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ATTAINABLE SETS APPROACH FOR LOW-ENERGY, LOW-THRUST INTERPLANETARY TRANSFERS

Abstract

The exploration and utilization of the deep space are all along the dreams of human beings. It has prompted trajectory design studies for a number of new deep space exploration missions. Preliminary design of interplanetary space trajectories is commonly done using the patched conics method, describing the motion of the spacecraft with a two-body model. Dealing with future interplanetary transfers, the purpose of astrodynamics could be the maximization of the payload mass without any particular restriction on the ight time. The main idea is to design a low-energy low-thrust interplanetary transfer which links two stable orbits around Earth and target planets employing the ballistic structures enabled by the restricted three-body model.

The restricted three-body or the n-body problem, allows us to compute unique orbits, whose features cannot be achieved in the classic Kepler problem. It has been demonstrated that the n-body dynamics can be used to design transfer trajectories requiring less propellant than the patched-conics transfers. More recently, new techniques have been developed to combine n-body dynamics and low-thrust propulsion. These solutions, known as "low-energy, low-thrust" transfers, allows us to combine the features typical of n-body dynamics with those associated to low-thrust propulsion means. However, introducing the low-thrust term into the equations of motion is not trivial, and requires a high number of variables to describe a single trajectory. This is not desirable when searching for a rst guess solution to be later optimized.

The purpose of the paper is to introduce an approach of attainable sets which efficiently enclose a set of feasible solutions associated to a set of admissible initial conditions. The method to incorporate low-thrust propulsion into the invariant manifolds technique is presented in this paper. The low-thrust propulsion is introduced by means of special attainable sets that are used in conjunction with invariant manifolds to define a first-guess solution. This is later optimized in a more refined model where optimal control formalism is used.

Planar low-energy low-thrust transfers to the moon, as well as spatial low-thrust stable manifold transfers to halo orbits in the Sun-EarthMoon system, are presented. These solutions are not achievable via patched-conics methods or standard invariant manifolds techniques. The results of the work demonstrate the usefulness of the proposed method in delivering efficient solutions for the low-energy low-thrust interplanetary transfer mission, which are compared with known examples.

Key words: Low-energy Trajectories; Low-thrust Propulsion; Attainable Sets; Restricted Three-body Problem.