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SPACECRAFT POSITION AND ATTITUDE MANEUVERS USING FINITE-TIME CONTROL TECHNIQUE

Abstract

Spacecraft position and attitude maneuvers are a critical element of most space missions. For a certain type of missions, such as on-orbit service, assembly of space systems and formation flying, the chaser spacecraft is required to approach or rendezvous with the target spacecraft, and perform large angle slews and complicated translational maneuvers. In the practice, the attitude and translational motions are coupled and highly nonlinear. Although previous studies have proposed various algorithms to achieve position and attitude control, they only guarantee asymptotic stability and convergence. This implies that the control objective can be achieved in infinite time. The requirement for rapid convergence is, however, vital for many space missions. Consequently, it is imperative to develop a new control algorithm endowed with properties of fast stability and convergence.

To tackle this problem we make use of finite time control technique. The coupled dynamics and kinematics equations are firstly proposed in the form of six degrees of freedom (6DOF), and are formulated as a Lagrange-like equation. Then a finite time controller, based on the novel fast terminal sliding mode technique, is designed to perform the desired position and attitude maneuvers. The finite-time stability and convergence of the closed-loop system are discussed by Lyapunov method. It should be noted that the controller has demonstrated superior performance, which can drive the attitude and translational motions to the expected trajectory in finite time rather than in the asymptotic sense. Model uncertainties and disturbances are also addressed in the paper to evaluate the algorithm's robustness. A modified finite-time controller that deals with this problem by using a finite-time generalized disturbance observer is then proposed. In particular, the observer can estimate the generalized disturbances in finite time. The simulation results are finally provided and discussed to illustrate the performance of the proposed controllers by comparing with asymptotic-stability-based sliding mode control. This will demonstrate that the finite-time controllers can drive the attitude and translational motions to converge to the expected values more rapidly. To the best knowledge of the authors, previous studies mainly focus on finite-time control of spacecraft attitude, and have very limited results on the coupled position and attitude maneuvers. The spacecraft position and attitude control using finite-time technique is, therefore, a novel and important topic, as it provides a theoretical method for fast spacecraft maneuver.