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CONSTRAINED MULTI-OBJECTIVE SPACE TRAJECTORY OPTIMISATION UNDER SEVERE SYSTEM AND OPERATIONAL UNCERTAINTY

Abstract

In this paper we propose novel methods for the multi-objective optimisation of spacecraft low-thrust trajectories subject to severe uncertainty in system design, operations and launcher parameters, including outage scenarios where thrust is temporarily reduced significantly due to engine failure.

Uncertainty in system parameters and thrust profile is propagated through the spacecraft dynamics to compute the lower expectation on the satisfaction of the terminal constraints on position and velocity and the optimal value of the propellant consumption. The lower expactation is the minimum expected value of a given quantity of interest with respect to a family of probability distributions that caracterise the uncertainty in the system parameters.

In this paper we investigate a new efficient method for describing this family which scales well under an increase in the number of uncertain variables. In our previous work we considered a very agnostic formulation assuming very little a priori information. In this paper we consider the case in which mission designers have sufficient information to define some constraints on the probability associated to the system parameters. This information can come from previous missions or from on ground testing of components and subsystems.

We will show that when constraints on the input distributions are available the family of distributions can be approximated as a sum of a relativelly small number of kernels of positive functions, for which the lower expectation can be computed by solving a simple constrained linear system. This process is fast and one can easily assess the sensisitivity to the number of kernels and values of the input constraints.

Furthermore, in this work we will include in the computation of the lower expectation of the terminal constraints also the effect of intermediate orbit determinations and the associated replanning of the remaining leg of the trajectory.

Unlike our previous work in which we were computing the full lower probability function, in this paper we propose the use of the more easily understandable upper percentile, which corresponds to the threshold value that makes the lower expectation equal a pre-defined target value, such as 95

We will test our methodology on a multi-target asteroid exploration case study using with small satellites.