AS-LIO: Spatial Overlap Guided Adaptive Sliding Window LiDAR-Inertial Odometry for Aggressive FOV Variation

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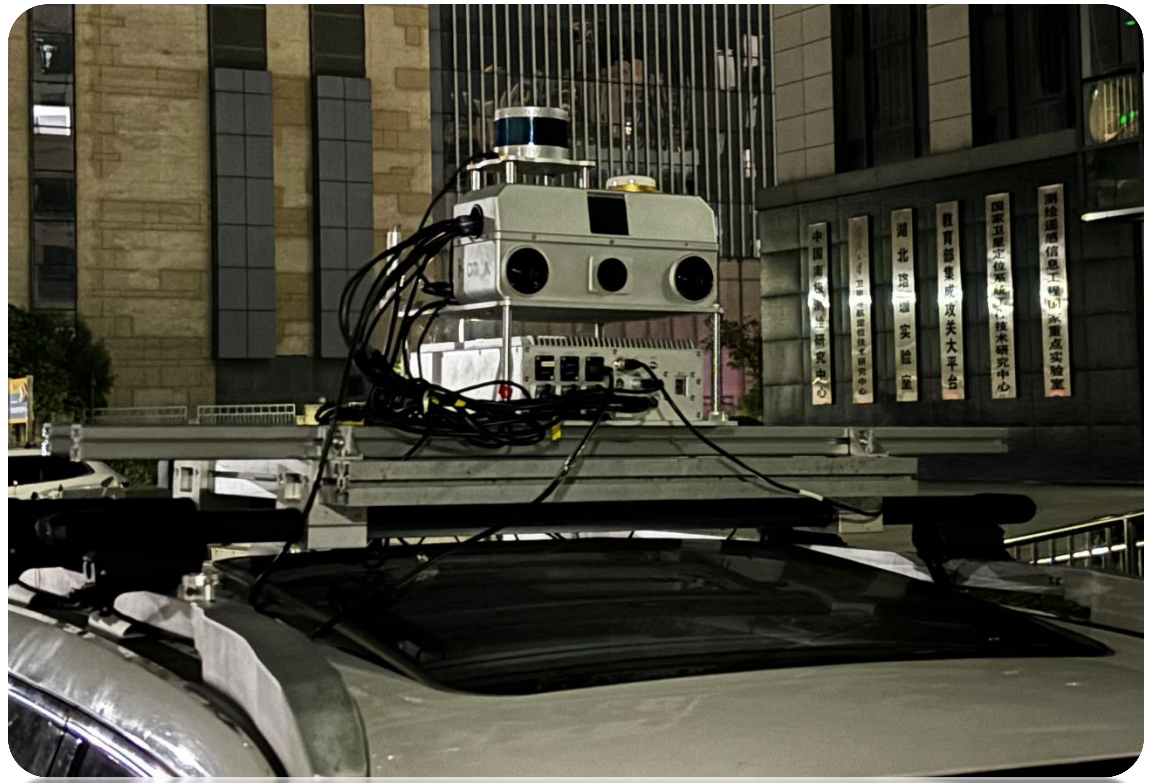
Contribution

- A new metric **SOD** to assess the spatial overlap between LiDAR frame and pointcloud map, directly evaluating the impact of current FOV variation on pointcloud registration.

- An **Adaptive Sliding Window** to manage the continuous LiDAR stream based on SOD, allowing the LIO system to refine the trajectory with more dense states as necessary.

Motivation

- LiDAR-Inertial Odometry (LIO) excels in general low-speed and smooth motion scenarios.
- However, there still remain challenges in **high-speed, intense motion** scenarios, such as sharp turns.



From on-vehicle scene

Stable

More dynamic
&challenging

To handheld/wearable

Flexible

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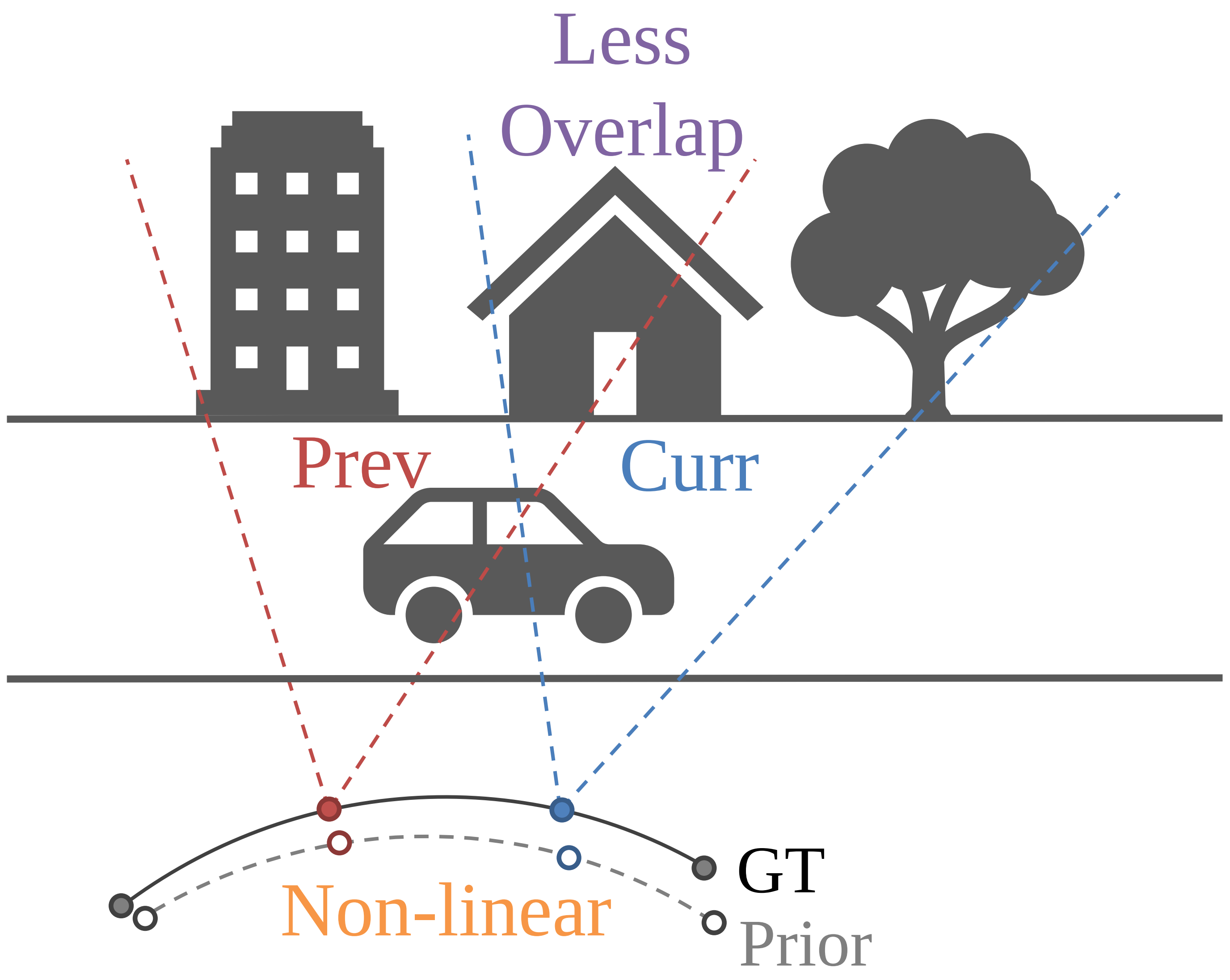
Motivation

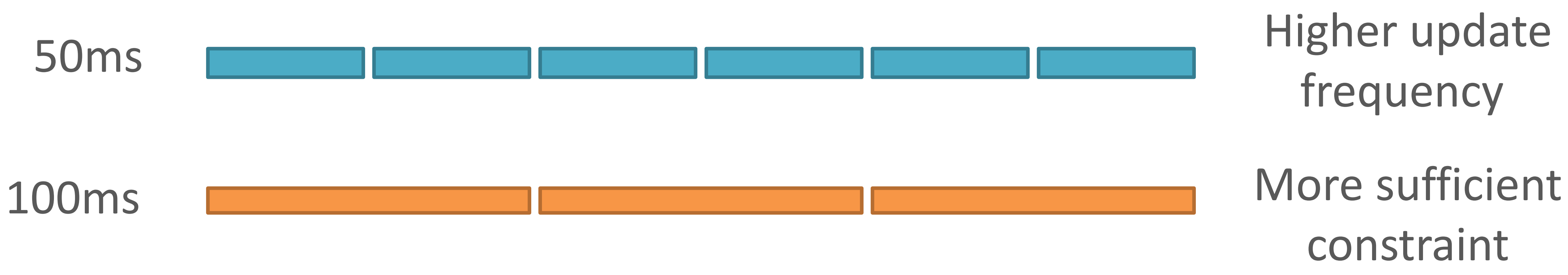
- What challenges will intense motion bring to LIO?
  - For IMU: Increased **Non-linear Error** in state propagation
  - For LiDAR: **Aggressive FOV Change** will reduce the **Spatial Overlap** between LiDAR frame and pointcloud map



Motivation

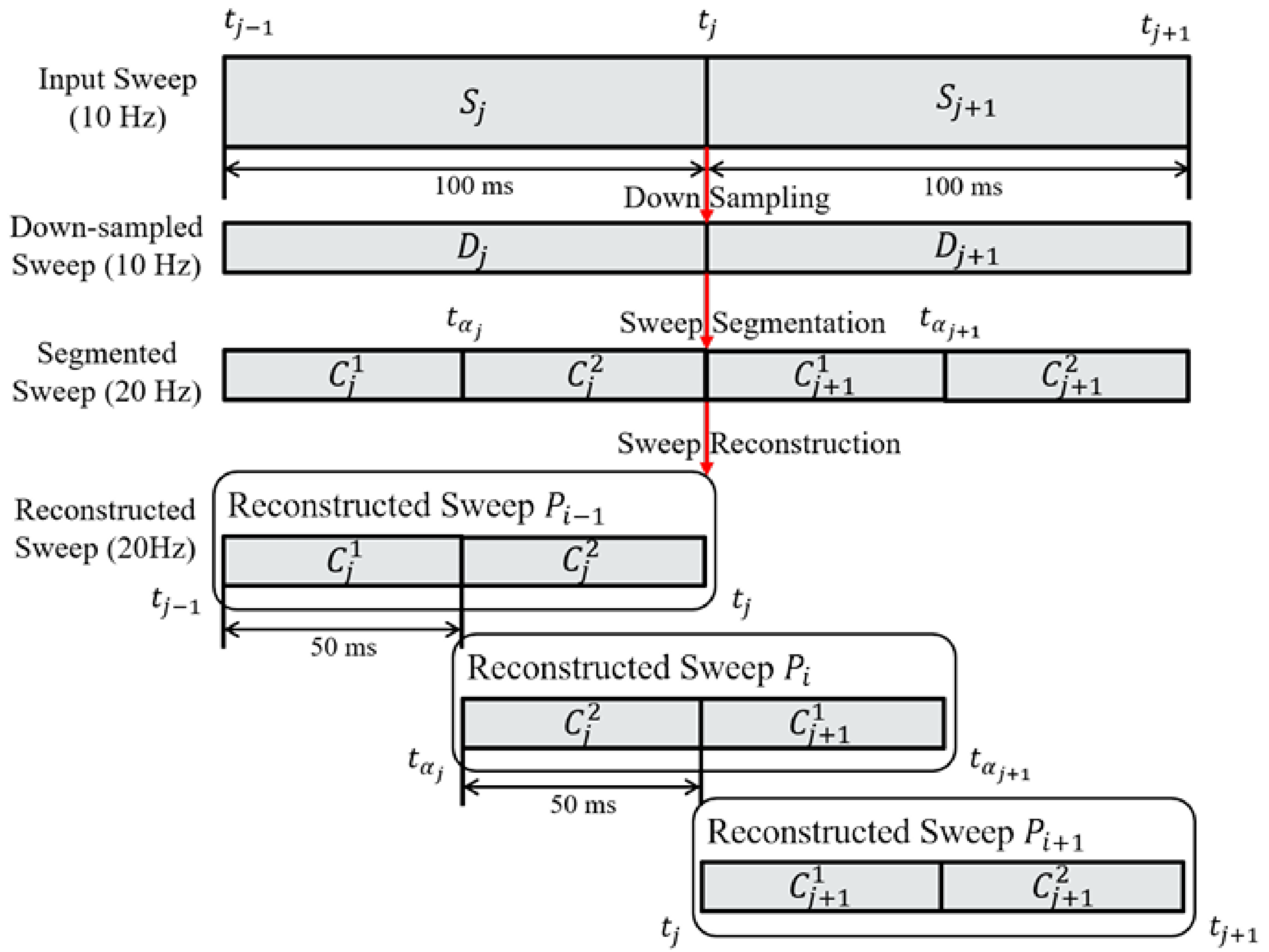
- The dilemma in selecting time scale of LiDAR frame
  - Shorten time scale => Higher update frequency may suppress non-linear error, but insufficient constraints could increase **degradation risk**
  - Expand time scale => LiDAR constraints are sufficient, but the accumulation of prior error and motion distortion may **impact accuracy**

Different LiDAR frame length:

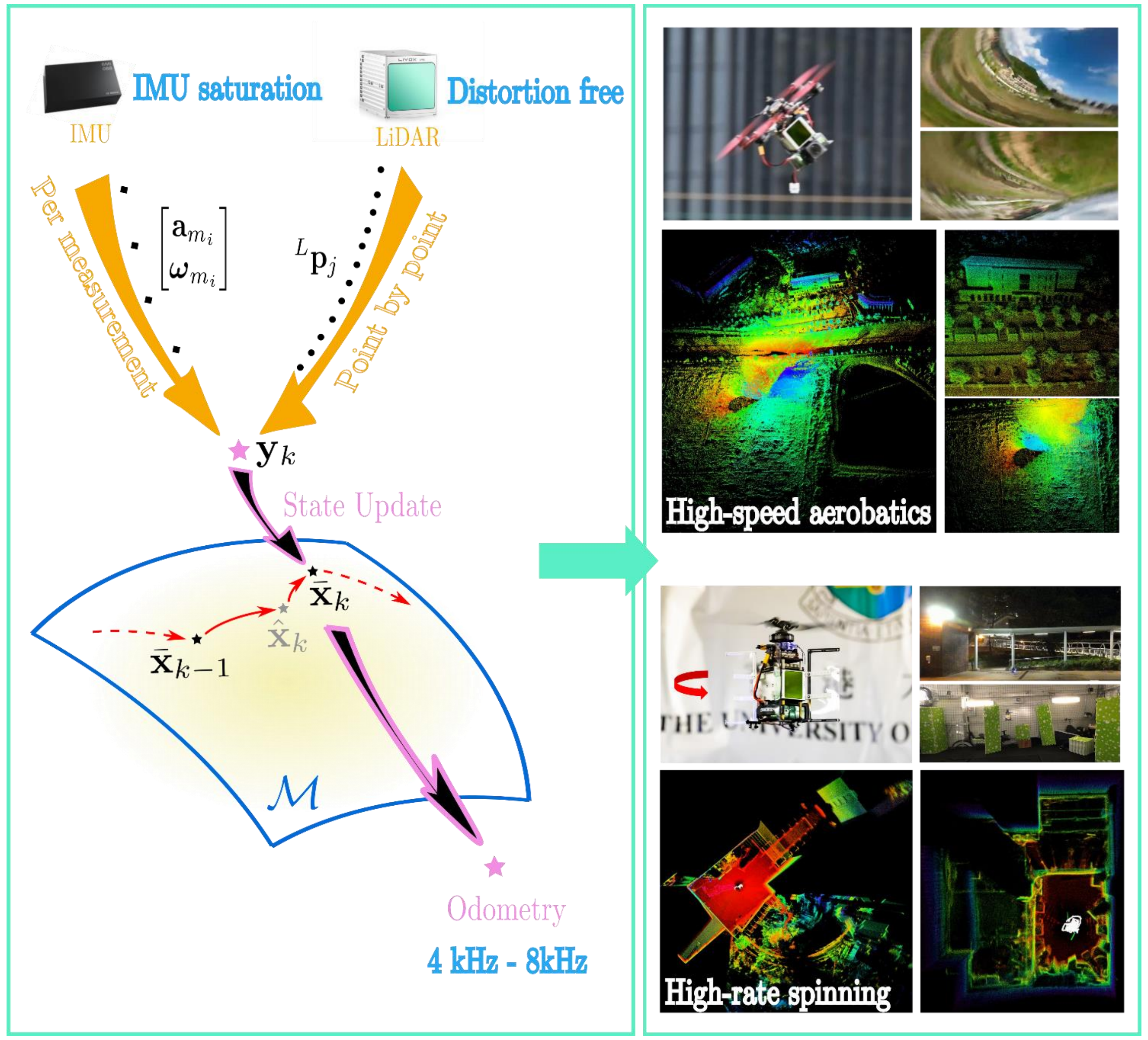


Related Work

- Sweep reconstruction



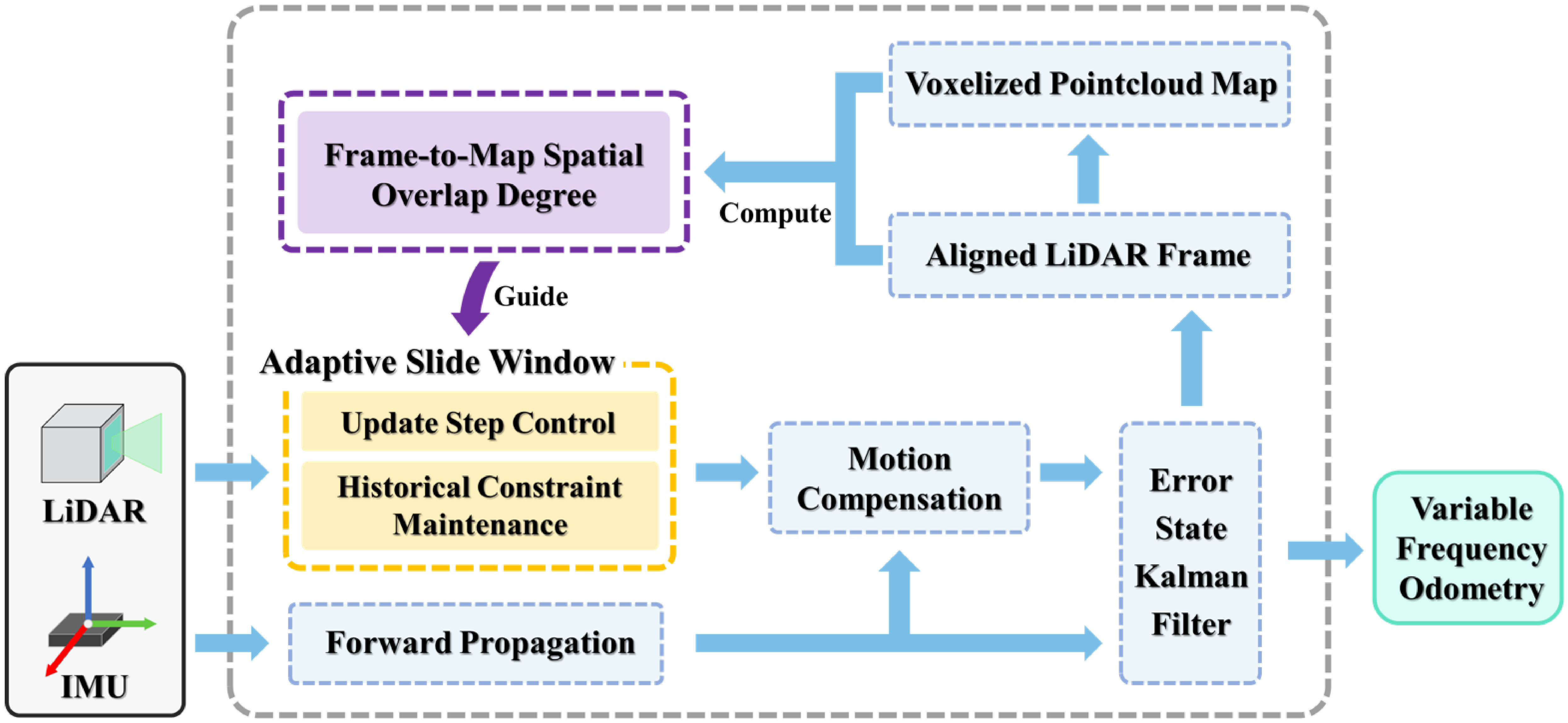
- Point by Point



[1] Z. Yuan, F. Lang, T. Xu, and X. Yang, Sr-lio: Lidar-inertial odometrywith sweep reconstruction, arXiv preprint arXiv:2210.10424, 2022.

[2] D. He, W. Xu, N. Chen, F. Kong, C. Yuan, and F. Zhang, Point-lio:Robust high-bandwidth light detection and ranging inertial odometry, Advanced Intelligent Systems, vol. 5, no. 7, p. 2200459, 2023.

System Overview



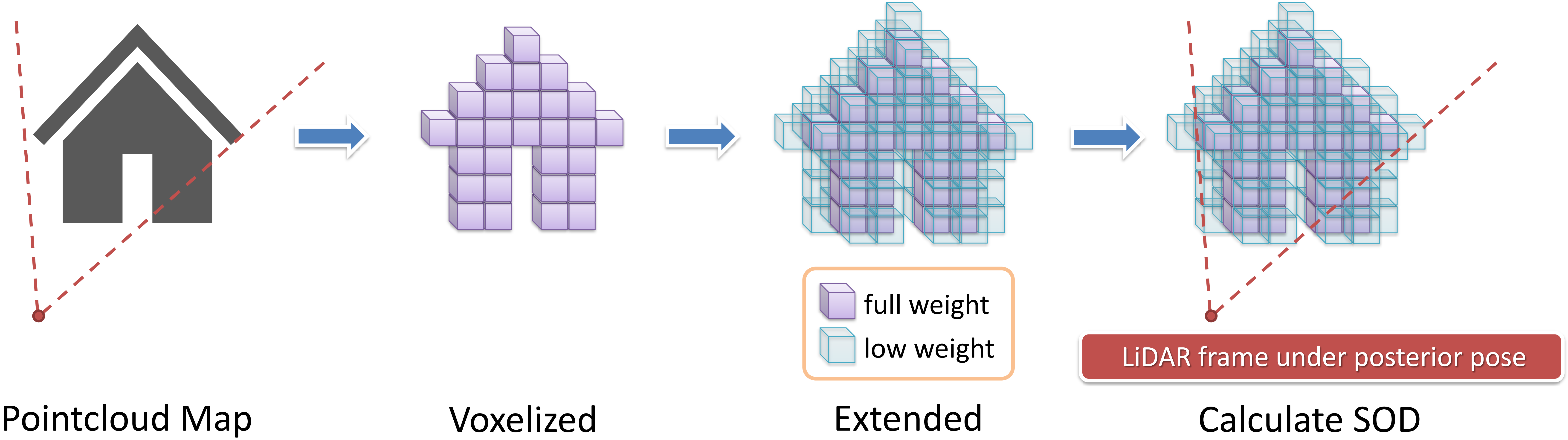
- Frame-to-map SOD used to assess the impact of current FOV change on pointcloud registration
- Adaptive sliding window manages LiDAR stream and dynamically adjust the update step according to SOD.

Method

1. Spatial Overlap Degree (SOD)

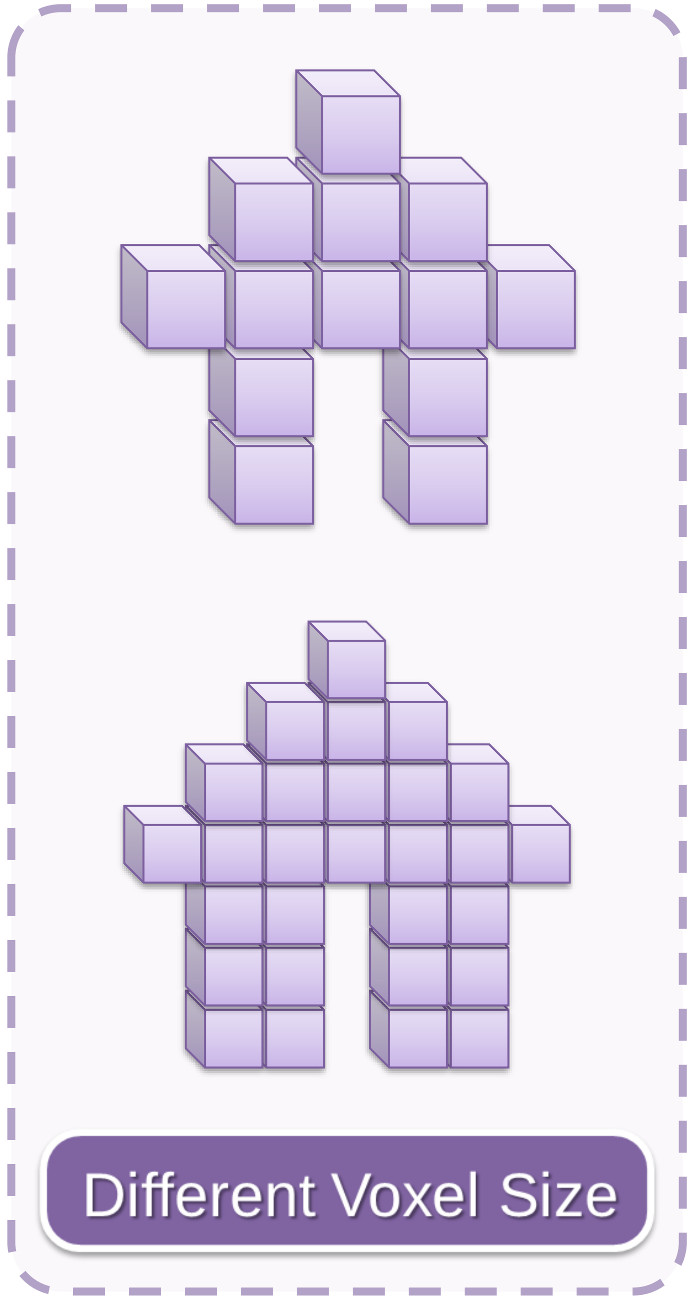
$\Rightarrow$ Aligned LiDAR frame hits the voxelized global map

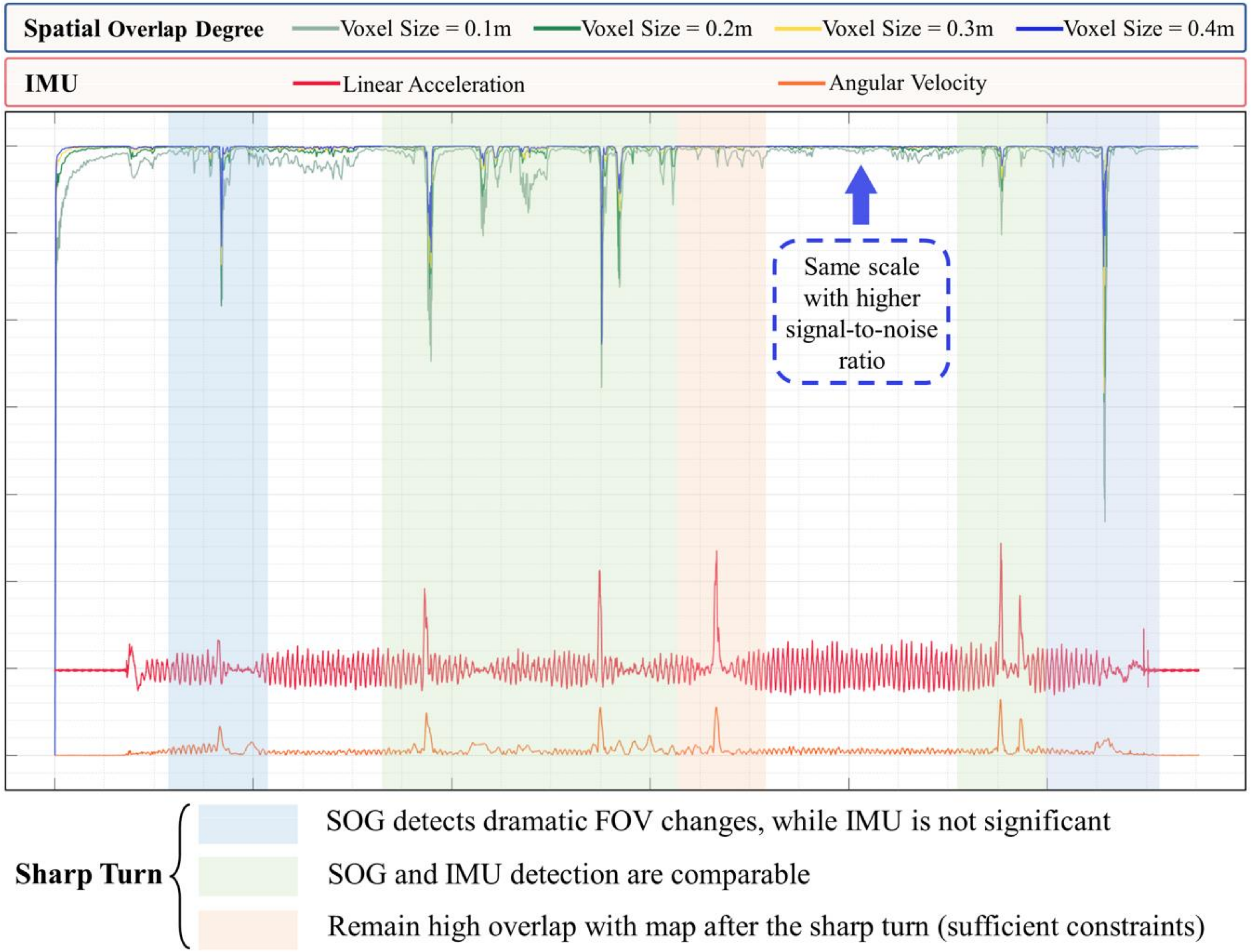
$\Rightarrow$ Appropriate expansion to enhance SOD robustness



Evaluation

- SOD Evaluation

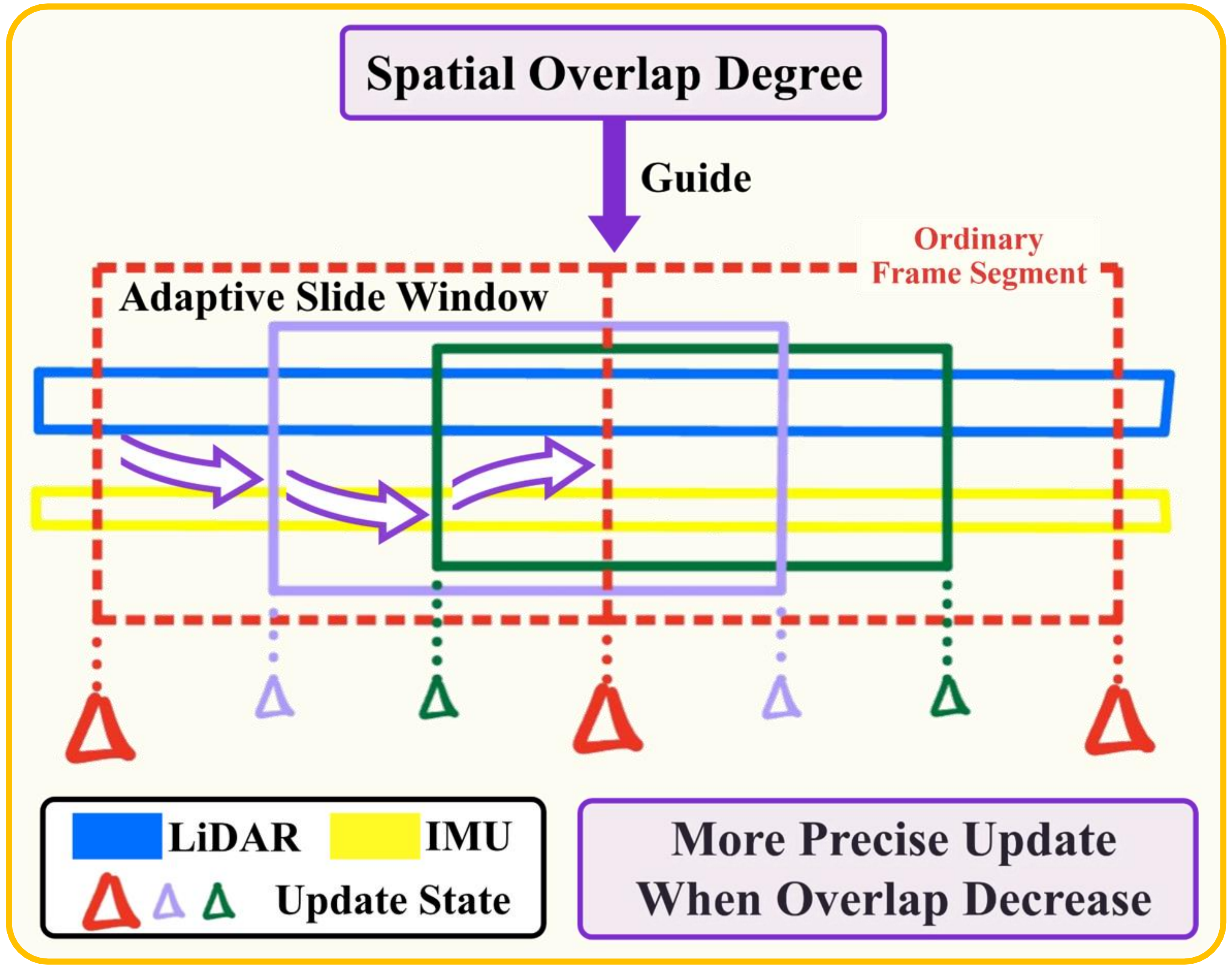




Method

2. Adaptive Slide Window

$\Rightarrow$ Adjust the shift_time according to SOD (Fixed frame_length)



1. Compute the seg_time of LiDAR frame base on seg_step as SOD decrease

$$seg\_time = \lceil (1 - O_f^{M^*})/seg\_step \rceil + 1$$

2. Compute the shift_time of Slide Window

$$shift\_time = frame\_length * 2/seg\_time$$

3. Maintain refinement with the echo_time

$$echo\_time = (seg\_time \leq 2)\ ?\ 1 : seg\_time$$

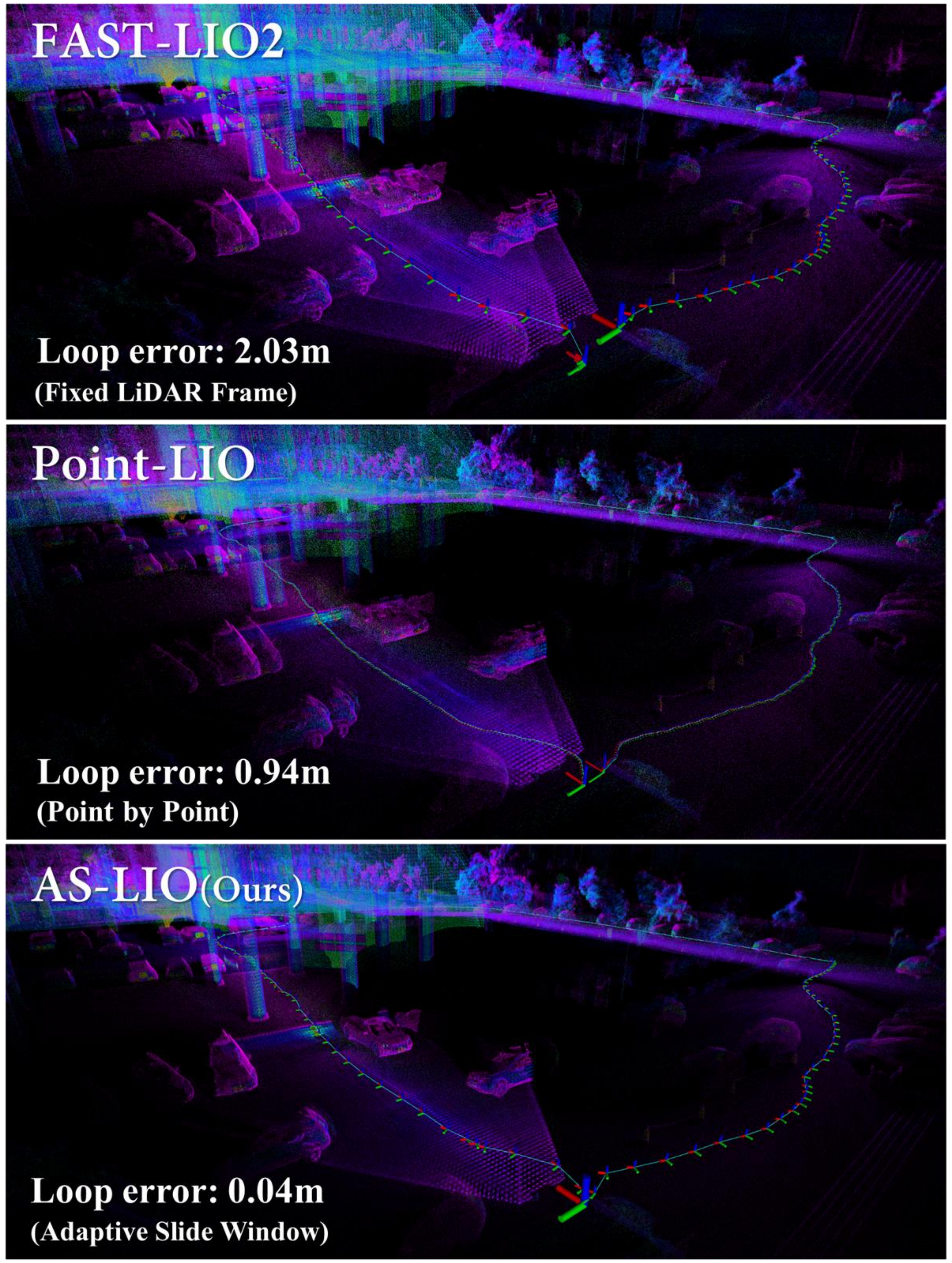
Evaluation

- Odometry Accuracy Evaluation

TABLE I
END TO END ERRORS (CM)

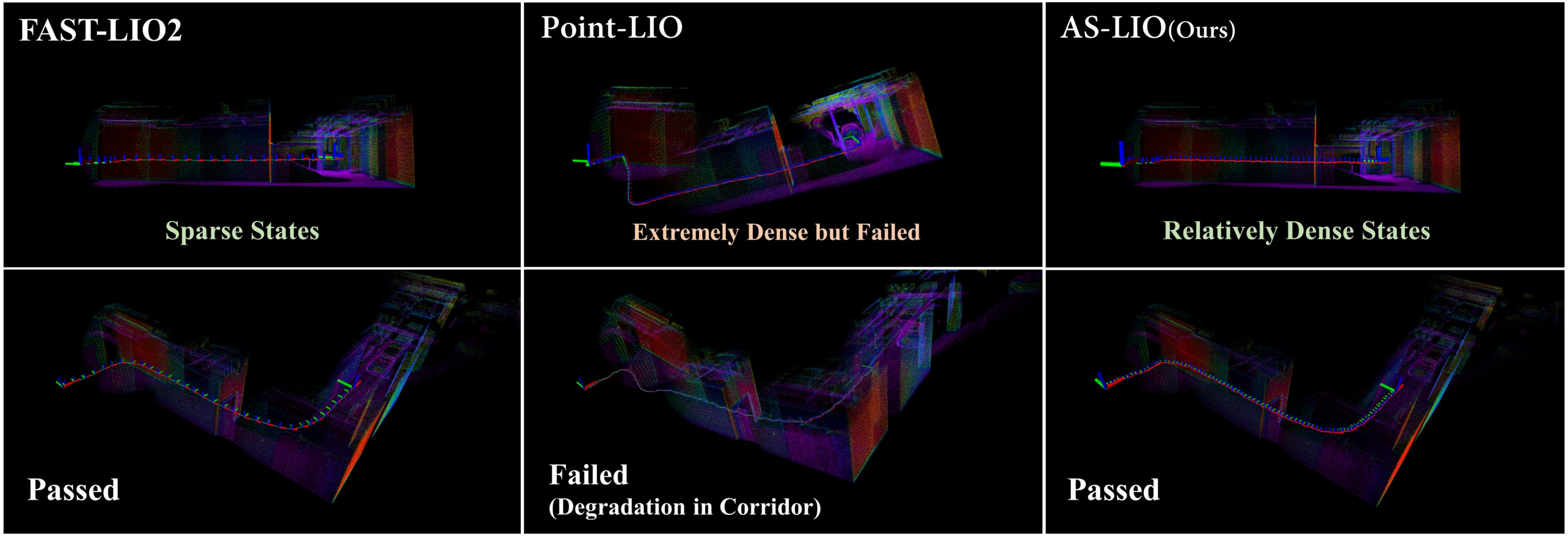
	AS-LIO(Ours)	FAST-LIO2	Point-LIO
indoor_1 (~100m)	**2.25**	28.19	-[1]
indoor_2 (~100m)	20.88	**14.58**	95.78
indoor_3 (~100m)	**119.88**	247.17	249.97
outdoor_1 (~300m)	**14.38**	×[2]	17.24
outdoor_2 (~300m)	**91.64**	227.88	230.57
outdoor_3 (~300m)	**112.98**	426.47	256.40
outdoor_4 (~300m)	**96.90**	113.38	104.59
outdoor_5 (~400m)	**4.41**	202.51	94.37
outdoor_6 (~500m)	**393.31**	483.04	410.77

[1] - denotes that the system severely diverged midway.
[2] × denotes that the system totally failed.



Evaluation

- Robustness Evaluation in Degradation Scenario



Thank you!

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