Map-Assisted State Estimation for Autonomous Driving

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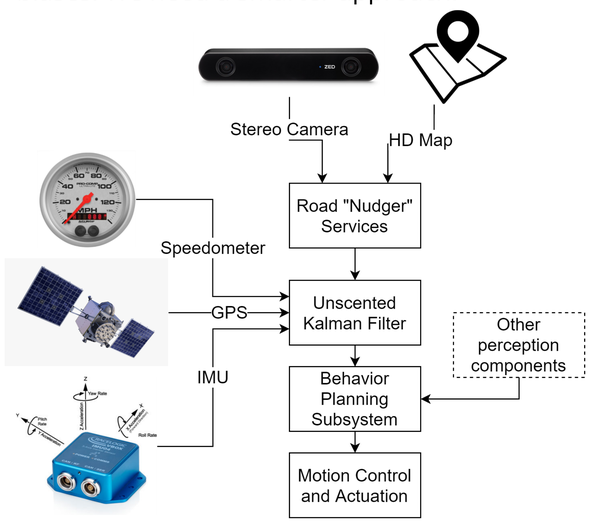
Problem and Significance

State estimation is tough, and no single solution has emerged despite decades of research.

State estimates are also important: All other parts of the robot rely on it.

Traditional fusion approaches can't eliminate biases. We need a smarter approach.



Above: Simplified architecture of our autonomous driving system (ADS).

OK, how about...?

Point matching is a popular approach, but it's noisy, unstable, costly, and hard to maintain. Marking-based localization is prone to adversarial or unintentional disturbance.

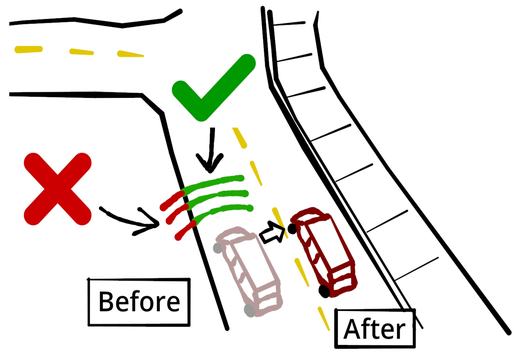
Visual odometry does not eliminate global bias.

Factor graphs are computation-heavy [1].

Methodology

Traditional sensor readings are combined with an ML-driven map correction using an Unscented Kalman Filter [2]. Our estimate is "nudged" until road points align with our map.

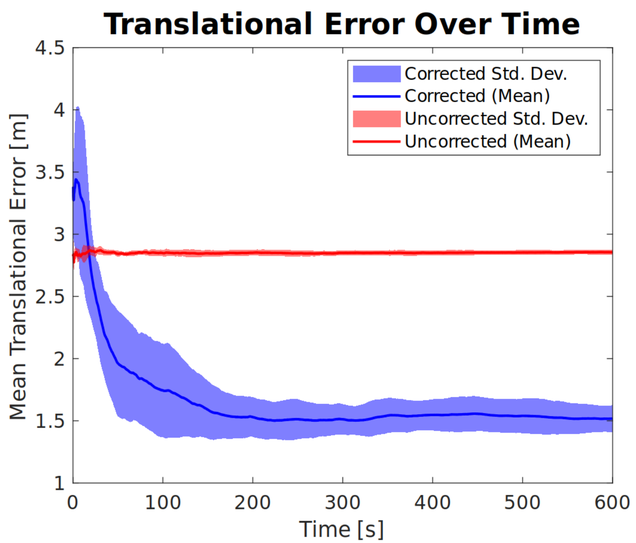
For experimental control, data was collected in a simulator [3].



Above: Misaligned points are identified and nudged back onto the road, yielding a more accurate position estimate.

Results

Our correction reduced estimation error by 47%, despite poor sensor quality.



Above: Corrected and uncorrected averages were each formed over six ten minute runs, for a total sample size of two hours.

Benefits and Limitations

Good news: Prexisting HD maps make system viable on common streets [4]. System is self-contained. Works even if lane markings are missing. Uses inexpensive sensors and is computationally efficient.

However, the UKF requires extensive tuning, and our system can be improved to handle sharp turns.

Counterclockwise and center: The car's view, including the road boundary (blue) and the identified road points (purple); an orangutan putting robots to shame; simulated camera; semantic segmentation; our HD map.

Future Work

- Parse open-source HD maps as inputs
- Implement ISAM2, which can accept motion constraints more naturally than UKFs

About Nova

Nova is an all-undergrad autonomous driving group sponsored by Dr. Justin Ruths. Our current goal is to drive two miles around UTD, with no human control. We're nearly there. Learn more at nova-utd.github.io.

Acknowledgements

We used several open-source tools here, including ROS, CARLA, robot_localization, libOpenDRIVE, DDRNet, Shapely, and Numpy. Visit heit.mn/thanks for more information.

References

[1] Borglab, (2022) GTSAM [Source code]. github.com/borglab/gtsam

[2] T. Moore and D. Stouch, "A generalized extended Kalman filter implementation for the Robot Operating System," In Proc. 13th International Conference on Intelligent Autonomous Systems, 2014.

[3] Carla Simulator, (2021) CARLA [Source code]. github.com/carla-simulator/carla

[4] "Lanes," in *OpenStreetMap Wiki*, OpenStreetMap [online document], 2022. Available: wiki.openstreetmap.org [Accessed April 22, 2022]

Videos, updates, and more: nova-utd.github.io