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ANALYSIS OF TRANSFER TRAJECTORIES TO HALO ORBITS AROUND THE LAGRANGIAN POINTS IN THE CRTBP FRAMEWORK AND EPHEMERIS MODELS

Abstract

The mission design to orbits around the Lagrangian points from Earth involves complex multi-body dynamics and therefore some restrictive assumptions are required to obtain the physical insights necessary to start the preliminary trajectory design. The framework of Circular Restricted Three Body Problem (CRTBP) provides a good initial approximation which is required to initiate the real mission design involving full force ephemeris models. The typical mission design profile involves two steps; in the first step, an orbit with prescribed geometrical characteristics is designed and in the second step, an optimal transfer trajectory to the orbit from an Earth parking orbit is constructed.

For the design of transfer trajectories, there are two approaches followed in the literature. The first approach is based on the manifolds theory and leverages the behavior of stable manifold near the Earth originating from the target orbit. For the transfers in the Earth-Moon system, this approach requires a bridge maneuver because the manifolds do not pass close to the Earth. The second direct approach involves two maneuvers, first at the Earth parking orbit to insert the spacecraft into the transfer trajectory and the second maneuver to insert the spacecraft into the target orbit.

In this paper, the design of direct transfer trajectories to orbits around the Lagrangian points in the Earth-Moon system are constructed using differential evolution (DE), an evolutionary optimization technique. The analysis is first done in the CRTBP framework and then extended to an ephemeris model. The location of insertion on the target halo orbit and the components of halo orbit insertion velocity are treated as unknowns and determined using the DE based process. The proposed technique has the following advantages: 1) the geometry and nature of the target orbit remains unaltered during transitioning of the CRTBP solution to the ephemeris model, whereas the conventional differential correction based method modifies the target orbit and 2) the transfers are constructed in a single level scheme whereas the differential correction based method necessitates multiple levels.

For the optimal transfers to a halo orbit having Az amplitude 15,000km around the Lagrangian point L1 in the Earth-Moon system using the proposed method, the total cost in the ephemeris model is found to be more compared to the cost in the CRTBP framework and the variation in total cost with epoch over a month is around 287m/s. Further results will be presented in the full paper.