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CONTROL OF 6DOF SPACECRAFT HOVERING ABOUT ASTEROIDS WITHOUT VELOCITY MEASUREMENTS

Abstract

Asteroids are mostly small in size and have weak gravitational attraction. It is thus feasible to maintain an inertial hovering or a body-fixed hovering state about the small body using active control. In other words, an effective equilibrium position and attitude can be created at the desired location in the inertial frame or the small-body-fixed frame by applying nearly-continuous thrust to balance the residual acceleration of the spacecraft. Controlled hovering avoids the extreme difficulty in designing stable closed orbits about small bodies and is useful for global mapping, high-resolution observation of a particular site, identifying candidate landing sites, and a holding stage before landing on the surface. A key enabling technology toward this objective is concurrent relative position and attitude control with high precision. 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.

In order to recover the spacecraft velocity, we propose a Hölder continuous, second-order, velocity observer with fractional power functions. It is shown that the fractional power gains, if appropriately adjusted by means of a homogeneous method, can result in a uniformly almost globally finite-time stable estimation error system independently of the control input. In other words, velocity estimates from the observer converge 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 spacecraft can achieve and maintain the desired hovering position and attitude in finite time. The proposed method is efficient in computation due to its simple structure and is thus suitable for online implementation. In addition, both the observer and the output-feedback controller avoids the unwinding problem on the attitude space. Finally, a body-fixed hovering operation of a spacecraft about an Eros-like asteroid is simulated to demonstrate the effectiveness of the proposed method.