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Author: Dr. Shunan Wu
Dalian University of Technology (DUT), China, wushunan@dlut.edu.cn

Prof. Gianmarco Radice
University of Glasgow, United Kingdom, Gianmarco.Radice@glasgow.ac.uk
Prof. Zhigang Wu
Dalian University of Technology (DUT), China, wuzhg@dlut.edu.cn

ADAPTIVE FINITE TIME CONTROL OF RELATIVE TRANSLATION IN PROXIMITY OF A FREELY TUMBLING SPACECRAFT

Abstract

Spacecraft relative translation maneuver is a critical element for most space missions, such as on-orbit servicing and formation flying. Previous studies have proposed different control paradigms to guide the chaser spacecraft to approach or rendezvous with the target spacecraft, but these studies have mainly focused on cooperative targets. Very few results however exist on the control problem of relative translation in proximity of a freely tumbling spacecraft. Two critical issues need be addressed for this type of maneuver. On one hand, the orbit parameters of the freely tumbling target cannot be determined precisely, and only the relative position and velocity can be obtained through measurements performed by the chaser. Furthermore, the freely tumbling target maybe perform translational maneuvers using redundant thrusters, while the values and directions of the thrusters are generally unmeasurable. On the other hand, rapid maneuverability is highly desirable, and then the orbital maneuver in proximity of a freely tumbling spacecraft needs to be performed in schedule time.

To tackle the above problems, we make use of adaptive finite time control technique. The relative motion model for a freely tumbling spacecraft is firstly proposed in the body coordinate system of the chaser, which only contains relative position and velocity rather than other orbit information. A finite time controller, based on nonsingular terminal sliding mode technique, to perform the desired relative translation maneuvers, is then designed. The transient and steady-state performance of the relative translation system is discussed by Lyapunov method. It should be noted that the controller can drive the chaser to the expected position in finite time rather than in the asymptotic sense, where time tends to infinity. A modified adaptive finite-time controller that deals with the possibility of translational maneuvers is then proposed. In particular, the controller can estimate unknown thrusters of freely tumbling target, and guarantee the globally finite-time stability of the closed-loop system in the presence of uncertain orbital parameters and unknown thrusters. Simulation results are finally provided to illustrate the performance of the proposed controllers by comparing with a PID controller. This will demonstrate that the finite-time controllers can drive the relative position and velocity to the desired values more rapidly than other approaches. Using adaptive finite-time techniques for the relative translation in proximity of a freely tumbling spacecraft appears to provide a promising method for such missions.