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AN IMPROVED APPROACH TO PRELIMINARY MISSION DESIGN USING FAST LINEAR QUADRATIC INTERMEDIATE OPTIMISATIONS

Abstract

During the preliminary design of a space mission employing low thrust propulsion, numerous options have to be investigated in order to make decisions on the viability of a given mission scenario. Therefore, a thorough and reliable low-thrust preliminary mission analysis is vital to provide initial estimates of the driving parameters of a mission.

In this paper, we present an approach to the fast preliminary design of low-thrust trajectories over large search spaces. The approach combines three steps. The first one serves to assess a broad range of alternative mission options and to identify favourable ranges of driving parameters, e.g. launch date or time of flight. The large number of alternatives demands for a low computational load while accuracy is not a requirement. We developed two novel shape-based methods that represent a good compromise between the optimality of the trajectories and the required computational cost. The first method assigns a shape to the modified non-singular elements defining the motion of the spacecraft, while the other shapes the geometry of the trajectory in spherical coordinates. The former method generally yields trajectories that are closer to optimal, while the latter is computationally faster. The paper will present how to use the proposed shaping approaches in conjunction with both a systematic branch and prune algorithm and an efficient multiobjective evolutionary algorithm.

After families of promising first guess solutions are identified with the shaping methods, a more refined optimisation can be performed. The second step consists of a linearization of the dynamics in the neighbourhood of each first guess solution and in the computation of an optimal feedback control for a quadratic objective function.

The perturbations minimising the cost function can be computed in a feedback form after integrating a Riccati differential equation backwards in time. The computational cost of this second step is limited and yields a substantial improvement of the solution coming from the shaping approach.

The final step in the design process is the more accurate optimisation of selected trajectories. In this paper, a local optimiser is employed; it uses a direct collocation method based on Finite Elements in Time (implemented in the software code DITAN). Both the solutions coming from step one and the ones coming from step two are re-optimised to assess their optimality and their suitability to initialise a direct method.