Key Technologies (7)
Key Technologies (4) (4)

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TUBE-BASED ROBUST MODEL PREDICTIVE CONTROL FOR ASTEROID SOFT LANDING.

Abstract

Missions to asteroids are of great scientific interest, and many have been recently proposed and flown. The in-situ analysis of the composition and mineralogy of asteroids requires surface operations and, therefore, a soft-landing manoeuvre. Nevertheless, operations in environment close to small bodies in the solar system are often characterized by a degree of uncertainty in the dynamics. Currently, methods for addressing the uncertainty consists of extended surveying and mapping phases in the mission operation profile. In order to reduce the turnaround time and to improve the autonomy of future operations, robust Guidance, Navigation, and Control (GNC) systems is of research interest. This paper investigates utilising Tube based Robust Model Predictive Control (TRMPC) as a GC algorithm for the final descent phase on asteroids. Violations on constraints and errors in apriori optimizations may result in catastrophic failure in the descent phase due to neglected or unobserved environmental features or parameters. As such, the online optimisation provided by an MPC like scheme is of interest, as it can continuously re-evaluate its trajectory based on up-to-date sensory information. Improving both the autonomy and the robustness of the mission. TRMPC has already been proposed for rendezvous and docking space applications, and it has been shown that in the presence of disturbances, it outperformed regular LQMPC with regards to constraint satisfaction, a key mission criterion for soft landing. TRMPC is an appealing semi-optimal strategy consisting of a control input determined by a quadratic optimization problem, combined with a feedback disturbance rejection term that forces the uncertain trajectory to lie in a minimal Robust Positively Invariant set of the uncertain system. In this way, arrival to the desired terminal conditions fulfilling path constraints is robust if the disturbances stay within the predefined bounds. Offline tuning of the disturbance rejection term enables the balancing between manoeuvrability and precision for the different phases of the descent phase. For the controller, the environment is modelled as a linear system with the error stemming from the linearization, approximated as a bounded, random additive polytopic set. The resulting TRMPC, optimizing with regards to performance and fuel efficiency, is designed to provide sub-optimal, online GC algorithm for soft-landing. The performance and optimality of the controller is finally compared to a nonlinear robust optimization of descent trajectories, simulated in a high-fidelity environment.