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OPTIMIZATION OF IMPULSIVE LOW-ENERGY TRAJECTORIES TO THE EARTH-MOON L2 HALO ORBIT

Abstract

A new method for optimizing impulsive low-energy spacecraft trajectories by using primer vector theory is presented. A restricted four-body problem is considered, which takes into account the gravitational potential of the Earth, the attraction of the Moon and the Sun, and high-precision ephemeris of the planets and the Moon. Particular attention in the development of the method was paid to ensuring its computational stability during a prolonged stay of the spacecraft in the zone of weak stability near the boundary of the Earth's sphere of action. Low-energy trajectories under consideration are also called ballistic capture trajectories. Low-energy transfers to Earth-Moon L2 halo orbits have great practical importance in the study of the Moon. When designing advanced space missions, optimization of impulsive trajectories is often used, which is provided to obtain a good estimate of main parameters of the trajectory and a good initial approximation for subsequent mission planning. The primer vector theory was proposed by D.F. Lawden and it was further developed in many works of other researchers. However, in the considered ephemeris model of the four-body problem, the strong influence of perturbed acceleration makes the existing methods for optimizing impulsive trajectories insufficiently stable. The proposed method is as following: (1)The stable manifold of the target halo orbit is discretized, and the problem of transfer between the stable manifold and low Earth orbit is reduced to the problem of transfer between low Earth orbit and a fixed point on the stable manifold. To calculate this two-impulse trajectory, the parameter continuation method is used, based on the Newtonian homotopy between solutions of the unperturbed and perturbed boundary value problems. (2)The primer vector on the obtained impulse trajectory is analysed. When the necessary conditions for optimality are met, the trajectory is optimal and the optimization ends there; if the optimization conditions are not met, the addition of an initial or final coast or an internal impulse is considered. (3)If it is necessary to add an internal impulse, then it is introduced at the local maximum point of the primer vector modulus. Taking the position and moment of adding the internal impulse as the initial value, the position and moment of application of the internal impulse are obtained by an iterative method from the necessary conditions for optimality. (4)Returns to step (2). The computational efficiency and stability of the proposed method are considered. Numerical results of optimization of low-energy trajectories are presented.