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MANIFOLD-BASED ROBUST STABILIZATION OF LIBRATION-POINT ORBIT WITH NAVIGATIONAL UNCERTAINTY

Abstract

The libration-point orbits have grabbed the attention of lots of researchers in the past several decades, as an excellent scientific experiment platform and the low-energy-transfer gate to the outer space. Such orbits, however, are generally unstable, a tiny deviation has strong influence on the trajectory, even causing the spacecraft away from the target orbit. Massive literatures have been published on the stabilization of unstable libration-point orbits, which can be segmented into two categories: advanced control-based method and dynamical structure-based method. Manifold-based structure-preserving control was first proposed by Scheeres et al. and extended by many researchers, which is a feedback control method to stabilize an unstable trajectory utilizing the eigenstructure of the linearized equations to insert the spacecraft onto center manifold of unstable periodic orbit. It has been demonstrated that the method can save the fuel and long-term stability can also be guaranteed by selecting large enough gain. However, the navigational uncertainty, meaning the exact orbital knowledge of the spacecraft is unknown, has not been taken into account on designing control gains in most of literatures so far.

The primary purpose of our research is to analyze the manifold-based control under the influence from the navigational uncertainty. Especially, given the theoretical model of the newly developed X-ray pulsar navigation, the Kalman filter is efficiently utilized for the spacecraft navigation, which allows relatively smaller navigational uncertainty compared with other traditional methods in deep space exploration. We first apply a theoretical analysis to an unstable planar trajectory in a rotating frame, and derive the range of control gain to ensure the local stability. Then the navigational uncertainty is included, which is assumed to be independent and identical distributed in each dimension. By linearizing the expression of the expectation of the system matrix along a reference trajectory, the feasible range of the control gain can be re-estimated under the navigational uncertainty. It is found that the feasible range of control gain becomes smaller than that without consideration of the navigational uncertainty. Resulting analytical formula also enables to design robust control gain to preserve the structure of the system. Finally, Monte Carlo simulation is performed for the halo orbit about Earth-Moon L_2 in the Earth-centered inertial frame, and the consistent results with the theoretical analysis are obtained.