Asynchronous Multi-Sensor Fusion for 3D Mapping and Localization

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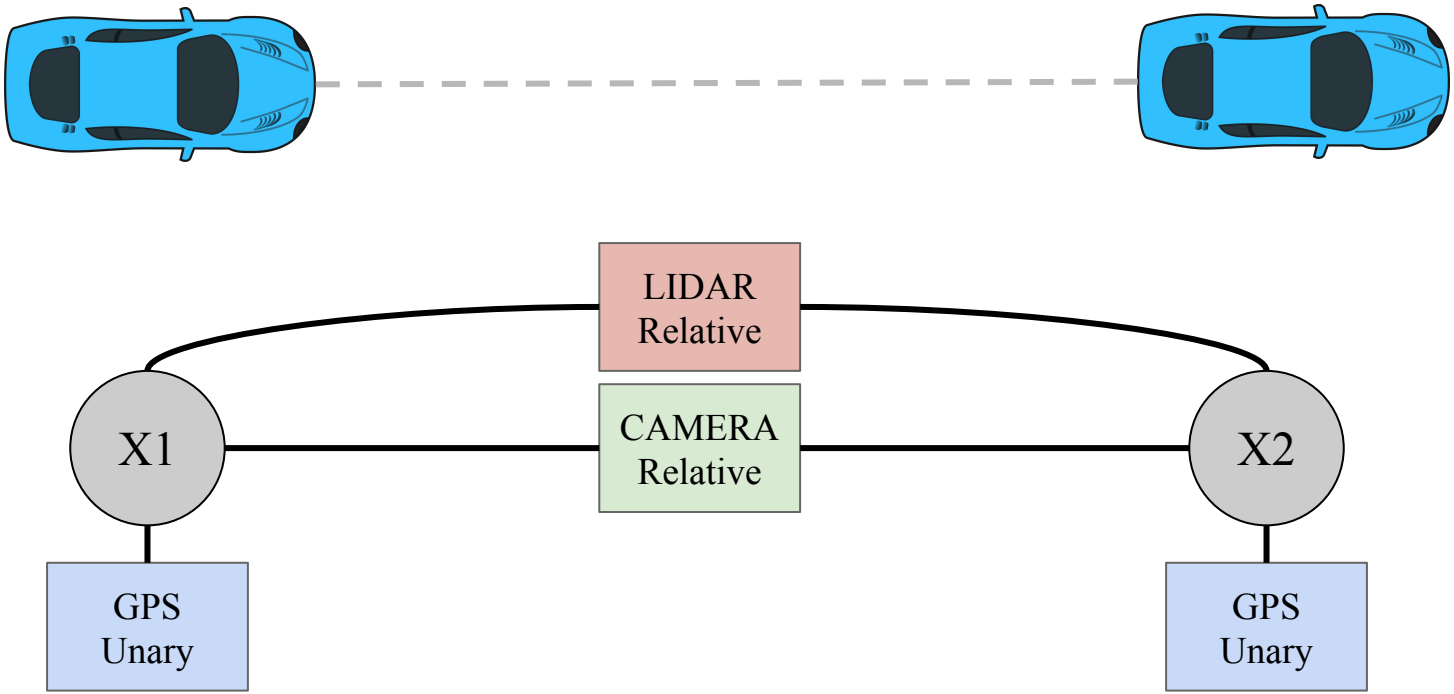
Motivations

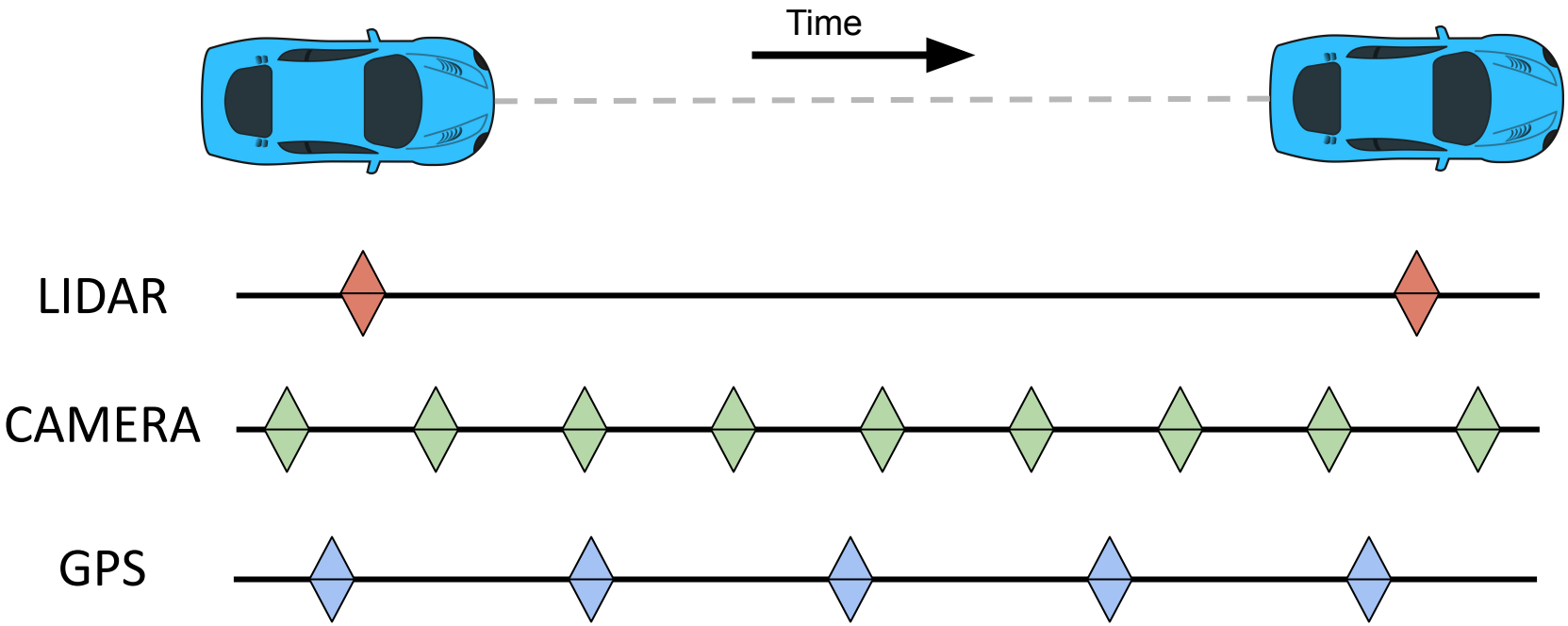
- **Asynchronous** sensor fusion for localization and state estimation through linear 3D pose **interpolation**
- **Modular** framework for multi-sensor 3D pose fusion for robust and accurate estimation
- Low graph complexity due to **direct** incorporation of delayed measurements through temporal alignment

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

Factor Graph

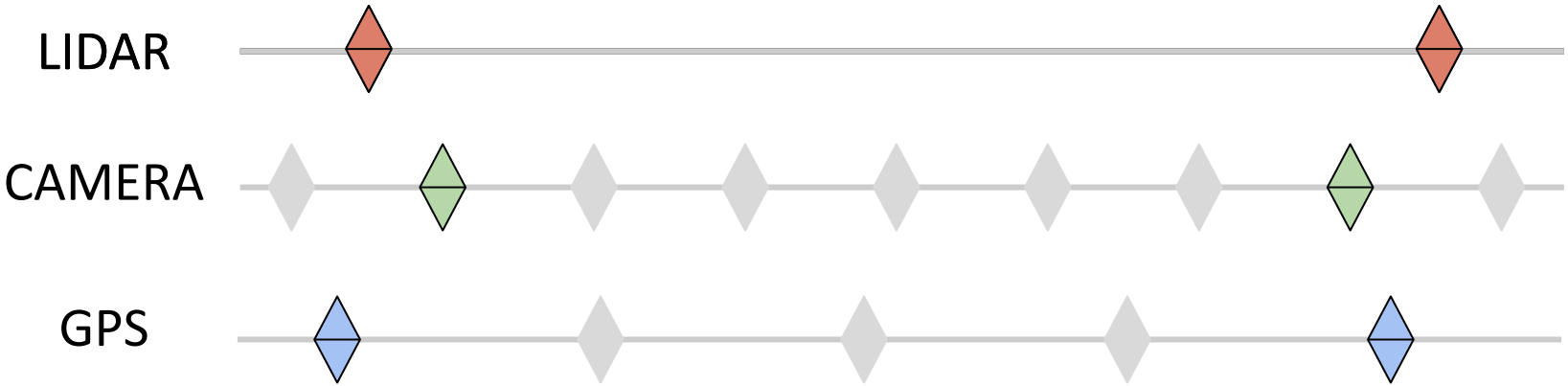


Asynchronous Measurements



Asynchronous Measurements

- **ISSUE:** Measurements are asynchronous, so no way to directly combine them without ignoring the time differences

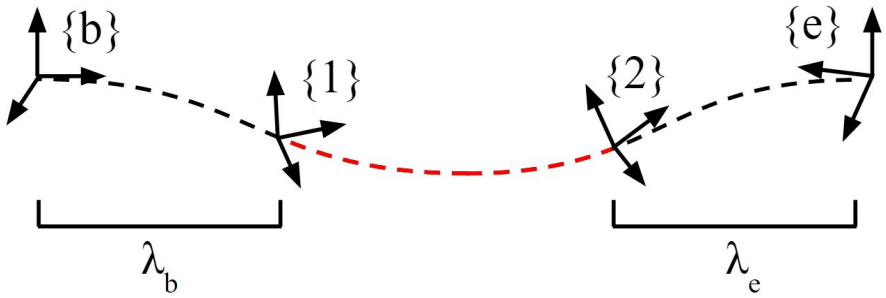


Proposed Measurement Alignment

- **SOLUTION:** Linear interpolate pose measurements so that they align with a given state time

Proposed Measurement Interpolation

- Linear interpolation of relative measurement to bounding state times
- Orientation is interpolated on the SO(3) manifold
- Covariance propagation is performed to calculate new measurement covariance
- *Assumptions:* Constant angular and linear velocities



System Design

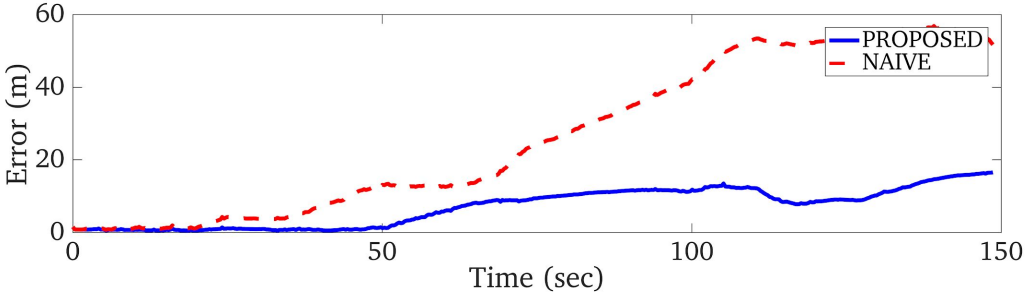
Design Goals:

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

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

Impact of Asynchronous Alignment

- Position error over 10 runs
- Odometry only (no prior LIDAR ICP factor)
- Average RMSE error:
  - 26.74 m naive approach
  - 7.026 m proposed



Conclusion

- 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
- Compared asynchronous measurement alignment to a naive approach and showed **accuracy improvement**