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ATTITUDE STABILIZATION CONTROLLER FOR UNDERATUATED SPACECRAFTS BASED ON HIERARCHICAL ADAPTIVE SLIDING-MODE CONTROL

Abstract

The rigorous space environment often causes the malfunctions of long-running spacecrafts in orbit, the risk of unexpected actuator and/or sensor failures can not be negligible. The problem associated with the attitude stabilization by using less than the degrees of freedom of a rigid spacecraft should be addressed. In this paper, an attitude stability controller based on hierarchical adaptive sliding-mode control for underactuated spacecrafts is designed. To realize the whole state feedback, the attitude euler angles and angular rates are used as state variables. The attitude control affine systems including the kinematics and dynamics equations are modeled and analyzed. Meanwhile, aiming at the time-varing, interfering moments and unmodeled errors, input-output feedback linearization is utilized to decouple the nonlinear system with bounded uncertainties. To acquire an appropriate sliding surface which should ensure the stabilization of sliding mode asymptotically and the tracking error approaches zero, synchronously, the first-layer sliding surface is defined by a positive definite diagonal gain matrix and a given reference command of the underactuated system. Then, the second-layer and third-layer sliding surface are constructed in sequence to aviod attitude across zero oscillations repeatedly. The global asymptotic stability of all sliding surfaces is proved by using Lyapunov stability theory and Barbalat theory, and the switching controller is derived by using the sliding-mode control theory. A desired hierarchical sliding mode controller should be adaptive with various disturbing terms of the real system to prevent exciting the high frequency uncertainties. Therefore, we present a parametric adaptation law with adjusting control parameters in real time via estimating time-varying parameter perturbations online from metrical informations. By defining the parameter-error vector and the prior parameters vector to ensure indeterminate parameters vector converging to the true value, an adaptive updating strategy is adopted: stop renovating the parametric adaptation law if parametric estimate is beyond the border, while persist in initiating it on the contrary. The numerical contrastive simulations indicated that the attitudes and angular rates of underactuated axes can be decreased to zero faster than other axes, furthermore, the decaying rate of angular rates is faster than the attitudes of underactuated axes. Meanwhile, the proposed controller is robust to the parametric perturbations and external disturbances, and has the excellent dynamic tracking performance with no zero-cossing stabilization and switch chattering.