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A ROBUST PATH-TRACKING GUIDANCE CONSIDERING UNCERTAINTY FOR MARS ATMOSPHERIC ENTRY

Abstract

The capability of pinpoint landing at certain site of special scientific interests will be required by the future Mars landing missions. The atmospheric guidance during Mars entry phase is critical for pinpoint landing. The success of Mars Science Laboratory mission also demonstrated the contribution of path-tracking guidance to the landing precision. Even though several Mars atmosphere model has been built based on previous measurements, an accurate determination of atmosphere density can still not be achieved due to the randomness and time-varying disturbance. Furthermore, the limited navigation measurements result in the large errors in state estimation. These uncertainties and disturbances may cause the performance degradation of traditional path-tracking guidance based on deterministic system. This paper is devoted to develop a robust and feasible path-tracking guidance law for the Mars entry phase. First, the dynamics of Mars entry scenario is introduced and the formulation of drag and drag rate feedback is derived. Meanwhile, the uncertainties in the atmosphere density and the navigation errors together with their impact on the deviations in drag and drag rate are analyzed. Based on the optimized entry trajectory and bank angle profile, the concept of Model Prediction Control (MPC) is introduced to develop guidance law. In order to simplify the computation, only the tracking error and control command deviation are considered in the performance index. A dynamic model is also linearized to predict the drag and drag rate analytically. Considering the uncertainties in atmosphere density and navigation errors, a robust path-tracking guidance law is modified to minimize the standard deviation of predicted errors of drag and drag rate. In the algorithm, linearization method or polynomial chaos method can be used to analytically calculate the propagation of path-tracking error. For performance analyze, entry corridor is designed to correct the crossrange error. Meanwhile, the entry navigation system based on radiometric measurements is also considered to estimate the vehicle's position and velocity. Both proposed guidance laws considering and without considering the uncertainties are simulated, and a throughout analyze of corresponding path-tracking errors is performed. It is found that the standard deviation of tracking error from proposed robust path-tracking guidance law is over 30