Miller, Megan Ph.D., Purdue University, July 2018. A Pseudo-Rigorous LiDAR System Calibration Approach and a Strategy for Stability Analysis. Major Professor: Habib A. Professor.

With LiDAR systems being a crucial technology for near real-time mapping and spatial analysis, the user community needs standardized LiDAR system calibration procedures that are robust for the wide range of users and scenarios. More specifically, a comprehensive calibration approach should entail rigor in automation for matching and handling the irregularity of LiDAR data, as well as generality in terms of type of terrain used and of raw measurement availability. Most times, the sensor model and raw measurements are unavailable to the end user, and therefore r*igorous* LiDAR system calibration is not possible. For this scenario, *pseudo-rigorous* methods have been developed that synthesize the raw measurements from the point cloud (and in some cases the trajectory) using certain assumptions (e.g. parallel flight lines). This work introduces a new *pseudo-rigorous* calibration approach called the *Quasi-Rigorous/Quasi-Simplified.* The existing *pseudo-rigorous* approaches include the *Simplified* and *Quasi-Rigorous*. The *Quasi-Rigorous/Quasi-Simplified* approach requires less raw measurements than the *Quasi-Rigorous* and it can be used for any type of terrain and can incorporate control unlike the *Simplified*approach. In addition to this new calibration approach, there is a performance analysis to test the robustness of the new and existing *pseudo-rigorous* approaches in non-ideal conditions, as well as a stability analysis strategy to analyze LiDAR system calibration results from two different dates. The stability analysis strategy quantifies the variation in system parameters over time and serves as an important Quality Assurance tool for consistently producing accurate point clouds throughout the lifespan of a LiDAR mapping system. The experimental results show the successful implementation of the new *Quasi-Rigorous/Quasi-Simplified* approach with real and simulated data, and compares the results with existing *rigorous* and *pseudo-rigorous* approaches. After inspecting the point cloud alignment and adjusted coordinates, it was shown that the *Quasi-Rigorous/Quasi-Simplified* approach is successful in significantly reducing the impact of systematic errors even though it makes several assumptions. Also, when compared to the existing *Simplified* and *Quasi-Rigorous pseudo-rigorous* approaches, the *Quasi-Rigorous/Quasi-Simplified* approach provides maximum capability while maintaining minimal assumptions and no requirements for raw measurements. In the performance analysis, it was shown that the *Quasi-Rigorous/Quasi-Simplified* and existing *pseudo-rigorous* calibration approaches are robust under non-ideal conditions, and a 52-

100 *Percent Improvement* was observed even in the extreme cases. Using simulated data, the stability analysis results show how to implement the strategy as a Quality Assurance tool and compared a 90-day stability analysis to a 270-day stability analysis. In addition to this, the new calibration approach, and the previous *pseudo-rigorous* calibration approaches, were successfully used to calibrate a multi-beam spinning LiDAR (VLP-16). This has not previously been done since the *pseudo-rigorous* calibration methods are developed specifically for single-beam linear scanning LiDAR systems.