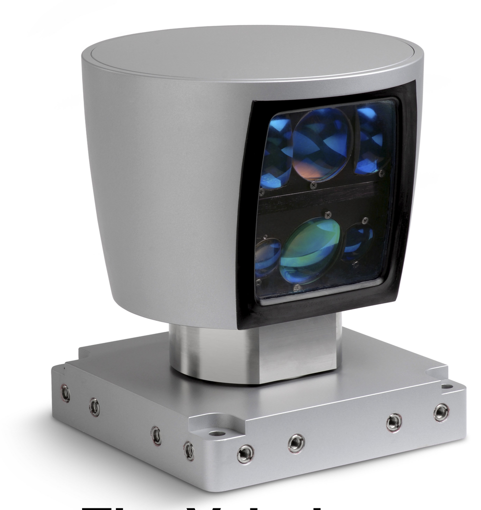
Unsupervised Remittance Calibration for Multi-Beam LIDAR

Summer Scholar: Colby Horn, Advisor: David Silver

Abstract

In recent years, multi-beam Light Detection and Ranging (LIDAR) sensors have become increasingly significant in autonomous navigation. While use of multi-beam sensors does have multiple benefits, such as increased resolution, it also significantly complicates calibration, including calibration of remittance returns. Consistent remittance returns from LIDAR sensors are particularly valuable for autonomous perception and action in real-world scenarios. Our goal is to develop an unsupervised remittance calibration approach which leverages the exceptional amount of data produced by the LIDAR sensor and the platform vehicle's change in pose to bring the multiple individual-beam sensors into agreement. We address this problem with 2 approaches: a simple conditional expected value over multiple beams[1] and a modified Expectation-Maximization (EM) algorithm[2]. Our calibration shows a decrease in variance between the remittance observations of individual beams while still maintaining the dynamic range of possible sensor outputs.

LIDAR



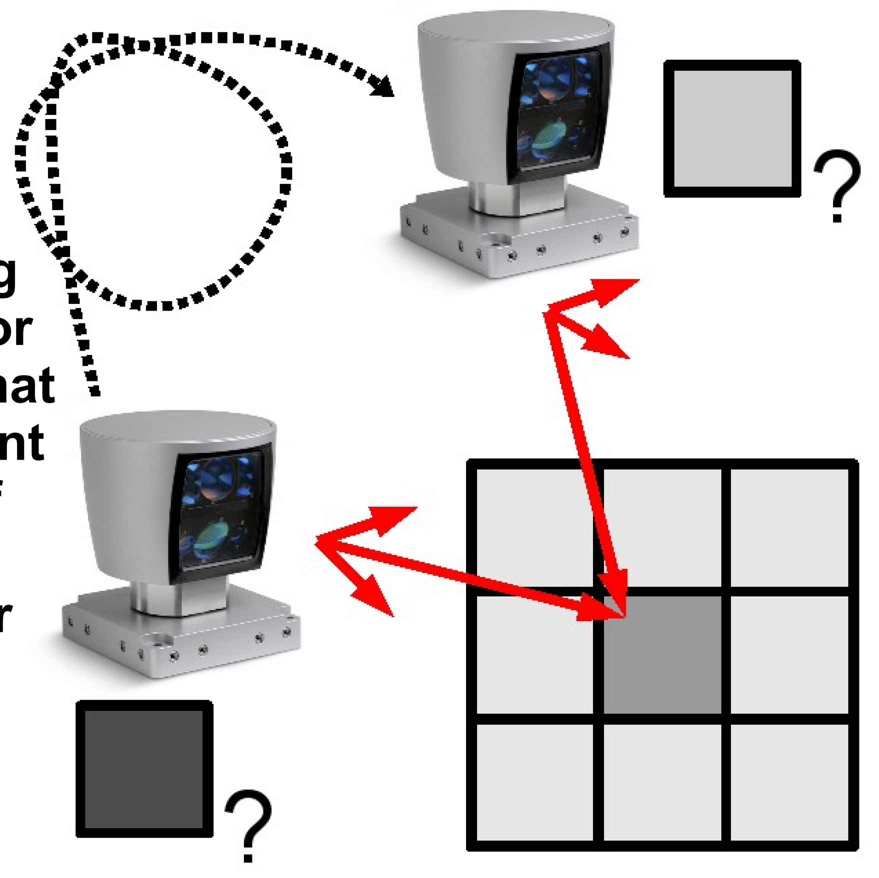
The Velodyne HD-64E Sensor

The Velodyne HD-64E sensor consists of 64 individual LIDAR beams spread in a vertical fan on a rotating platform. Each LIDAR beam continuously returns the distance and remittance of the nearest obstruction. Unfortunately, due to nuances of the manufacturing process each beam has a nonlinear error in its remittance returns both with respect to the world and to the other beams. In calibration we attempt to recover this error function and correct for it.

Calibration

As the vehicle platform moves through space, different LIDAR beams on the Velodyne observe the same location in space. Because the reflectivity of each location in space remains relatively constant over the short time in which we make our observations, we can incrementally approach a consistent calibration by altering beams which jointly observe a location in space so that they agree on its remittance. Care must be taken to avoid a trivially correct calibration which makes all LIDAR beams agree by returning only a single remittance value. This can be avoided by scaling the calibration so that its output range matches the domain of raw returns from the sensor.

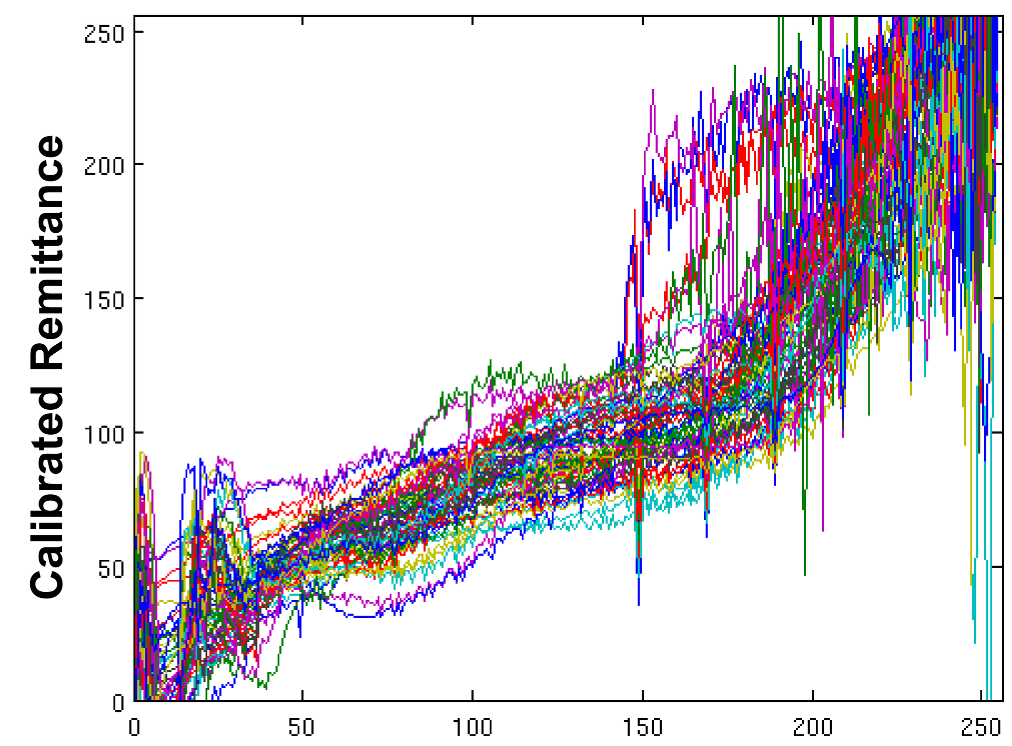
Calibration can be achieved by deriving an error functions for each LIDAR beam that maximizes agreement on the remittance of locations observed jointly with the other beams.

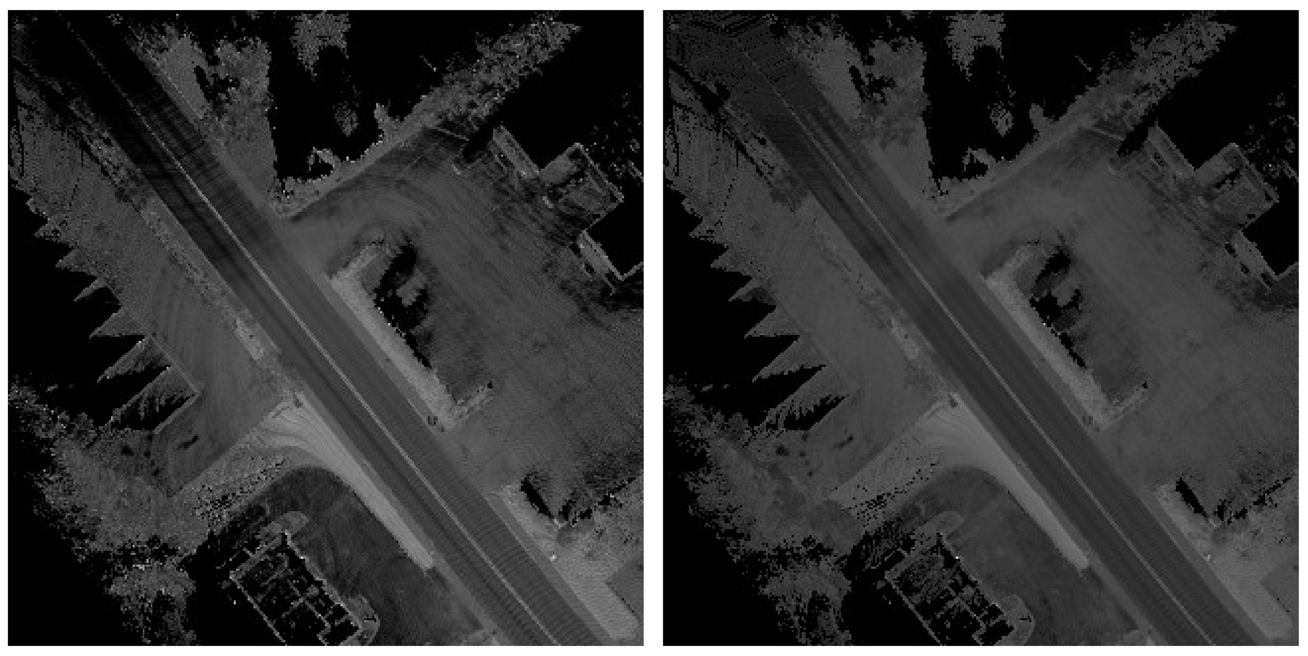


Results

Prior to calibration, Velodyne returns show evident biases in the observed remittance of some LIDAR beams, resulting in visual artifacts on surfaces of relatively constant remittance, such as the road bed. After calibration, these artifacts are minimized. In addition, The calibration process greatly reduces the variance in remittance observations of locations by multiple lasers. The calibrated output also maintains the dynamic range of the uncalibrated returns, avoiding convergence towards the uniformity of the trivially correct solution.

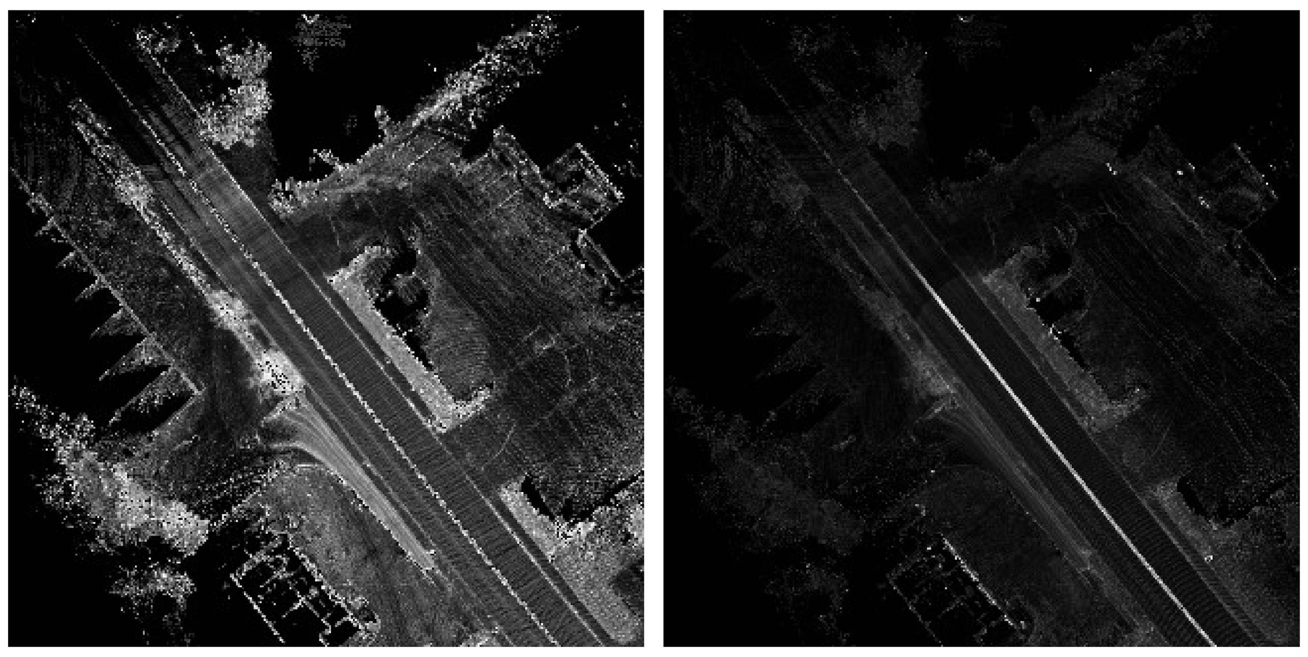
A complete calibration of all 64 LIDAR beams on the Velodyne sensor, each shown in a different color





Maps of remittance from uncalibrated (left) and calibrated (right) LIDAR sensors showing artifacts which result from variance in the uncalibrated beams' observations

Maps of remittance variance between beams from uncalibrated (left) and calibrated (right) LIDAR sensors showing a decrease in overall variance when calibrated



higher variance shown in lighter color

Acknowledgments

Special thanks to David Silver and Dean Anderson who were incredibly helpful and supportive throughout my work on the project.

References

[1]J. Levinson and S. Thrun, "Unsupervised Calibration for Multi-beam Lasers," in International Symposium on Experimental Robotics, 2010.

[2]J. Levinson and S. Thrun, "Robust Vehicle Localization in Urban Environments Using Probabilistic Maps," in International Conference on Robotics and Automation, 2010.