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HIGH-PRECISION PREDICTIVE SKIP ENTRY GUIDANCE FOR HUMAN LUNAR RETURN VEHICLES WITH LOW LIFT-TO-DRAG RATIOS

Abstract

A predictive guidance algorithm that regulates the bank reversal time online is proposed for low lift-to-drag vehicles in the skip entry phase of a lunar return mission. Firstly, deviation dynamics are obtained by applying the linearization method to the normal entry dynamical system with a spherical and rotating Earth as well as coupled lateral and longitudinal motions. Then, Gauss Pseudospectral method is applied to discretize these dynamical constraints into a group of linear algebraic equations. Thus, combining with the trajectory integration, boundary deviations can be explicitly expressed as the function of the state and control deviations at the initial point and Gauss collocation points. Since the skip reentry is consisted of the first skip phase, the Kepler orbit phase, and the second reentry phase, the terminal state deviations can be formulated by the transfer matrix. Next, the magnitude and reversal point of bank angle are selected as two control parameters, and the magnitude is parameterized as a piecewise linear function of the flight time. Finally, according to Calculus of variations, correction formulas are designed for the control parameters to eliminate the longitudinal and lateral errors simultaneously. In order to further decrease computational cost, the state deviations at the second reentry point is analytically derived as the function of the state deviations which collocate at the terminal point of the first skip phase. Compared with the traditional lateral guidance logic where a heading error deadband is defined to provide the maximum allowable error, the method proposed in this paper is able to prescribe the reversal time, so that only a few numbers of bank reversals are needed in the skip phase, thereby reducing the control complexity and saving the propellant for the attitude reaction jets. The performance of the proposed method is assessed by dispersion simulations and comparison with other methods. The results show that this method is not only accuracy mathematically, but also has strong robustness, and excellent performance.