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Author: Dr. Wentao Fu
School of Aerospace Engineering, Beijing Institute of Technology, China, wentao.fu90@gmail.com

Mr. Shengying Zhu
School of Aerospace Engineering, Beijing Institute of Technology, China, zhushengying@gmail.com

DUAL-QUATERNION IMMERSION AND INVARIANCE BASED ADAPTIVE CONTROL OF ASTEROID HOVERING SPACECRAFT

Abstract

Hovering of spacecraft near small bodies such as asteroids and comets is an essential capability for scientific investigation of these bodies. Recent researches, however, addressed either the orbital motion or the attitude motion of a probe in the vicinity of asteroid with no coupling between them assumed. In practical missions, the translational and rotational dynamics of a spacecraft are generally coupled in reality, it is also important to maintain the desired attitude when keeping the probe at the desired position in the vicinity of target asteroid due to the directional requirements of the onboard scientific instruments. The unique irregular gravitational field around the asteroid have a significant effect on both the orbital and attitude dynamics of the vehicle nearby. In this paper the relative translational and rotational motion of an asteroid-hovering operation is derived in terms of dual quaternions with the mass and moments of inertia matrix of the asteroid, and the mass of the spacecraft are not known. This paper presents an immersion and invariance based adaptive state variable feedback control law for hovering control of spacecraft in the vicinity of asteroids. Based on the immersion and invariance theory, a noncertainty-equivalence adaptive control system is designed for steering the spacecraft to fixed point with prescribed attitude for hovering control. The control system consisting of an stabilizing control module and an parameter identifier. To circumvent the complexity of the immersion and immersion methodology, filtered signals are used in the design of control law. The detailed design principles and a rigorous stability analysis are also provided. By the Lyapunov analysis, it is shown that the pose tracking error asymptotically converges to zero and all the signals in the closed-loop system are bounded. Finally, an asteroid hovering operation with the proposed method is simulated to demonstrate its effectiveness and application.