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ROBUST INTEGRATED ESTIMATION AND CONTROL OF PINPOINT LANDING ON MARS

Abstract

Landing on Mars has a significant importance in current and future space missions. Although there are ample works about the lander's control during this critical phase, concurrent estimation and control of the vehicle is so rare. Although most of the existing estimation and/or control techniques have been developed based on acquiring exact models of the system, considering uncertainties arisen in the Mars atmosphere and vehicle's dynamics, providing an accurate and reliable model of the dynamic system and the measurement package is not possible. In this regard, the present research has focused on robust integrated estimation and control of a Mars lander to address uncertain aerodynamic modeling, atmosphere instabilities and starting point of the powered descent phase. The proposed algorithm is shaped in the variable structure control framework. While the estimation technique is a combination of accurate cubature Kalman filter (CKF) and robust smooth variable structure filter (SVSF) called CK-SVSF, the sliding mode control has been adopted to control 6-DOF motion of the Mars lander. Nevertheless, this estimation algorithm suffers two disadvantages of requiring linear/linearized measurement vector as well as the same dimension of the state and measurement vectors. In this regard, the present work has modified the existing CK-SVSF to address these difficulties via replacing analytical linearization with statistical one and utilizing matrix generalized inverse theory. Consequently, state estimation error covariance matrix has emerged in the filter gain formulation against existing algorithm. Position vector and Euler angles are assumed to be measured, and the roto-translational motion of the vehicle is modeled using the non-singular method of the dual quaternion parameters. In addition, geometric constraint of the landing point is considered in system modeling, Mars planet is assumed an ellipsoid to model the gravity force, and the atmosphere rotation is considered in aerodynamic force and moments modeling. While all forces and moments are considered to simulate the measurement vector, atmospheric drag and side force are omitted from the model utilized in estimation and control algorithm, i.e. a huge uncertainty imposed to the system modeling. Then, performance of the proposed integrated estimation and control is investigated via Monte Carlo simulations. The obtained results show that despite modelling and initial uncertainties, the proposed algorithm has successfully converged the system to the desired point precisely.