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INTELLIGENT COOPERATIVE CONTROL METHOD FOR FLEXIBLE PROBE LANDING ON SMALL CELESTIAL BODIES

Abstract

In the landing mission of the small celestial bodies, the conventional rigid probe is prone to rebound or roll due to the low-gravity environment. In order to achieve a soft landing, a novel scheme named flexible landing is recently proposed. The flexible probe adopts a discoid shape to provide a large contact area, and flexible materials to damp the impact energy. The flexible probe can effectively reduce the risk of bounce or rollover while attaching the surface of the small celestial body. However, limited by the special configuration and influenced by the flexible deformation, the control of the flexible probe is challenging. First, the flexible probe deforms during the landing process, which indicates that the attitude dynamics of the rigid-body are no longer applicable. Moreover, the attitude of the flexible probe is controlled by multiple thrusters distributed on the probe surface. Due to the internal force caused by the flexible connections between the thrusters, the dynamic system of the flexible probe is nonlinear in high dimension, and the effect of the multiple thrusters is coupled. In order to achieve a stable flexible landing, it is necessary to investigate how to model the attitude of the flexible probe and how to control the probe attitude through the cooperation of the thrusters.

According to the special configuration and thrust distribution characteristics of the flexible probe, an altitude difference oriented intelligent cooperative control method is proposed in this paper. Firstly, taking each thruster as a node, a simplified dynamic model of the flexible landing is established, and a scheme describing the flexible probe's attitude by the difference of the nodes' altitude is proposed. Then, using the high-order sliding mode control, a closed-loop feedback control law of the nodes' altitude difference is designed to generate the attitude control command of the flexible probe. Next, to complete the allocation of the guidance command and the attitude control command, an intelligent control allocation method based on network is established. The network is trained by deep learning algorithm, with consideration of the complex internal force and the time-varying probe configuration caused by the flexible deformation. Simulation results show that the proposed method can coordinate the limited control ability of each thruster and stabilize the probe attitude during the flexible landing, and thus is suitable for high precision and stable landing missions on the small celestial bodies.