Uncertainty Evaluation for a Kinematic LiDAR-Based Multi-Sensor System

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SUMMARY

In many applications, the movement of kinematic multi-sensor systems (MSS) is described by trajectories, which consist of six degrees of freedom poses over time. These systems may operate in urban, industrial or natural environments. The determined trajectories are frequently evaluated solely based on their accuracy, even though their self-reported uncertainty is also a valuable information for further processing steps. While not every application requires the highest attainable accuracy, every system should accurately report the uncertainty of its trajectory. These uncertainties are crucial for algorithms to ensure correct and safe decisions.

In localization, as in other fields, technological advances bring forward new low-cost sensors for use in various systems, including light detection and ranging sensors (LiDARs). In the context of localization, LiDARs are widely applied for tasks such as generating, updating, and integrating information from maps supporting other sensors to estimate trajectories. However, these low-cost sensors present new challenges for uncertainty modeling.

This contribution will demonstrate the uncertainty evaluation of a LiDAR-based MSS localizing itself using an inertial measurement unit (IMU) and LiDAR observations in combination with map information. The necessary steps for accomplishing the sensor data fusion will be presented and discussed with respect to the accuracy and uncertainty. This is done using the Mahalanobis distance, which considers the deviations to a reference trajectory weighted by with the reported uncertainty, and can be used to evaluate the consistency in hypothesis testing. All aspects will be shown using a real dataset obtained from an MSS consisting of a tactical grade IMU and a Velodyne Puck. The evaluation is performed based on data by a Laser Tracker in a laboratory environment. The results provide insights into the open challenges related to the integration of low-cost LiDARs in MSSs in the context of uncertainty modeling.
