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A hybrid data fusion method for GNSS/INS integration navigation system

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Although DGNSS is widely used and PPP-GNSS is nowadays a viable precise positioning technology option, the major disadvantage of GNSS still remains: signal blockage due to obstructions in urban and built up environments, and extreme power attenuation of the signals when operated indoors. The combination of GNSS with other sensors, such as a self-contained inertial navigation system (INS), provides an ideal position and attitude determination solution which can not only mitigate the weakness of GNSS, but also bound the INS error that otherwise would grow with time when the INS operates alone. However, the navigation accuracy provided by GNSS/INS strongly depends on the quality and geometry of the GNSS observations, the quality of the INS technology used, and the integration model applied. There are two main types of coupled schemes for integration systems: loosely coupled integration and tightly coupled integration. In loosely coupled integration, position measurements are taken from both systems and combined optimally, usually in a Kalman filter. Tightly coupled integration directly combines the raw pseudorange or carrier phase measurements of GNSS with inertial measurements in an extended Kalman filter. The latter technique improves the ability to resolve ambiguities, i.e. allows a quicker recovery from outage events such as a loss of signal under vegetation. In recent years, tightly coupled differential carrier phase GNSS/INS integration has become popular, because it has the advantage of providing accurate position information even when GPS measurements are rank-deficient in stand-alone processing and is theoretically optimal in a filtering sense, especially in urban navigation applications. However, the heavier computational burden and sensor communication usually complicate the tightly coupled integration and reduce the system efficiency, compared with the loosely coupled integration.

In this paper, it has been proved that the loosely coupled and tightly coupled algorithms are equivalent when following conditions are satisfied: 1) there is enough redundancy on the GNSS raw measurements; 2) only pseudorange measurements are used; 3) If differential carrier phase measurements are used, only the float solutions of the ambiguities are considered; 4) the covariance of the loosely coupled measurement model should come from the GNSS standalone solution instead of conventional pre-determined values. Based on the equivalence proof, a dual-step loosely coupled procedure is proposed to regenerate the equal ambiguity fixing solutions in tightly coupled procedure. Accordingly, the tightly coupled differential carrier phase or pseudorange GNSS/INS integration can be simplified, which will degrade to an equivalent loosely coupled integration when there are enough measurement redundancy and recover to a tightly coupled integration when GNSS measurements are rank-deficient. By this hybrid data fusion method, both the optimality of the tightly coupled algorithm and the efficiency of the loosely coupled algorithm can be conserved. Field test results confirm the effectiveness of the proposed method.