Paper ID: 89297
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations - IAF ASTRODYNAMICS SYMPOSIUM (IPB)

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ROBUST ATTITUDE CONTROL FOR SPACE TARGET POINTING IN PROXIMITY OPERATIONS

Abstract

The space community has recently put considerable research efforts into innovative technological solutions enabling autonomous rendezvous of a chaser spacecraft toward a non-cooperative target for future Active Debris Removal or On-Orbit Servicing missions. Such in-orbit operations involve complex technical challenges, especially regarding the design of the chaser Guidance, Navigation and Control (GNC) system. For instance, it must be designed to provide relative state estimates meeting stringent accuracy requirements during proximity operations. To achieve this goal, the GNC system must operate in target pointing mode, meaning that the relative navigation sensor suite shall be kept continuously pointed toward the target, while the chaser follows complex relative trajectories. This work addresses such attitude control problem assuming that the chaser is equipped with a scanning LIDAR as a relative navigation sensor and reaction wheels as attitude actuators. The proposed attitude control strategy relies on a proportional-integrative-derivative scheme including a feed-forward term to follow the rate of variation of the target line of sight and an additional term to counteract the gyroscopic effects from actuators. Relative position and velocity estimates from the relative navigation subsystem are thus required to compute the desired chaser attitude and angular velocity. The attitude control performance is assessed in terms of pointing accuracy and control effort by means of numerical simulations reproducing far and close-range proximity manoeuvres toward a non-cooperative space target. The simulator takes into account (i) environmental disturbance torques (i.e., aerodynamic and solar radiation pressure torques and gravity gradient) (ii) high-fidelity reaction wheels modelling terms (i.e., static and dynamic imbalance torques, friction and electro-motive forces) (iii) and realistic estimation errors in chaser absolute state, mass and inertia properties. Moreover, the proposed control architecture is integrated with a state-of-the-art LIDAR-based multiplicative Extended Kalman Filter for relative state estimation, which relies on pose measurements obtained by processing synthetic point clouds generated using a scanning LIDAR simulator. The robustness of the designed attitude control system is analysed within a Linear Fractional Transformation framework by means of -analysis tools. Specifically, a linearized model of the chaser controlled rotational dynamics is derived for the definition of a nominal closed-loop plant around a desired trajectory. Then, a parametric description of the main uncertainties related to actuators, sensors, and the spacecraft configuration is provided to be included in the -analysis. Finally, the Structured Singular Values bounds are obtained for the control robustness evaluation.