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A DIRECT OPTIMIZATION APPROACH FOR ROBUST TRAJECTORIES OF INTERPLANETARY CUBESATS

Abstract

Nowadays, the space exploration is going in the direction of exploiting small platforms to get high scientific return at significantly lower costs. However, miniaturized spacecraft pose different challenges both from the mission analysis point of view.
Nominal trajectories of traditional spacecraft are designed and optimized in order to satisfy only scientific requirements as well as to comply with system constraints. Although, the nominal path will unlikely be followed by the spacecraft in real-life scenarios due to uncertainty in dynamic model, navigation, and command actuation, the correction maneuvers needed to compensate deviations are considered to be a minor problem, since changing the trajectory is relatively easy with a single, short burn. Robustness and feasibility assessment of the nominal trajectory against uncertainty are performed a-posteriori. Thus, the nominal trajectory and the uncertainty assessment are decoupled and their analysis and optimization are done in two separate phases. This approach can lead to sub-optimal solutions. For large spacecraft, this procedure is acceptable since they can produce high thrust levels and they can store relevant propellant quantities; hence, sub-optimal trajectories are not critical.
However, small platforms are characterized by low control authority, that poses challenges in maneuvering. Therefore, correction maneuvers cannot be considered a minor problem and preliminary trajectory design should take them into account.
To solve this problem, in this work, a direct optimization method is devised to design robust trajectories for interplanetary small spacecraft. The robust optimal control problem is translated in a nonlinear programming problem by means of transcription and collocation, while a linearized approach is exploited to propagate and quantify all the uncertainties related to unmodeled perturbations, imperfect knowledge of the state, and control application. This methodology has been than applied to the interplanetary transfer of the CubeSat M-ARGO, that is planned to be the first standalone ESA deep-space CubeSat to rendezvous a near-Earth asteroid (NEA). This new technique is able to bring a 50% save in the navigation costs, while being able to rendezvous the target asteroid with great accuracy.