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PARALLEL STATE ESTIMATION UNDER FLEXIBLE CONNECTIONS IN SMALL CELESTIAL BODY LANDINGS

Abstract

In small celestial body landing missions, the target environment is generally dark and unknown before launch. Useful information for onboard navigation is scarce on the small celestial body surface. Consequently, the autonomous navigation system suffers from little available information and limited state estimation precision in the landing process. Nevertheless, by employing a multi-sensory cooperative navigation system, the effective observation range would be extended and multi-scale measurements from various sources would be obtained. Through distributed measurements and sensor communications, the overall navigation performance is expected to be improved. The problem of state estimation for small celestial body flexible landing using cooperative navigation is investigated in this paper. Specifically, the influence between the flexible connections among the sensors and the sensor states is taken into account. A distributed extended state estimation method is proposed for precise cooperative estimation of each sensor's state.

First, the state of the cooperative navigation system and the sensor states are described in a multi-sensor united coordinate system, established upon the geometric relationship of the sensor nodes. Considering the restrained effect imposed by the flexible connections on each node, an equivalent restrained vector is defined. The actual state of the node can be regarded as the sum of the free state vector and the equivalent restrained vector. The equivalent restrained vector is then treated as the extended state of the node. A distributed extended state filtering algorithm is designed, which accomplishes a simultaneous estimation of both the free state and the equivalent restrained vector. In view of the bidirectional restrained effect of the flexible connections, a correction method that fuses equivalent restrained vector estimates is further proposed. By exchanging state estimates and measurements among the sensors, consensus of the adjacent nodes' estimation results with respect to the equivalent restrained vector can be guaranteed. The proposed method reduces onboard computation burden through a distributed state estimation manner. It also solves the consensus issue of the physical constraints under estimation errors. Afterwards, the proposed method is validated and compared with the standard distributed EKF algorithm through simulation. It shows that, for cooperative navigation systems with dynamic internal restraints, the precision of state estimation can be effectively improved by implementing the extended state estimation method.