ASYNCHRONOUS MULTI-SENSOR FUSION FOR 3D MAPPING AND LOCALIZATION

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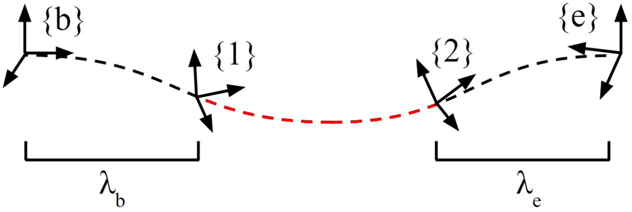
- Leverage cheap **asynchronous** sensors for localization and state estimation
- Design a **modular** system that can fuse multiple asynchronous sensors for estimation robustness and accuracy
- Use pose graph-based optimization and allow for **direct** incorporation of delayed measurements
- Reduce the overall **graph complexity** to allow for lower computation costs

Figure 1: Uber autonomous vehicle prototype testing in San Francisco. Credit Wikimedia Commons.

BINARY FACTORS - INTERPOLATION



- *Assumptions*: Constant angular and linear velocities
- Linear interpolate measurement in $SE(3)$ to stretch the relative transform in each direction
- Time-distance fractions are calculated based on the graph nodes and measurement timestamps
- Allows for direct addition into graph **without** adding new graph nodes

Design Goals:

- Use low cost asynchronous sensors
- Localize without using GPS sensors
- Localize in the global GPS frame of reference

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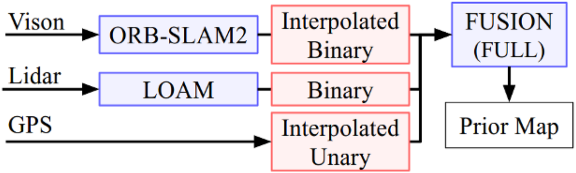
Proposed Two-Part System

1. Creation of an accurate prior map using a vehicle that has an additional Real Time Kinematic (RTK) GPS sensor unit.
2. GPS-denied localization leveraging the prior map to localize in the GPS frame of reference.



- Fuse odometry from ORB-SLAM2 and LOAM with **RTK GPS** readings
- Connected with vision **interpolated** binary factors
- Connected with GPS **interpolated** unary factors
- Generates prior map 3D point cloud in the **GPS frame** of reference

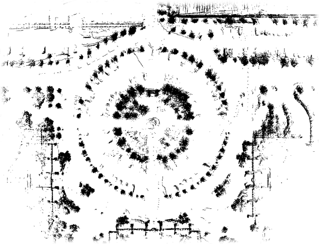
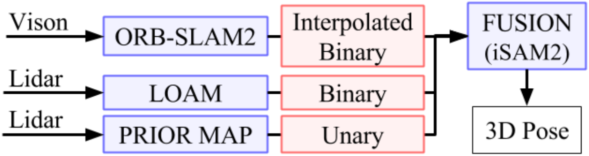


Figure 4: Prior map generated from the experimental dataset.



- Fuse odometry from ORB-SLAM2 and LOAM
- Connected with vision **interpolated** binary factors
- Perform ICP matching between LIDAR clouds and prior map
- Unary prior cloud factors constrain the estimate to be in the **global GPS frame** of reference

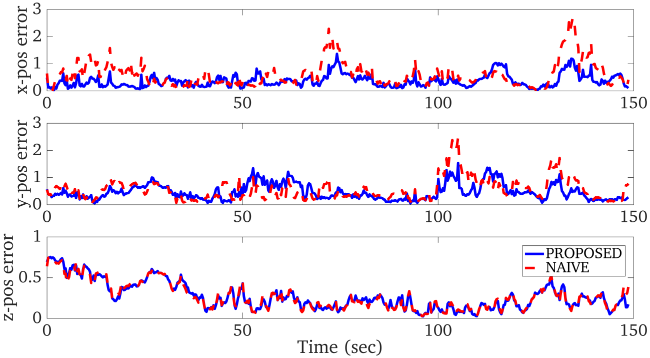


Figure 6: Position error in the x,y,z over 10 runs. GPS-denied estimation compared at each time instance, of the 500 meter long run, with the RTK GPS position. Average vehicle speed of 6mph. Average RMSE error was 0.71 meters for the proposed method and 0.93 meters for the naive approach (**overall 23.6% decrease**).

IMPACT OF ASYNCHRONOUS ALIGNMENT

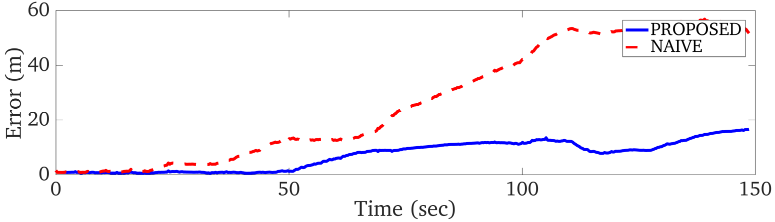


Figure 7: Comparison of the proposed method and naive approach position over 10 runs, using pure odometry measurements. RMSE error of the naive approach was 26.74 meters and the proposed method's average error was 7.026 meters (**overall 73.7% decrease**).

CONCLUSION

RPNG

- General approach of **asynchronous** measurement alignment
- Presented a modular system that allows for **any** sensor odometry
- Presented a **GPS denied** system that allows for localization in the global GPS frame of reference
- Tested on a experimental dataset, shown to have < 2 **meter accuracy**
- Compared asynchronous measurement alignment to a naive approach and showed **accuracy improvement**