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AN EXPLORATION OF NUMERICAL METHODS FOR LOW-THRUST TRAJECTORY OPTIMIZATION IN N-BODY MODELS

Abstract

The patched-conics method represents the classical technique adopted to design lunar or interplanetary transfers. When the low-thrust propulsion is introduced, a series of optimal control problems is solved in the different two-body problems experienced by the spacecraft (e.g., departure, heliocentric, and arrival phases). It has been proven that when the spacecraft is allowed to fly in an n-body model, the propellant mass can be considerably reduced by exploiting the inherent dynamics of the system. This is the case, for instance, of the ballistic capture, which reduces the hyperbolic excess velocity at arrival. Other examples are the transfers to libration point orbits, which cannot be even designed in the classic two-body problem.

The trajectory optimization is an optimal control problem. In space trajectory design, the optimal control problem is typically faced with numerical techniques, and direct or indirect approaches are considered. However, optimizing space trajectories in the n-body models, in place of the classic two-body problem, is not trivial, and asks for a number of issues to be deal with. The most important point is the increased nonlinearity of the system which requires accurate handling of the trajectories (to not lose accuracy) and may prevent converging to an optimal solution.

In this paper we have explored a number of different numerical methods for the low-thrust trajectory optimization in n-body vector fields. In the context of direct transcription, different numerical integration schemes, as well as different transcription strategies (collocation and multiple shooting) have been examined. These methods have been applied to the case of low-thrust transfers to the libration point orbits in the Earth-Moon system, and low-energy, low-thrust transfers to the Moon. As a result of the performed work, indications on the behavior of the different techniques in solving the considered problems are achieved. This work represents the first step toward the implementation of an integrated tool for the fast low-thrust trajectory optimization within highly nonlinear systems.