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Author: Prof. Zheng Hong Zhu
York University, Canada, gzhu@yorku.ca

RENDEZVOUS WITH SPINNING TARGET IN ELLIPTICAL ORBIT BY MODEL PREDICTIVE CONTROL

Abstract

This paper studies the integrated trajectory planning and attitude control problem for the autonomous rendezvous and proximity operations near non-cooperative and spinning spacecraft in elliptical orbits. The chaser is modeled by a six degree-of-freedom rigid-body to describe the approaching process to the tumbling target in highly elliptical orbits. The control problem is formulated by a newly proposed state dependent model predictive control method to minimize the control error and control roughness for a safe, smooth and fuel efficient approaching trajectory. The resulting nonlinear programming problem is converted into a series convex quadratic programming problem subject to operational constraints and then solved at every sample time instant. Numerical simulations are conducted in two different rendezvous scenarios: approaching to a stable and tumbling target. In addition, the effects of different eccentricities e and predictive horizon N on the control performance are also studied. The validity and advantage of the proposed method is demonstrated by comparing with the standard state-dependent Riccati equation control algorithm using the same set of initial conditions and parameters. The results show that the newly proposed method is valid and can achieve significant fuel saving by enforcing the smoothness of control input. The study also shows that (i) the state transfer matrix expressed in the time domain is applicable for both circular and elliptical orbits, including highly elliptical orbits; (ii) it is imperative to consider the size of the target into account by introducing a safety sphere around the target to prevent undesired collision; and (iii) the orbital eccentricities and the predictive horizons used in the control algorithm could significantly affect the fuel consumption and the computational efficiency and a trade-off between the fuel cost and computational efficiency should be carefully optimized for the potential onboard implementation of the proposed control algorithm.