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DIFFERENTIAL-ALGEBRA ACCELERATED POINCARE MAP OF CR3BP AND ITS APPLICATION IN SEARCHING FOR HALO ORBITS

Abstract

The motion of spacecraft near equilibrium points in the Circular Restricted Three-Body Problem (CR3BP) is always a hot issue for scholars. Its phase-space structure, including Halo orbits, is indicated by Poincaré map, which usually requires heavy numerical integration. This paper addresses the growing need for a highly effective Poincaré-map method accelerated by canonical transformation and differential algebra (DA) to decrease the computation and search for Halo orbits. It is first demonstrated that this method can efficiently reduce the computation of the canonical Hamiltonian to the simple evaluation of polynomials and identify Halo orbits based on bifurcations in the Poincaré map accelerated by DA.

Firstly, the Hamiltonian methodology models the dynamics near equilibrium points with canonical coordinates rather than initial ones. Particularly, The Hamiltonian is obtained with an invariant manifold tangent to central directions of the linear part by uncoupling the hyperbolic direction from the elliptic one. As the dynamics have been qualitatively explained, two degrees of freedom in the reduced Hamiltonian allow the numerical computation of Poincaré map. With the fixed Hamiltonian value increasing, the bifurcations, i.e., Halo orbits, appear.

Then, to decrease computation, DA is used for expanding the orbits and invariant tori in Poincaré map. It is proposed to obtain the high-order Taylor polynomial approximation of the Poincaré maps, which projects any point about the reference point on the section surface after one revolution. Specifically, the reference point is selected in an iterative way to guarantee the accuracy of Taylor polynomial approximation starting from the center. Compared with the traditional DA, our improvement in bifurcations of the phase flow can present them by simple evaluation of polynomials instead of purely numerical integration. Once Poincaré section has been drawn, periodic and quasi-periodic solutions contained in the center manifold can be plotted easily.

The proposed method can avoid the large multiple runs of intensive iterative procedures in describing the solutions. Numerical results show that the computation of Poincaré map can be further reduced as much as 90%. After inverse coordinate transformation, the accuracy of Halo orbits derived from bifurcations is obviously improved as much as 10% superior to conventional methods. It is concluded that the capability of this method for searching for Halo orbits as well as Lyapunov, Lissajous, and Quasi-halo orbits, is very promising and practical.