Integration of Odometer Readings with INS and GNSS for Land Vehicles Navigation

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Abstract
The use of INS sensors together with GNSS receivers is one of the best examples of data fusion between high and low frequency oriented devices in what concerns the spectrum of accuracies. In fact, with good satellite visibility, accurate results can be obtained for a continuous and large spectrum of frequencies with moderate cost inertial devices, which are typically more expensive than GNSS receivers. Within this setting, the GNSS receiver plays a dominant role regarding positioning, whereas the inertial device dominates attitude measurement and plays a role in bridging positions between satellite measurements. Surveying with such system in urban areas, where satellite obstructions are frequent, extends the desired time interval during which the inertial device can hold a good estimate of the vehicle position. This is particularly demanding if decimetric precision position accuracy is sought through carrier phase processing methods, as relative motion estimates are needed to help fixing and maintaining ambiguities when obstructions cause the carrier phase tracking loops to break. Typically, a low cost inertial device can hold position estimates within decimetric precision for just a few seconds.

This article addresses the integration of odometer readings and vehicle motion constraint equations into the inertial data processing loop, in order to significantly extend the ability of this device to stay aligned and, therefore, keep position accuracy within strict bounds for longer periods. This approach can also be oriented at lowering the inertial device accuracy and cost needed for certain position accuracy. From a macroscopic point of view, the advantage derives from the fact that these new readings contain biases that are integrated once into position estimates, whereas inertial sensor biases and misalignments are integrated twice in the short term.

Two approaches are presented: one in which the odometer readings and vehicle motion equations are used to compute positions and velocities, leaving the inertial sensor with the role of determining the vehicle attitude, with alignment information for the latter being fed by the former (and by the GNSS measurements, in an outer loop). In the second approach, all sensors are integrated in a single Kalman filter. The odometer and the constraints are now used as state observations. The first approach is simpler and more suitable when the inertial device is of lower quality. The second approach proves advantageous when the inertial sensor quality if good enough so that the double integration of its measurements into positions produces results that are comparable (on the short term) to the single integration of the odometer measurements. In both cases, the satellite raw measurements are used directly in the filter (tightly coupled integration).

Regarding accuracy, the goal is to provide a dead-reckoning navigation system that is able to maintain position accuracy within the bounds that make quasi-instantaneous ambiguity fixing of L1/L2 data possible after severe satellite blockages. Another goal is to provide this accuracy without the need for certain vehicle maneuvers, like stopping for INS alignment.

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