Paper ID: 64786
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (2) (2)

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ASTEROID LANDING TRAJECTORY OPTIMIZATION BASED ON STABILITY ROBUSTNESS CRITERION

Abstract

As a key technology in asteroid exploration missions, asteroid landing guidance is essential for the success of landing missions and sample return missions. To achieve a successful landing, the spacecraft must reach the desired target with a relatively low velocity with respect to the asteroid, which requires the spacecraft to have a high terminal landing accuracy. Therefore, state-of-the-art guidance technologies are adopted to guarantee landing accuracy. Generally, to satisfy certain constraints, guidance law is designed to track a predesigned reference trajectory, such as the fuel optimal trajectory which is the most used. However, in the design of the reference trajectory, the initial condition error and the parameter uncertainty are not usually considered. These unconsidered disturbances will cause the spacecraft to deviate from the reference trajectory, and thus the landing accuracy is difficult to guarantee. To improve the landing accuracy of the spacecraft under disturbances, this paper proposes a closed-loop trajectory optimization method considering the stability robustness of the system.

First, the nominal landing dynamics of the spacecraft are analyzed and we can obtain the unstable characteristic roots of this open-loop system. The linear quadratic regulator (LQR) method is used to track the trajectory so that the eigenvalues of the closed-loop system have negative real parts, which ensures the stability of the system in the nominal case. Then, in order to make the closed-loop system more robust to disturbances, a stable robustness index is designed. The index measured by the upper bound of the eigenvalue disturbance and minimized to reduce the effect of the disturbance on the real part of the eigenvalue. Finally, the stability robustness index is augmented onto the minimum fuel cost function through penalty factors to obtain the optimal reference trajectory and LQR parameters. Monte Carlo simulations are conducted with consideration of uncertain asteroid parameters, initial errors, and deviations in guidance parameters. Results show that the trajectory obtained by this method has a better tracking performance than the fuel optimal trajectory. The proposed method increases the landing accuracy by improving the robustness of the closed-loop system to disturbance, which indicates that the proposed method can be successfully applied in asteroid landing missions in uncertain environments.