IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (1) (3)

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MULTI-OBJECTIVE ROBUST OPTIMIZATION FOR STATION-KEEPING IN HALO ORBIT: AN LMI APPROACH

Abstract

In the circular restricted three-body problem (CR3BP), there are five equilibrium points, the Lagrangian points, and it is known that a family of periodic orbits such as Lyapunov orbits and halo orbits are possible around these points and are unstable. Station-keeping on an unstable orbit in the CR3BP has been studied by many researchers. The linear quadratic regulator (LQR) method is often adopted to transition to an unstable reference orbit and maintain it. An LQR can determine the optimal controller gain by selecting suitable weighting matrices. However, system uncertainty and external disturbance are not considered. In short, unexpected disturbance or system model error may make the system unstable or deteriorate control performance.

Post-modern control, such as the $\mathcal{H}_2$ or $\mathcal{H}_\infty$ control, is applicable to deal critically with system uncertainty and external disturbance. This type of control guarantees a system's performance and stability using linear matrix inequalities (LMIs), which take uncertainty into account. With LMIs, robust control is realized; moreover, multi-objective control is also possible by solving simultaneous LMIs. The mixed $\mathcal{H}_2/\mathcal{H}_\infty$ control guarantees optimality and robustness at the same time. The $\mathcal{H}_2$ control minimizes an integral of the transfer function from the disturbance input to the performance output, and the $\mathcal{H}_\infty$ control constraints the supremum of the maximum singular value of the same transfer function. However, these designs operate in the frequency domain and may introduce slight transient behavior. Therefore, some studies have solved this problem using a regional pole placement constraint.

This study investigated the CR3BP equations of motion and a conventional LQR controller for station-keeping then developed a multi-objective controller that guarantees robustness to disturbances and considers optimality and regional pole placements. Lastly, the effectiveness of the proposed controller was demonstrated through numerical simulations, including spacecraft station-keeping on a Sun-Earth halo orbit and an Earth-Moon halo orbit in the CR3BP.