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A NOVEL VELOCITY OBSERVER FOR 6DOF SPACECRAFT FORMATION FLYING

Abstract

Simultaneous position and attitude control of a rigid spacecraft has been the focus of much recent research because of its applications in formation flying, spacecraft rendezvous and docking, space-based interferometry, etc. Concurrent relative position and attitude control with high precision is a key enabling technology for these missions because they fit more naturally into simultaneous rather than sequential position and attitude control. Traditional position and attitude control of spacecraft have been treated as decoupled problems which are later concatenated. The stability of the overall 6 degrees-of-freedom (6DOF) system, however, may not be directly implied by the individually stable translation and rotation systems and must be further addressed. In addition, most of the existing studies assumed that linear and angular velocity measurements are available for control law design. The velocity information, however, can be corrupted by large noises and is thus unsuitable for utilization. Due to the faults or failures of the velocity sensors, the velocity measurements can be unreliable or even unavailable.

This paper investigates 6DOF spacecraft formation flying control without linear and angular velocity feedback. In other words, we assume that only the position and attitude of the follower are available from measurements. Specially, the 6DOF kinematics and dynamics of the follower spacecraft relative to the leader spacecraft is described in the framework of dual quaternions. Dual quaternions, as an extension of quaternions, lead to compact unified representation of the full rigid-body motion and thus facilitate the design of an integrated position and attitude control strategy. We propose a continuous, finite-time, second-order velocity observer to recover the spacecraft velocity. It provides velocity estimates convergent to the true values in finite time. After that, a 6DOF output-feedback controller can be obtained by driving a nonlinear, proportional-derivative, full-state feedback tracking law. With the proposed method, the follower can track the desired trajectory relative to the leader in finite time. The proposed method is efficient in computation due to its simple structure and is thus suitable for online implementation. Finally, a circumnavigation operation of a leader-follower spacecraft system is simulated to demonstrate the effectiveness of the proposed method.