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ROBUST GUIDANCE FOR SURFACE CHARACTERIZATION OF MINOR BODIES

Abstract

In recent years, interest in exploring minor bodies has increased significantly. Studying these objects is important for planetary defense against potential impacts and for the valuable scientific and economic opportunities they offer. However, despite their high relevance, minor bodies exploration is dampened by the challenges associated with their environment. For example, fulfilling one key objective of small-body exploration missions, i.e., surface characterization, requires the spacecraft to operate in close proximity of the target body, where it is exposed to a complex and uncertain environment that leaves no margin for communication delays typical of deep-space missions. Consequently, robust and efficient guidance algorithms are required to enable a broader exploration of these resourceful celestial objects.

In this context, the work proposes a methodology for generating robust trajectories for minor body surface mapping using impulsive guidance maneuvers. The methodology is composed of two stages. First, a sampling-based model predictive algorithm is used to generate an initial guess. The sampling is performed in the control domain, and the objective function is defined according to observation requirements. In order to enhance computational efficiency, a search space domain reduction based on Keplerian reachability is proposed. In the second stage, the trajectory is refined through sequential convex programming to minimize fuel consumption and ensure that mission requirements, expressed as chance constraints, are satisfied with a prescribed confidence level. The robustness of the solution is guaranteed considering in the optimization the main uncertainties characterizing the dynamic environment.

The developed methodology is tested through simulations of close-proximity operations around asteroid Itokawa. The results demonstrate that the approach can generate inspection trajectories that satisfy observation requirements, minimize fuel consumption, and guarantee passive safety and robustness with respect to the main uncertainties associated with the asteroid environment. In general, the outcomes of this work represent a step toward autonomous close-proximity operations around minor bodies, a capability required to sustain a massive exploration of these objects and unlock their full scientific and economic potential.