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ATTITUDE-TRAJECTORY COUPLING ADAPTIVE CONTROL FOR FLEXIBLE LANDING ON SMALL CELESTIAL BODY

Abstract

Soft landing missions on small celestial body possess significant scientific value. Due to the weak gravity and the rugged terrain environment, conventional rigid lander is at the risk of bouncing or rolling on the small celestial body. To reduce such risk, novel flexible landing scheme is recently proposed and investigated. The flexible probe conceived for flexible landing adopts a discoid shape, and is mainly made of flexible material. While attaching the surface of the small celestial body, the impact energy can be damped by the flexible material to avoid bouncing, and the discoid shape provides huge contact area to prevent rolling. Multiple thrust-nodes distribute symmetrically on the flexible probe, each equipped with a pair of thrusters. The overall attitude and landing trajectory of the flexible probe are both controlled by the multiple thrusters. For each thruster, the magnitude of thrust is limited, and the direction of thrust can only be deflected within a certain angle around the node's axial direction. Furthermore, the axial directions of the nodes are always affected by the flexible deformation, making the control process of the flexible probe strongly coupled. To achieve integrated control of the flexible probe's attitude and trajectory under thrust constraints and time-varying flexible deformation, an adaptive control method is proposed in this paper. Firstly, the overall attitude-trajectory control command is designed, based on the fractional-polynomial power decent guidance law and proportional-plus-derivative controller. Nominal values of the tunable parameters in the overall command are determined for optimal landing performance, regardless of constraints or flexible deformation. Then, the real-time thrust allocation model is established and solved, which assign the overall command to each thrust node, as well as verify the feasibility of the overall command under thrust constraints and flexible deformation. For the infeasible situation, adaptive adjustment strategy is implemented to adjust the tunable parameters in the nominal overall command. For the feasible overall command, consistent strategy among the thrust direction of all nodes is employed to minimize fuel consumption. Based on the two strategies, real-time attitude-trajectory command of the flexible probe is modified and the thrust command of each thruster is obtained using intelligent learning algorithm. Simulation results show that the proposed control method is capable to coordinate multiple thrusters under constraints and time-varying flexible deformation. Smooth control for both attitude and trajectory of the flexible probe can be integrated achieved for flexible landing.