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Analysis of a Rendezvous Mission in Non-Keplerian Orbit using Electric Propulsion

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This paper presents the analysis of a low-thrust rendezvous mission to a target non-Keplerian orbit of the circular restricted three body problem (CR3BP) in the Earth-Moon system. The dynamical characteristics of this system are revisited, and some non-Keplerian orbits (e.g., L1 halo orbits, NRO and L2 halo orbits) have been simulated to study their suitability for a rendezvous mission. Starting from analytical approximations, a shooting method has been used for the numerical
description of these orbits. Afterwards, the different monodromy matrices related to the integrated non-Keplerian orbits has been studied to analyse their stability and to describe stable and unstable manifolds of the orbit, i.e., ballistic trajectories that can be covered by a spacecraft without any propellant usage.

The design of a low-thrust rendezvous mission in a non-keplerian orbit is approached as an optimal control problem, in which the solution is the thrust magnitude and direction along the path. The propellant consumption has been set as the objective function to be minimized, and the trajectory is subjected to a set of constraints ranging from thrust limitations and time requirements specified for each mission. The problem to be tackled is a rendezvous mission to a specific target in a L2 Halo orbit. Hermite-Simpson collocation method has been used for the numerical description of the dynamical constraints of the system. Then, the problem has been solved numerically with IPOPT (Interior Point OPTimizer). An unpowered trajectory integrated from the problem initial conditions is used for the solver initialization. The rendezvous mission implementation and the interface with that solver have been developed in Matlab.

Three different cases of rendezvous at the target L2 Halo orbit have been studied: 1) rendezvous from a nearby halo manifold, 2) rendezvous from a close halo orbit and 3) phasing manoeuvre starting from the same halo as the target. All the cases have shown to be feasible for being performed with the use of an Electric Propulsion thruster. The final optimal trajectories for those cases are presented. In addition, it has been shown that propellant consumption can be greatly reduced if the stability properties of the targeted orbits are exploited.

Summary

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