

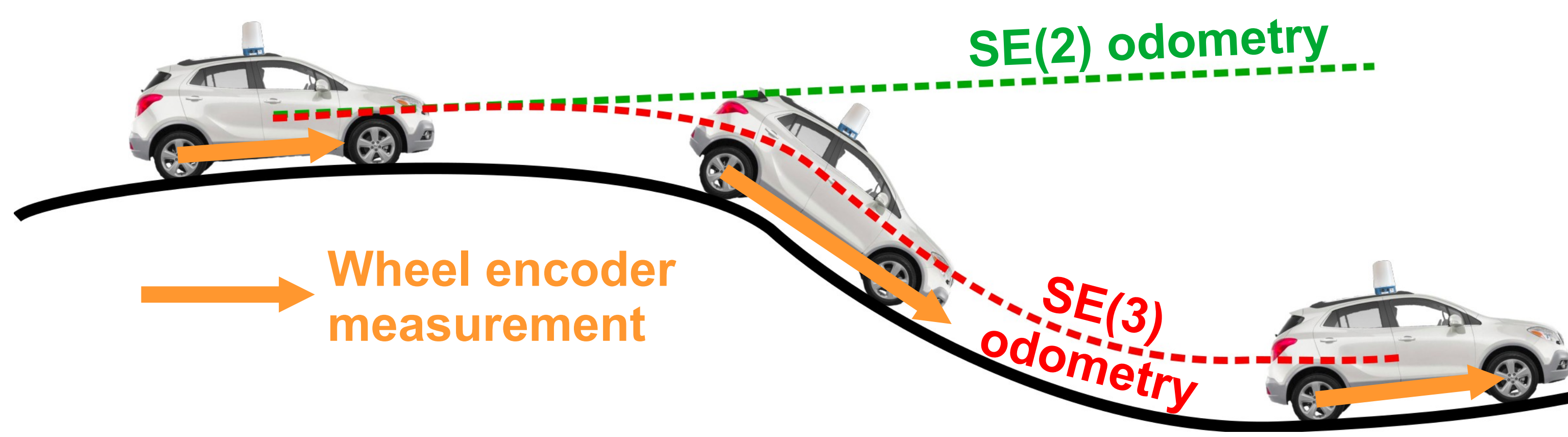
Did We Need to Reinvent the Wheel?

Lidar-level SE(3) Odometry with an Encoder and a Gyroscope

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How good can wheel-based odometry be for autonomous driving?

- Promising SE(2) results [1]
 - Limited performance for SE(3) localization



- This work**
 - Odometer Gyroscope SE(3) odometry
 - Denoted **OG3**
 - Intrinsic and extrinsic calibration
 - Wheel diameter
 - Wheel-IMU transformation

- Odometer Gyroscope SE(3) odometry**
 - Integration of angular velocities and encoder ticks

$$\mathbf{T}_W^{t_i} = \mathbf{T}_W^{t_{i-1}} \begin{bmatrix} \text{Exp} \left(\mathbf{R}_E^I \frac{\omega_{i-1} + \omega_i}{2} \Delta t \right) & \Delta \mathbf{p} \\ \mathbf{0} & 1 \end{bmatrix} \text{ with } \Delta \mathbf{p} = d \begin{bmatrix} 0 \\ \Delta e \\ 0 \end{bmatrix}$$

Encoder-IMU extrinsic rotation Wheel intrinsic

- Calibration is the key**
 - Non-linear least-squares optimization
 - $\mathbf{T}_E^I$ encoder-IMU relative transformation (5-DoF)
 - d wheel intrinsic parameter

$$\hat{\mathbf{T}}_E^I, \hat{d} = \underset{\mathbf{T}_E^I, d}{\text{argmin}} \sum_{i=0}^{N-M} \|\text{Log}(\Delta \mathbf{T}_i)\|$$

$$\text{with } \Delta \mathbf{T}_i = \mathbf{T}_E^I (\mathbf{T}_{GT_I}^{t_i})^{-1} \mathbf{T}_{GT_I}^{t_{i+M}} (\mathbf{T}_E^I)^{-1} (\mathbf{T}_W^{t_{i+M}})^{-1} \mathbf{T}_W^{t_i}$$

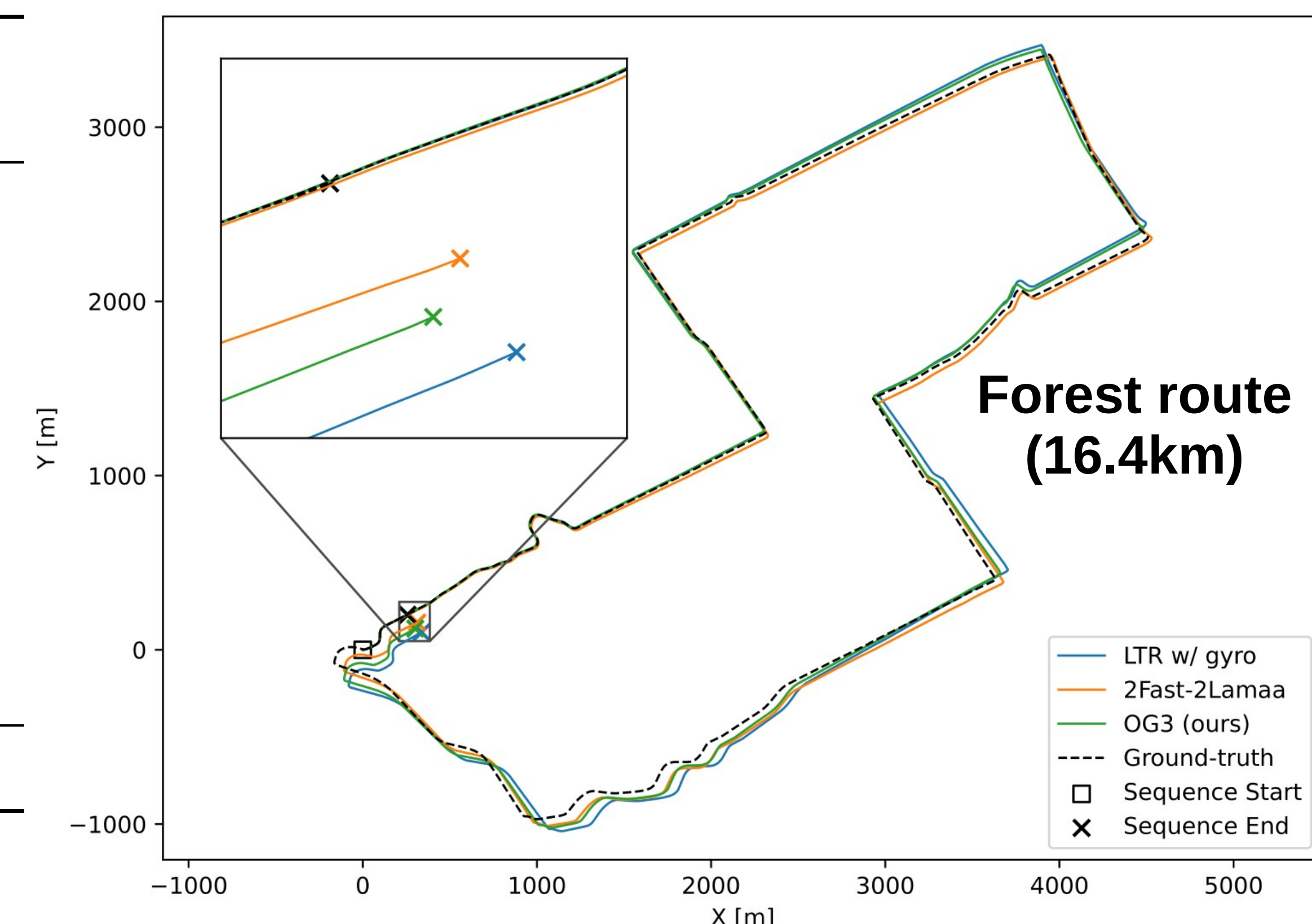
Experimental results using ~650km of data (made public as Boreas-RT [2])

“Wheel-based odometry is simple and efficient but ...

*... is not accurate and cannot beat lidar odometry” **WRONG***

Seq. type	Length	LTR w/ gyro [3]	2Fast- 2Lamaa [4]	Fast-LIO2 [5]	DLIO [6]	KISS-ICP [7]	OG3 (ours)
suburbs	10 × 7.9km	0.29/0.09	0.22/0.08	0.33/0.11	0.86/0.25	0.84/0.25	0.32/0.09
industrial	5 × 5.4km	<u>0.25/0.09</u>	0.20/0.07	0.28/0.10	0.87/0.28	1.18/0.37	0.38/0.13
urban	7 × 8.6km	0.49/0.20	0.38/0.10	0.57/0.16	0.92/0.25	0.77/0.23	0.53/0.23
forest	4 × 16.4km	0.70/0.11	0.47/0.18	<u>0.49/0.16</u>	1.10/0.31	1.14/0.32	0.47/0.08
farm	10 × 10.8km	0.44/0.12	0.36/0.10	<u>0.41/0.12</u>	0.73/0.20	4.86/0.28 ⁹	0.43/0.15
regional	6 × 9.3km	0.35/0.09	0.20/0.08	0.35/0.11	0.83/0.23	0.79/0.18	<u>0.28/0.07</u>
tunnel	10 × 1.9km	2.06/0.10	<u>0.35/0.11</u>	0.34/0.12	0.95/0.22 ¹	-/- ¹⁰	0.46/0.07
skyway	5 × 11.1km	0.77/0.08	0.30/0.09	<u>0.45/0.09</u>	2.62/0.19	3.18/0.27	0.57/0.05
freeway	3 × 57.6km	0.46/0.12	0.24/0.09	3.35/0.11 ²	-/- ³	1.02/0.15	<u>0.41/0.09</u>
average		0.65/0.11	0.30/0.10	0.73/0.12 ²	1.11/0.24	1.72/0.26 ¹⁹	<u>0.43/0.11</u>

KITTI odometry metric XX / YY with XX [%] and YY [°/100m] the translation and orientation errors, respectively.
The subscript ^{*n*} indicates the number of failed sequences (error > 5%)



*... does not work when it's slippery” **WRONG***



*... only works on flat terrain” **WRONG***



- Advantages of wheel and gyroscope odometry**
 - Extremely efficient
 - Negligible computation time (~4μs/step)
 - Estimate available at sensor frequency (~200Hz)
 - Agnostic to dynamic objects

- Future work**
 - Full integration in a lidar localization stack
 - OG3 as odometry prior
 - Finding limitations
 - Tests in extreme conditions and simulate noise

[1] C. Le Gentil, et al. "Do We Still Need to Work on Odometry for Autonomous Driving?" IEEE ICRA Workshop on Field Robotics, 2025.

[2] D. Lisus, et al. "Boreas Road Trip: A Multi-Sensor Autonomous Driving Dataset on Challenging Roads." Under review, accessible on arXiv, 2026.

[3] K. Burnett, et al. "Are we ready for radar to replace lidar in all-weather mapping and localization?." IEEE Robotics and Automation Letters, 2022.

[4] C. Le Gentil, et al. "2Fast-2Lamaa: Large-Scale Lidar-Inertial Localization and Mapping with Continuous Distance Fields." The International Journal of Robotics Research 2026.

[5] W. Xu, Y. Cai, D. He, J. Lin and F. Zhang, "FAST-LIO2: Fast Direct LiDAR-Inertial Odometry," in IEEE Transactions on Robotics, 2022.

[6] K. Chen, R. Nemiroff and B. T. Lopez, "Direct LiDAR-Inertial Odometry: Lightweight LIO with Continuous-Time Motion Correction," IEEE Int. Conference on Robotics and Automation, 2023.

[7] I. Vizzo, T. Guadagnino, B. Mersch, L. Wiesmann, J. Behley and C. Stachniss, "KISS-ICP: In Defense of Point-to-Point ICP – Simple, Accurate, and Robust Registration If Done the Right Way," IEEE Robotics and Automation Letters, 2023.