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ORBIT-ATTITUDE COUPLED GUIDANCE AND CONTROL FOR CONSTRAINED TRAJECTORY GENERATION AND TRACKING DURING FINAL APPROACH TO NON-COOPERATIVE SPACECRAFT

Abstract

In recent years, autonomous In Orbit Servicing and Active Debris Removal missions have aroused a great interest by the scientific community to increase the operational lifespan of satellites and reduce the source of space debris by applying active remediation measures. In this context, the Guidance, Navigation and Control system shall rely on advanced algorithmic solutions capable to be run in real time on board a chaser spacecraft to allow autonomous, safe rendezvous to a non-cooperative target. The final approach phase of a rendezvous manoeuvre, i.e., starting at target distances of few meters down to a minimum separation at which docking or berthing operations can be activated, is critical especially if the non-cooperative target is characterized by a tumbling motion. In such a scenario, the translational and rotational dynamics are strictly coupled especially if path, sensors, and actuators constraints are accounted for. This paper addresses this problem by proposing an original guidance and control architecture applicable to close-range rendezvous and final approach to a non-cooperative, potentially tumbling, space target based on an impulsive actuator system. The coupled rotational and translational guidance solution is obtained by solving a minimum propellant consumption problem (considering constraints on collision avoidance, target visibility in the sensor field of view, and actuators' limitation) applying a sequential convex programming (SCP) method. This approach is possible since the original non-linear and non-convex problem is transformed into a series of linear and convex sub-problems, considering a linearization and discretization of the translational and rotational dynamics, and converting the collision avoidance and sensor field of view constraints into affine inequalities. Given a reference guidance solution, trajectory tracking is entrusted to a roto-translational H-infinity controller designed following a mixed-sensitivity loop shaping approach, including reference trajectory, actuation disturbances and relative navigation errors as exogenous inputs. The proposed architecture is tested in a realistic numerical environment, in which orbital and rotational dynamics are reproduced accounting for environmental disturbances, i.e., atmospheric drag, solar radiation pressure and non-sphericity of the Earth. The simulator considers chaser absolute navigation errors, and integrates a state-of-the-art LIDAR-based relative navigation filter which outputs consistent relative state measurements by processing synthetic point clouds. Finally, actuators'

models, e.g., for cold gas thrusters and reaction wheels, and a dispatching function for the distribution of the commanded control actions, based on the actuators' configuration, are included too. Tests are carried out on final approach trajectories towards both a stabilized and a tumbling satellite.