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MODEL PREDICTIVE CONTROL FOR RELATIVE GNC DURING PLANETARY SAMPLE CANISTER RENDEZ-VOUS AND CAPTURE PHASE

Abstract

This work presents a Guidance Navigation and Control (GNC) model to manage the rendezvous phase of an active spacecraft with an uncooperative small orbiting capsule, containing samples collected on a planetary surface. To enable autonomous navigation the chaser exploits a Model Predictive Control system (MPC) to settle a close loop architecture and to handle close proximity maneuvers constraints, such as the Line-of-Sight cone constraint on position, and safety path constraints imposed to design safe trajectories in case of contingencies occurrence, like thrusters failures. Since these constraints are convex, the optimization step of the guidance algorithm exploits the linear and quadratic programming and, since the mission may ask for an elliptic orbit, the prediction of the relative trajectory uses the Linear Time Variant state transition matrix developed by Yamanaka-Ankersen. The guidance algorithm is split into two phases: a first phase, which privileges the fuel consumption containment, applies a Variable Horizon MPC with linear programming and is composed by a set of “hop” branches and holding points; a second phase which is based on a fixed receding horizon MPC and quadratic programming to minimize the target capture error. The MPC with LTV state prediction, taking advantage of a linearized attitude error modelling, is exploited to include in the proposed architecture the attitude dynamics and control, harmonized with the orbital required dynamics. As a consequence, the control is given in terms of each thruster activation timeline (assuming Pulse Width Modulation) to provoke expected control force and torque on the chaser. Relative navigation is based on an single optic camera, modelled to assess the target illumination conditions impact on the guidance performance. Results from the Montecarlo analyses - run to assess the GNC sensitivity to different parameters (e.g. sampling time, cost function weights, horizon length, target orbit parameters) –are presented. The proposed GNC architecture performances are also discussed in the case of a Lunar Sample canister capture scenario.