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TRANSFER TO ASTEROIDS DURING CLOSE ENCOUNTER USING FINITE-TIME LYAPUNOV EXPONENT FIELDS

Abstract

There have been many asteroid-close-encounters with the Earth in the past, and more are expected to happen in the future. Close encounters rise the risk of asteroids impact, but the other hand, they can also provide a great opportunity for asteroid exploration missions. Transfer from the Earth to asteroids during the close encounter requires less transfer time. More significantly, fuel cost of the transfer might be reduced if designed properly. However, the dynamical model is complicated because the asteroid is in a hyperbolic orbit around Earth. Furthermore, under hyperbolic restricted three body problem (HR3BP), libration points do not exist except for upper/lower boundary problem, which only have theoretical significance. Therefore, common methods for low-energy transfer in circular restricted three body problem including manifold and weak stability boundary transfer cannot be used in HR3BP.

This work is aimed to develop a novel approach for the design of asteroid transfer during close-encounter via the computation of finite-time Lyapunov exponent (FTLE) fields. Designing variables of the problem including asteroid's true anomaly, initial position, initial velocity and others. Thus, Poincare section technique is introduced to separate these variables and reduce the dimension of the FTLE field. The FTLE fields are first calculated in the Poincare section on which the x coordinate and Jacobi energy are given. With the shape character of the FTLE field, different areas on the Poincare section can be identified in which all points share the same transfer character. Different FTLE fields corresponding to different true anomaly are compared and relation between true anomaly and possible transfer areas are obtained. Then suitable true anomaly is concluded and arcs to the asteroid are derived. With differential correction and arcs patching, these arcs are converted to transfer trajectories from low Earth orbits (LEO) to the asteroid. As the shown in the result, transfer to asteroids during close encounter can be obtained by the propose method with both the transfer time and the fuel cost reduced.