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OPTIMAL GUIDANCE TRAJECTORIES FOR A NANOSATELLITE DOCKING WITH A TUMBLING RESIDENT SPACE OBJECT USING A HIGH FIDELITY J2 AND QUADRATIC DRAG PERTURBATIONS MODEL

Abstract

There has been an increasing interest in on-orbit autonomous servicing and repair of satellites as well as controlled active debris removal (ADR) in the space industry recently. One of the most challenging tasks for servicing/repair as well as for ADR is the rendezvous and docking with a non-cooperative tumbling resident space object (RSO).

The research described here elaborates on the previous work by Boyarko [1,2] who studies the minimum-control-effort and minimum-time problem for a 3-D rendezvous to a tumbling object which considers the full six-degree-of-freedom model that consists of the general six kinematics states (position and velocity) along with the seven attitude states (quaternion and angular rates) of the chaser and target. The current work expands the scope by adding Quadratic drag and J_2 to investigate their effect on the proximity operations and establish the requirements for algorithms for closed loop attitude control and relative navigation. Additionally, the paper explores the impact of these perturbations and assesses the importance of implementing them in the linear equations of relative motions. Previous work by P.Patel et al. [3] has studied the effects of only J_2 perturbations on the optimal rendezvous trajectories. Current paper expands the linear equations with the addition of quadratic drag.

The control problem features additional path constraints with relative motion dynamics pertinent to the proximity space operations to match the perching state vector of the nano-satellite over a feature of interest of the RSO. The path to final docking, with a terminal constraint of a small but finite positive relative speed at contact, is also discussed. The consequences of limited thrust and finite attitude maneuver time are taken into account and their effects on the closed loop translation and attitude control of the nano-satellite are analyzed. Moreover, the research also elaborates on the homotopic nature of the optimal control trajectories for variations in different mission design parameters including inclination, maximum thrust, and altitude.

[1] Boyarko, G. "Spacecraft Guidance Strategies for Proximity Maneuvering and Close Approach with A Tumbling Object." Vol. PhD, Naval Postgraduate School, 2010.

[2] Boyarko, G., Yakimenko, O., and Romano, M. "Optimal Rendezvous Trajectories of a Controlled Spacecraft and a Tumbling Object," Journal of Guidance, Control, and Dynamics Vol. 34, No. 4, 2011

[3] Patel, P., Udrea, B., and Nayak, M. "Optimal Guidance Trajectories for a Nanosatellite Docking with a Tumbling Resident Space Object", 2015 IEEE Aerospace Conference