Precise RTK Positioning with GPS/INS Tight Coupling and Multipath Estimation

Real-Time Kinematic (RTK) positioning is attractive for numerous applications including autonomous driving of vehicles. However, multipath remains a challenge for RTK positioning especially in urban environments. Choke-ring antennas which suppress code multipath cannot be used due to restrictions on the size, weight and costs. The used low-cost patch antennas cannot suppress the multipath, which can be of several tens of meters. Therefore, we will include a code multipath parameter for each satellite in our RTK positioning to prevent a mapping of the multipath into other state parameters and to exploit the temporal correlation of the multipath. We also enhance the ambiguity fixing by introducing two fixing phases: A candidate determination phase and a candidate tracking phase. In the first phase, we determine sets of integer candidate vectors using LAMBDA's integer decorrelation and tree search [1]. As the float solution and/ or its statistics might be biased, we determine integer candidate vectors at multiple epochs with different float solutions and merge these integer candidate vectors.
vectors. Thereby, we increase the likelihood of including the correct candidate vector in the set of candidate vectors. In the second phase, a conditional least-squares phase-only baseline estimate is determined for each candidate vector at every epoch. The sum of squared measurement residuals is accumulated over time for every candidate vector. This second phase has two important advantages over an instantaneous decision: First, the accumulation of the residuals improves the discrimination between candidates. Secondly, the used single epoch least-squares phase-only solutions are not affected by the float solution. This is helpful since any temporal correlation in the phase measurements (e.g. due to phase multipath) could lead to erroneous statistics of the float solution. We fix the RTK and attitude ambiguities sequentially: First, the attitude ambiguities are fixed in a tree search using soft a priori information on the baseline length. Subsequently, the RTK ambiguities are fixed in another tree search using both the measurements of the RTK baseline and the fixed measurements of the attitude baseline. We select the final candidate based on the accumulated sum of squared phase residuals and the baseline stability. The fixed attitude enables a precise estimation of the accelerometer and angular rate biases. A precise RTK position and attitude is then be obtained by tracking the fixed solution with GPS/ INS tight coupling. We show the RTK performance for both static and kinematic measurements: We obtained a millimeter-level positioning accuracy for static conditions and a centimeter-level positioning accuracy for kinematic conditions with multipath errors of up to 50 m.

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