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OPTIMAL TRANSFERS IN THE EARTH-MOON SYSTEM THROUGH POLYHEDRAL REPRESENTATION OF INVARIANT MANIFOLDS

Abstract

Analysis and design of low-energy trajectories to the Moon has attracted a long interest in the last decades. Exterior and interior transfers, based on the transit through the regions where the collinear libration points L1 and L2 are located, have been studied for a long time and some missions have already taken advantage of these studies. These missions are based on the use of unstable periodic orbits, which are associated with stable and unstable invariant manifolds. Recent efforts have been devoted to developing a suitable representation for the manifolds, which would be extremely useful for mission analysis and optimization. The manifolds are topologically two-dimensional, because each point belonging to them (and the associated instantaneous position and velocity) can be identified by means of two quantities: (i) the injection point along the periodic orbit, and (ii) the time of flight on the manifold. This fundamental property discloses the possibility of representing the position and velocity components as functions of two variables. This means that geometrically each state component is associated with a surface. This research proposes and describes an intuitive polyhedral interpolative approach for each state component, regarded as a function of the two previously mentioned variables. Accuracy of this representation is proven to be satisfactory, under the assumption of employing an adequate grid of data, coming from the numerical propagation of a finite number of manifold trajectories. In the end, the polyhedral representation allows expressing the position and velocity components on the manifold as continuous functions. This circumstance has apparent applicative relevance. In fact, a continuous representation of the boundary conditions is usually required for defining space trajectory optimization problems. In particular, orbit transfers originating from or arriving at the manifolds can be optimized using the necessary conditions for optimality if the manifolds are described through continuous functions. With this regard, this work addresses the optimization of four paths, using the representation at hand, in conjunction with an indirect heuristic method: (i) impulsive transfer from Earth orbit to Lyapunov orbit at L1, (ii) impulsive transfer from the Lyapunov orbit at L1 to a specified lunar periodic orbit, (iii) impulsive transfer from Earth orbit to Halo orbit, and (iv) low-thrust transfer from Earth orbit to Lyapunov orbit at L1. These four applications demonstrate the utility and effectiveness of the intuitive, geometrical approach employed in this study with the objective of representing invariant manifolds, both in two and in three dimensions