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6-DOF CONTROL FOR SPACECRAFT HOVERING OVER AN ASTEROID WITH DISTURBANCES

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. Additional considering the fuel consumption and probe body rotation, the mass and inertia moment of the probe may vary slowly, the variation will result in parameter uncertainty. In this paper a 6-DOF dynamic equation describing the relative translational and rotational motion of a probe is derived, taking the irregular gravitation, model and parameter uncertainties and external disturbances into account. We present a novel and robust guidance approach for the hovering of spacecraft near small bodies, which is based on non-linear sliding mode control theory and extended state observer adapted to the problem of hovering control. It is desired to design an active control strategy to null out the accelerations and torques due to the existence of the irregular gravitation, parameter uncertainties and external disturbances, realizing the probe hovering at a desired position with the desired attitude in vicinity of an asteroid. The proposed guidance law is based on the idea of using sliding mode surface and extended state observer, to guarantee the system state converge asymptotically to the desired state in the presence of uncertainty and external disturbance. Extended state observer is applied to estimate the uncertainties and disturbances mentioned above, by which sliding mode controller is designed combining the two approaches respectively to force the state variables of the closed loop system to converge to the desired state. The detailed design principles and a rigorous stability analysis are also provided. Finally, simulation results demonstrate the validity of the effectiveness of the proposed strategy.