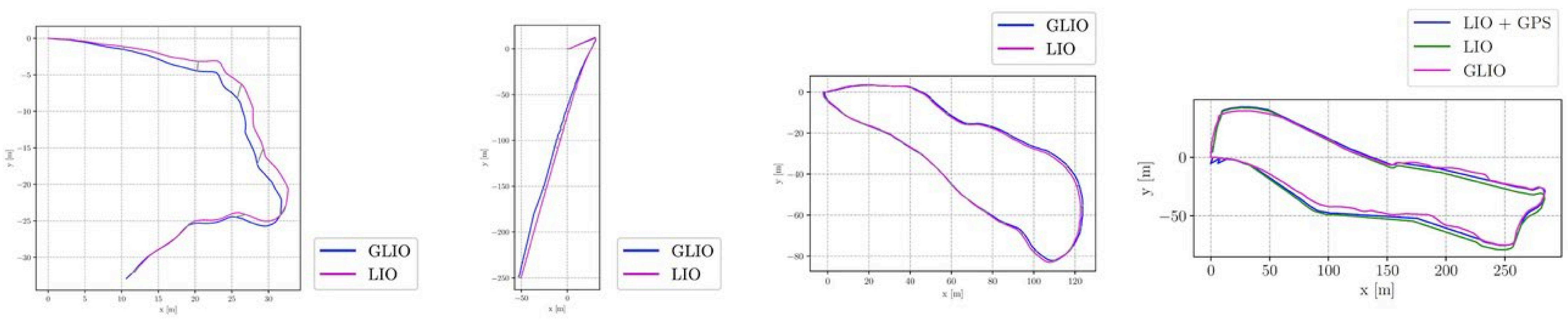


- Detect NLOS satellites using LiDAR pointcloud submap
- Weight the measurement based on the pointcloud density

Result (Acquired Dataset)

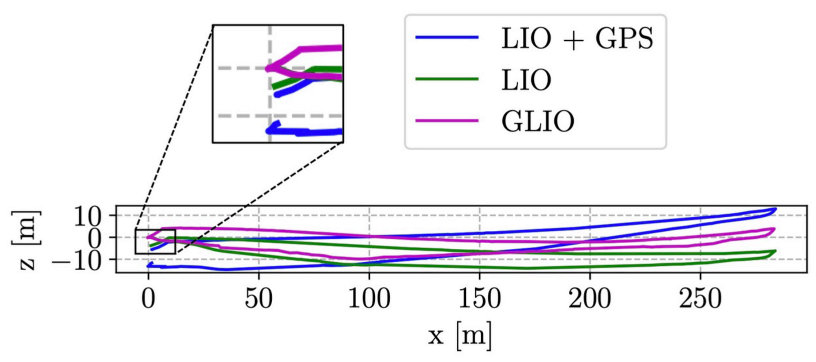


Sequence 1 | Sequence 2 | Sequence 3 | Sequence 4



	GLIO	LIO-SAM [1]
Sequence 1	**0.04498**	0.07502
Sequence 2	0.48934	**0.3945**
Sequence 3	**1.08757**	1.20461
Sequence 4	**0.47547**	5.41202

Lower ATE (absolute trajectory error) than LIO-SAM

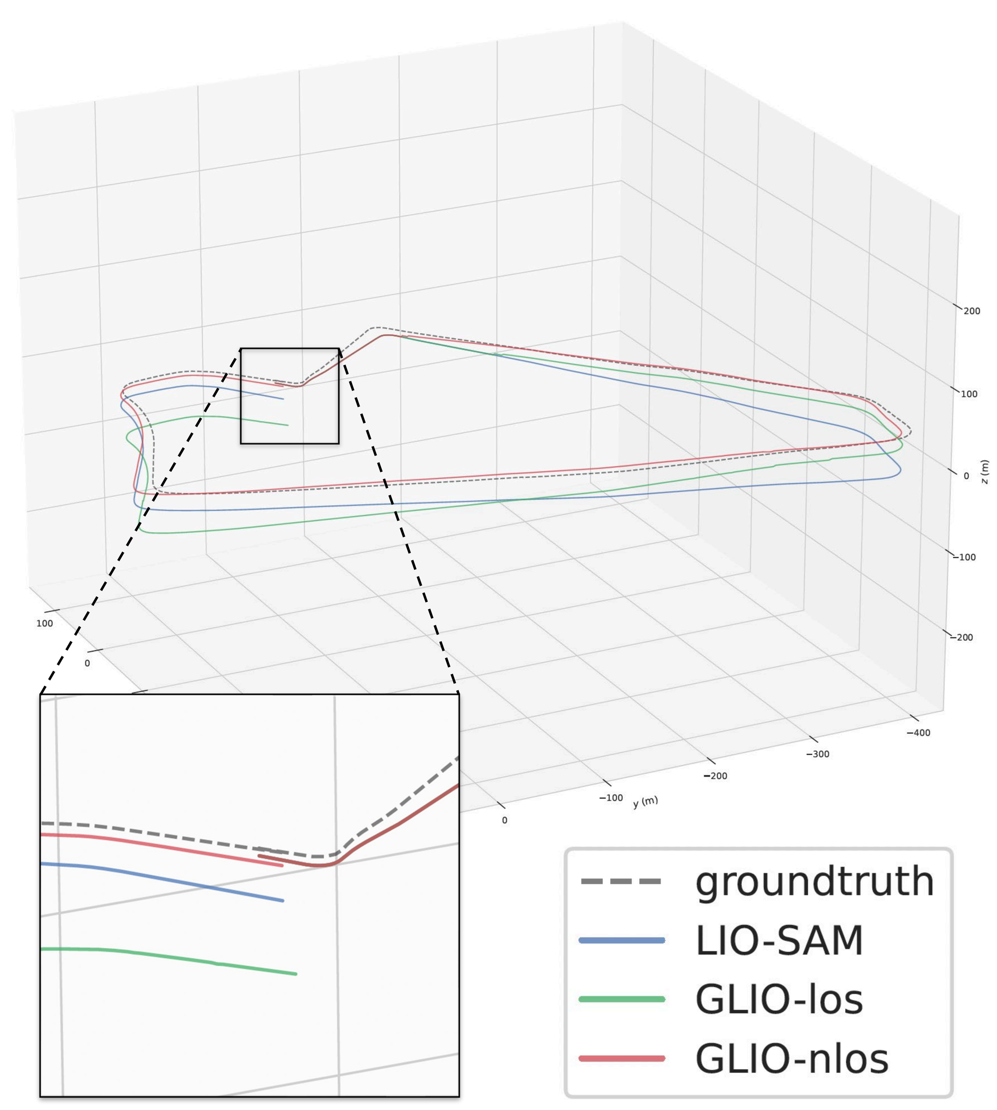


	GLIO	LIO-SAM	LIO-GPS
error [m]	**0.47547**	5.41202	7.42899

about 11.5 times lower z-axis error

Result (Public Dataset)

TST sequence of UrbanNav [2] Dataset



	LIO-SAM	GLIO-LOS	GLIO-NLOS
Mean	4.286	5.739	**3.227**
Median	3.650	3.628	**2.787**
RMSE	4.916	7.226	**3.669**

Handling NLOS signal yields the best ATE

Reference

[1] T. Shan, B. Englot, et al. " LIO-SAM: Tightly-coupled lidar inertial odometry via smoothing and mapping," *IEEE International Workshop on Intelligent Robots and Systems (IROS)*, Las Vegas, USA, 2020.

[2] L.-T. Hsu, et al. "UrbanNav: An Open-Sourced Multisensory Dataset for Benchmarking Positioning Algorithms Designed for Urban Areas," *The 34th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2021)*, pp. 226-256, 2021