

A Novel Trajectory Evaluation Metric: Distance Travelled Error (DTE)



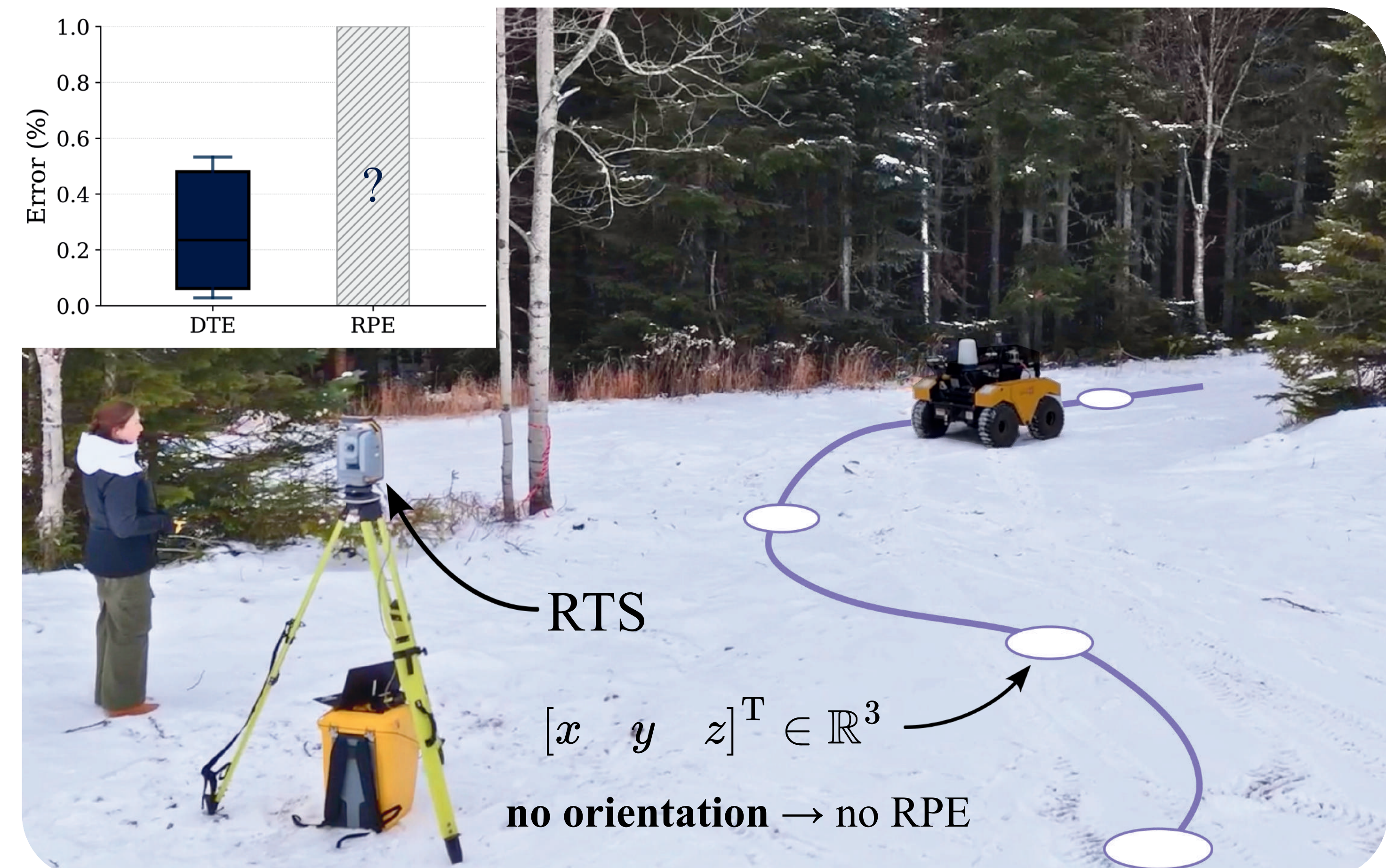
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Overview

- Gathering large scale ground truth trajectory is **difficult at best, impossible at worst**
- Distance Travelled Error (DTE)** quality error metric evaluating motion consistency solely with positions
- Temporal matching** based on curvature cross-correlation between trajectories
- Path length correction **without extrinsic calibration**
- GNSS against RTS reference trajectories **real-world experiments**

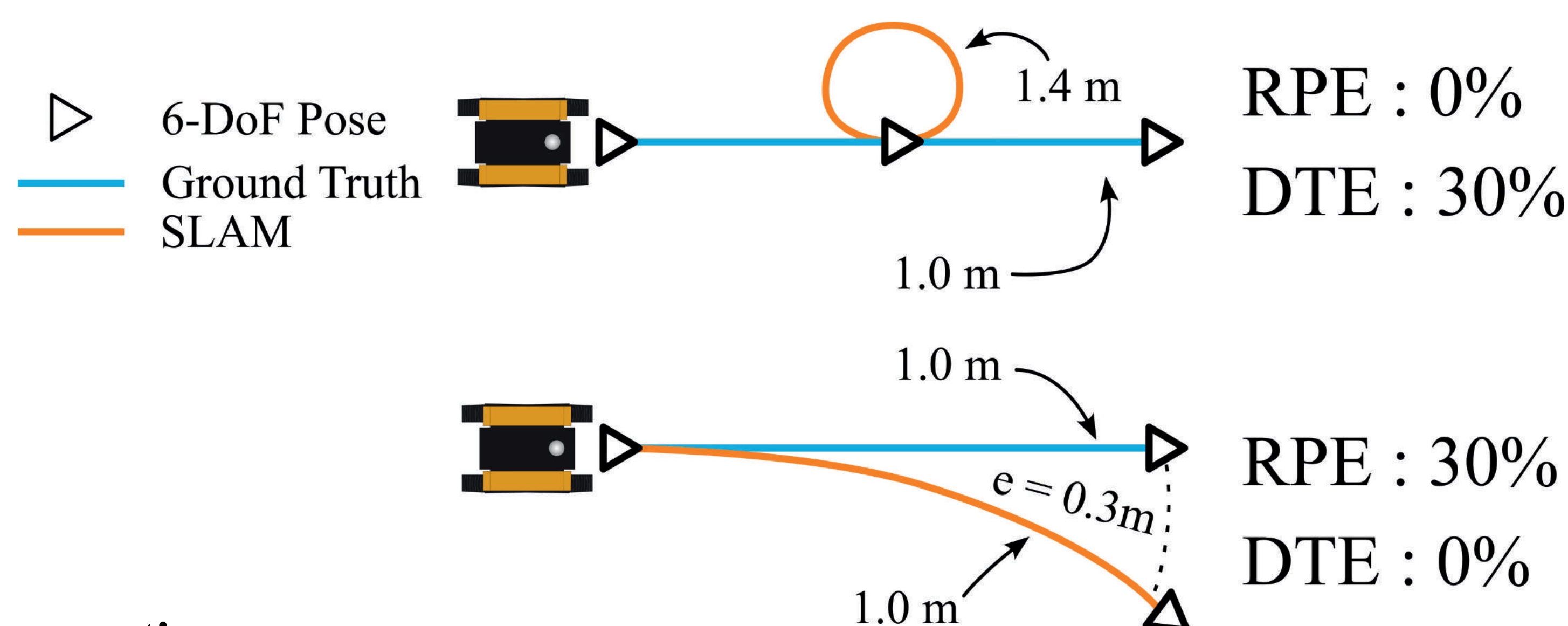
Can we find a relevant error metric without 6-DoF information at all times ?



Complementary Metric for ATE and RPE

Metrics like Absolute Trajectory Error (ATE) and Relative Pose Error (RPE) [1] evaluate system accuracy by requiring spatial alignment between SLAM and Ground Truth 6-DoF trajectories.

Distance Travelled Error (DTE) addresses this gap by validating motion consistency through distance comparisons over time, independent of 6-DoF poses.



Assumptions:

ATE, RPE: $\mathbf{P}^{est}, \mathbf{P}^{gt} \in SE(3)$ (6-DoF poses), $\mathbf{S} \in SE(3)$ (spatial alignment), $\mathbf{T}_{est}^{gt} \in SE(3)$ (extrinsic calibration), Δt (time calibration).

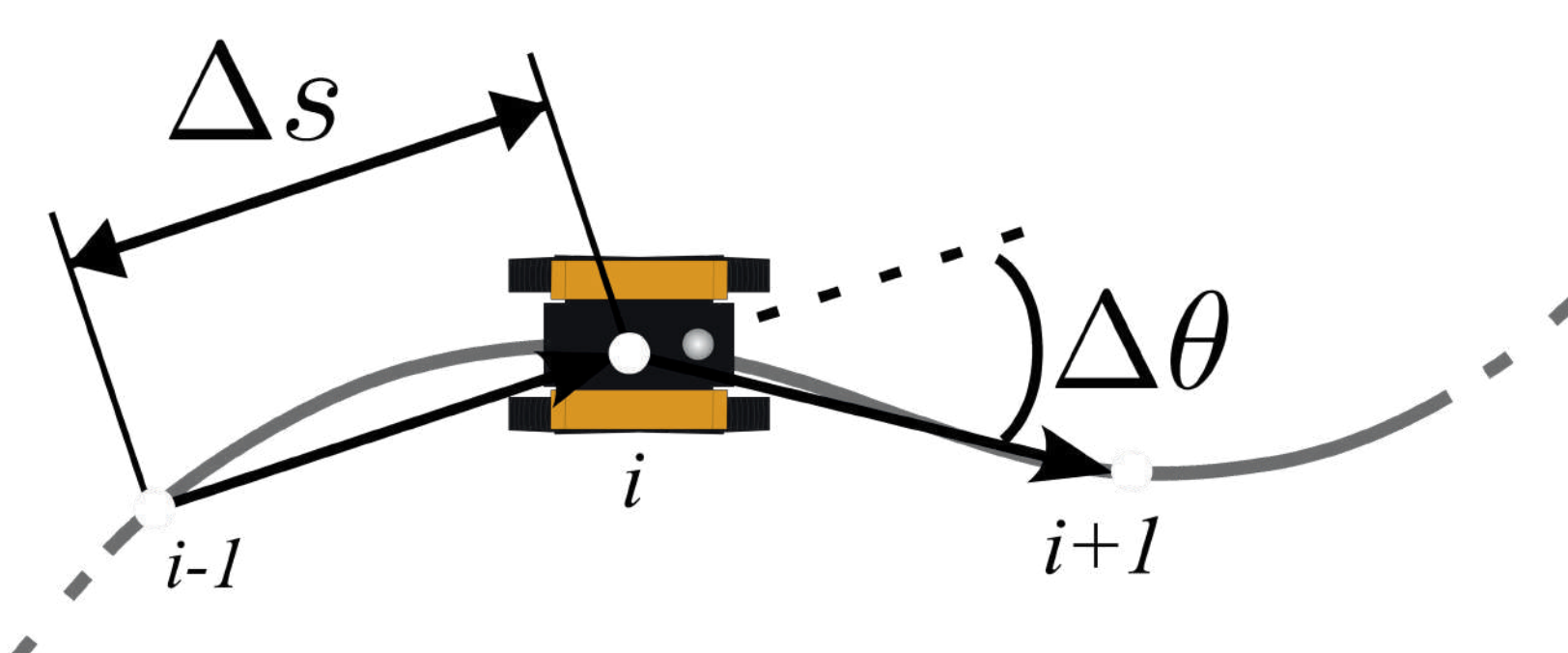
DTE: $\mathbf{p}^{est}, \mathbf{p}^{gt} \in \mathbb{R}^3$ (positions), Δt (time calibration).

Trajectory Curvature

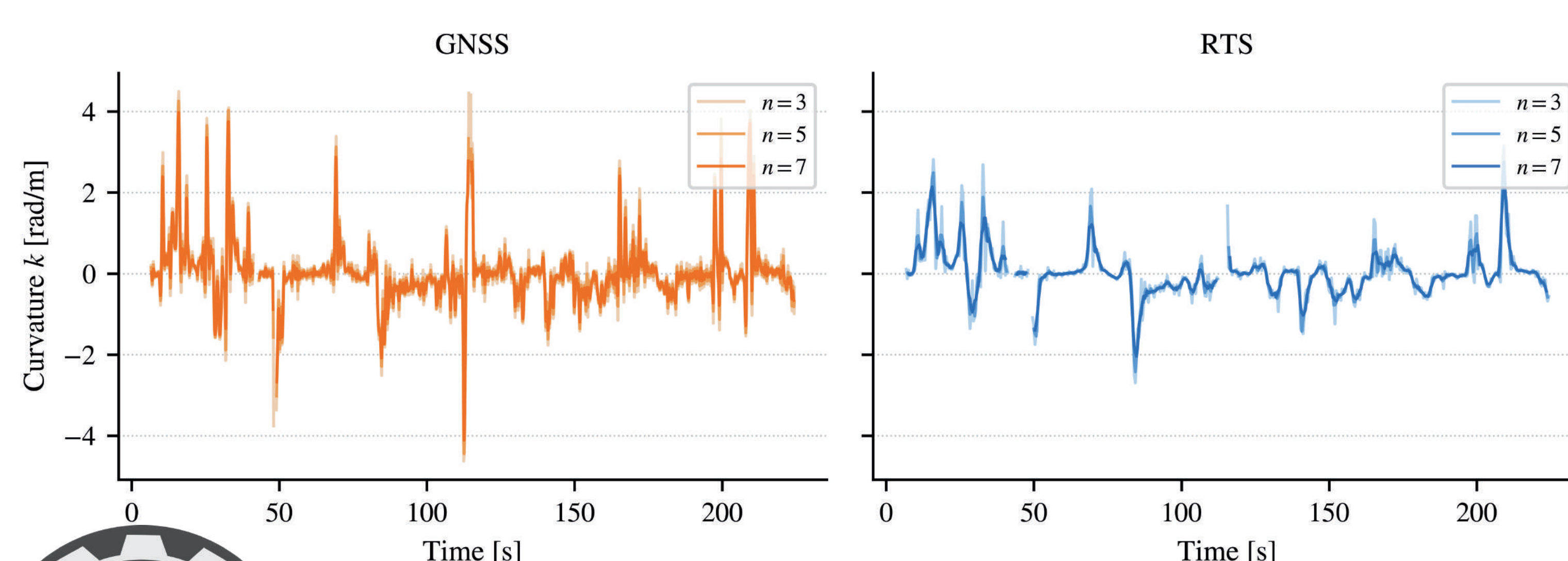
Definition:

Curvature κ at the point i is defined as :

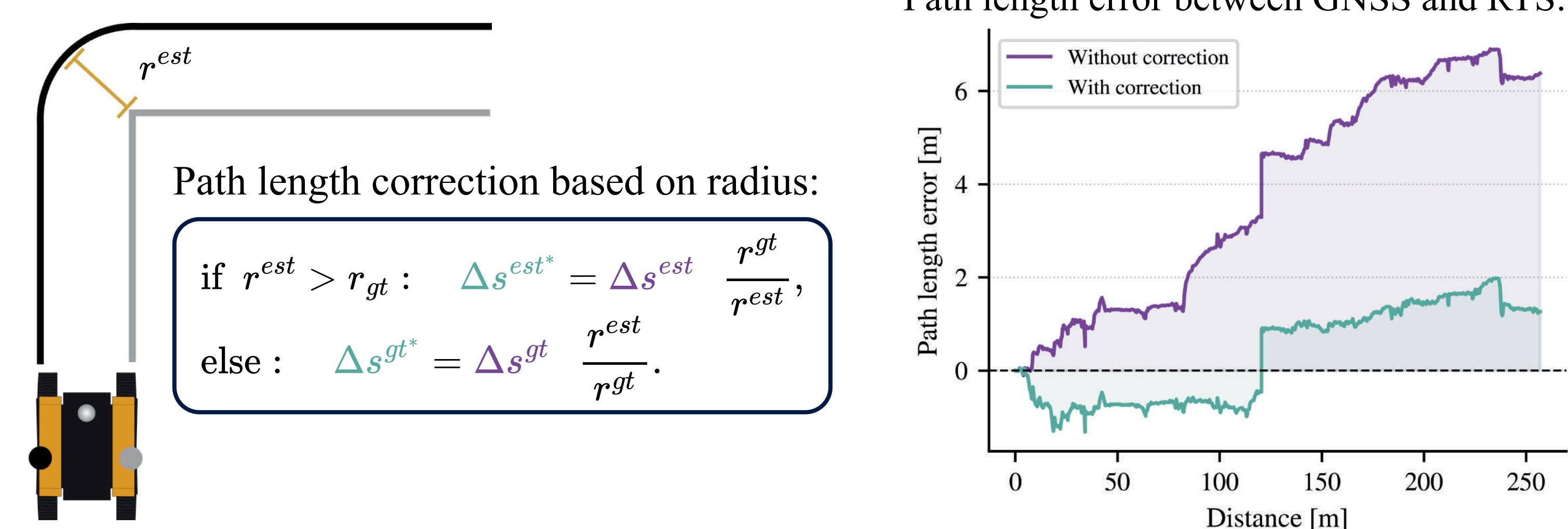
$$\kappa = \frac{\Delta\theta}{\Delta s}, \quad r = \frac{1}{\kappa}.$$



Curvature κ computed from $n = \{3, 5, 7\}$ consecutive points for the GNSS (left) and RTS (right) trajectories. Larger n smooths out noise but reduces temporal resolution. The shared curvature structure between both signals enables temporal alignment via cross-correlation.



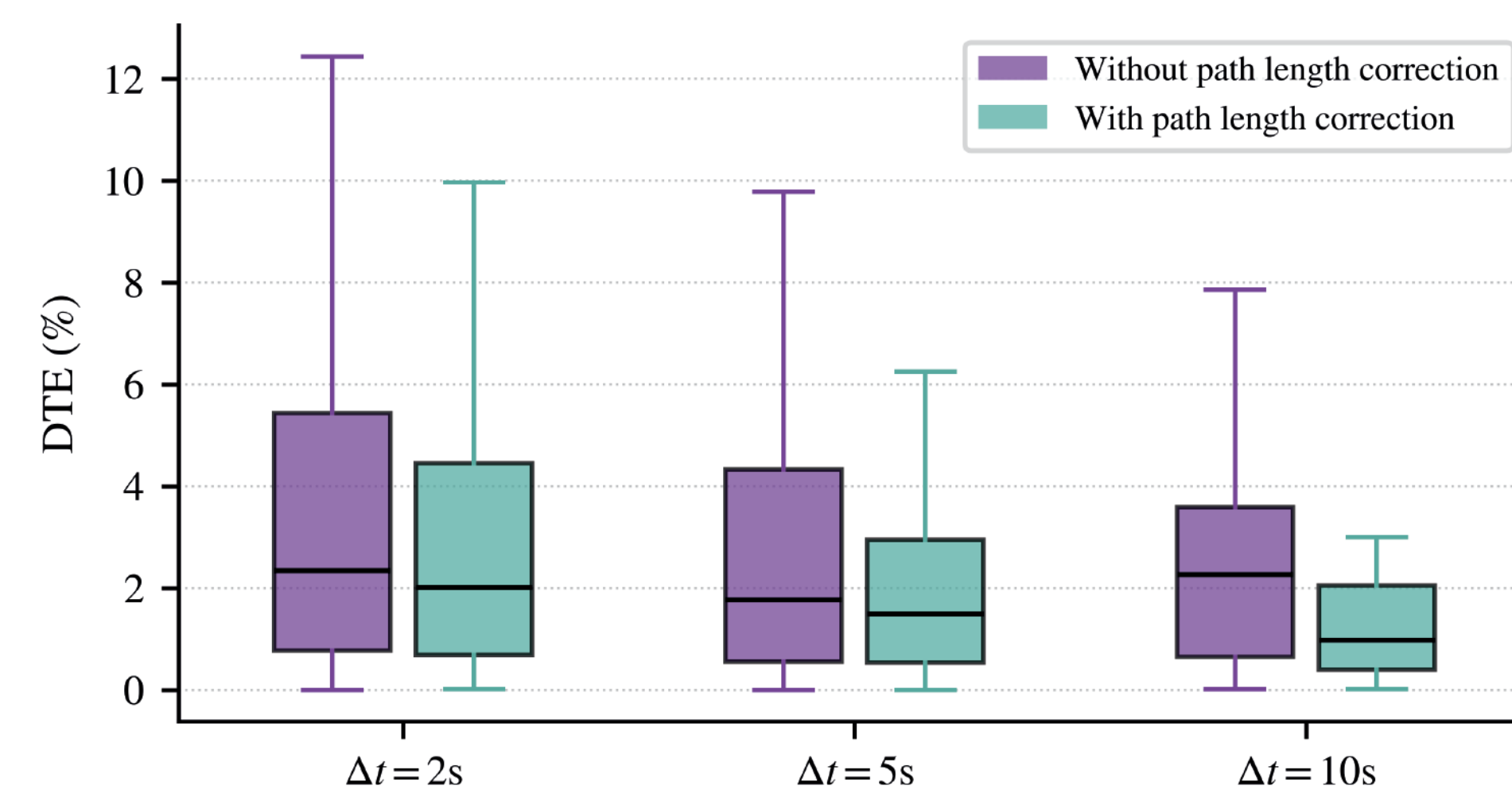
Path length correction



Sensors at different positions on a platform measure biased path lengths on curved paths. DTE compensates via radius-based segment correction — no extrinsic calibration required.

Real-world results show a reduction of the path length error of 300 % over 200 m.

DTE results shows an improvement across all time windows ($\Delta t = 2$ s, 5 s, 10 s).



Lessons Learned



Time synchronization matters a lot.

Ground Truth Pose (6-DoF) is expensive at scale.



Curved paths enable orientation-free evaluation.

[1] J. Sturm, N. Engelhard, F. Endres, W. Burgard, and D. Cremers, "A benchmark for the evaluation of RGB-D SLAM systems," in 2012 IEEE/RSJ international conference on intelligent robots and systems, IEEE, 2012, pp. 573–580.