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Author: Dr. Zeyue Li
National University of Defense Technology, China

Prof. Haiyang Li
National University of Defense Technology, China
Mr. zhen yang
National University of Defense Technology, China

NON-SMOOTH DEVIATION EVOLUTION ANALYSIS IN CISLUNAR MIDCOURSE CORRECTION TRAJECTORY UNDER MANEUVER EXECUTION THRESHOLD

Abstract

With the resurgence of lunar exploration, manned lunar missions have emerged as crucial avenues for major spacefaring nations to explore and exploit lunar resources. Typically, in engineering, deviations in Earth-Moon transfer orbits are mitigated through several trajectory midcourse corrections. This will result in the deviation propagation of Earth-Moon transfer orbits exhibiting non-smooth characteristics, which conventional deviation propagation methods struggle to handle effectively. Study in this paper investigates the evolutionary effects of non-smooth orbit deviations on midcourse correction trajectory under the maneuver execution threshold. And the influence mechanisms of non-smooth control segments on the results of orbit deviation evolution is explored. Initially, the maneuver execution threshold is introduced, and impulsive differential equation is used to describe the non-smooth dynamical system of midcourse correction orbits whose maneuvers are executed at fixed time. Then the uncertainty caused by measurement and maneuvering actuator is considered and the initial state deviations and maneuvering execution deviation of spacecraft are introduced. Assuming that the initial state deviations and maneuver execution deviation are Gaussian distributions, the probability density mapping of this nonlinear dynamical system is established based on the Fokker-Planck equation, facilitating an accurate characterization of deviation distributions as they evolve along the non-smooth dynamical system. To elucidate the deviation evolution mechanism under non-smooth effects, Lyapunov function for this nonlinear system is further constructed, considering a four-dimensional parameter space composed of maneuver execution threshold, initial position and velocity deviations, and execution deviations to assess the stability of the system. Finally, Monte Carlo simulations reveal some bifurcation instances where initial state deviations evolve to the terminal time with a transition from single-connected domains to multi-connected domains. Thereby the correctness of stability assessment is validated. And the effectiveness of the proposed method in characterizing deviation distributions is shown by simulation results. Research content in this paper can provide theoretical support for the robust midcourse correction orbit optimization method for manned lunar exploration missions.