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MODEL PREDICTIVE TRAJECTORY GENERATION AND CONTROL FOR BALLISTIC LANDER DEPLOYMENT ON SMALL BODIES FROM SMALL-SAT PLATFORMS: THE TASTE MISSION CASE STUDY

Abstract

The scientific interest in the exploration of asteroids and other small bodies has been growing constantly in recent years, due to the insights that can be obtained on the formation of our solar system. The latest advancements in the miniaturization of electronics suggest that small satellites may provide a precious support to classical-size missions for small bodies exploration, increasing accessibility, cadence, and return-to-cost ratio. Small satellites however provide limited technological capabilities that must be compensated with proper redesign or even rethinking of the classical guidance, navigation, and control strategies that have successfully been used in the past for larger spacecraft.

In fact, a higher degree of flexibility and autonomy seems mandatory to be able to react to unexpected events with limited communication windows to ground and in presence of communication delay. Moreover, due to the low control authority available on small platforms, traditional strategies like body-fixed hovering cannot be used, and the dynamic environment shall be leveraged with proper robust predictive schemes to achieve the mission goals. Accordingly, this paper, in the framework of the TASTE mission study, financed by ASI and focused on in-situ sampling Deimos surface, investigates the possibility of autonomously deploying a ballistic lander at a desired landing spot on a small body from a CubeSat-like orbiting platform.

A Model Predictive Control (MPC) scheme is here proposed to lead the small orbiter to a waypoint from which the lander can safely be released, reaching the selected landing spot with suitable relative velocity locally perpendicular to the surface. The MPC exploits the knowledge of dynamics in the body-fixed rotating reference frame, which can be linearized allowing the formulation of a suitable convex optimization problem. In addition, the trajectory generator includes an iterative strategy to consider the effects of the irregular gravity field, modelled according to a polyhedral model, and to refine the rotating-hyperplane constraint preventing collisions of the orbiter with the surface. The approach easily manages additional system related constraints such as limits imposed by a single electric engine as main propulsion unit, and by acceptable slew rates.

Numerical simulations are performed in Deimos environment in the context of TASTE mission and in other realistic scenarios on small bodies, to assess the algorithm efficiency and effectiveness in satisfying all imposed constraints. Finally, parametric analyses are conducted to check the algorithm robustness to navigation and modelling errors, assessing their impact on the small lander touchdown accuracy and success rate.