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COOPERATIVE GUIDANCE FOR SMALL BODY FLEXIBLE LANDING STRATEGY USING MULTIPLE SLIDING SURFACES METHOD

Abstract

Small body landing missions face challenges such as irregular gravitational fields, uncertain dynamic environment, complex surface morphology, and broadly distributed terrain obstacles. Limited by the intolerable communication time delay, the Earth-based command cannot exert effective real time control to the lander. Autonomous trajectory generation and guidance are necessary at the final stage of powered descent process. Due to the estimation errors of the navigation system, control errors of the actuator, and insufficient perception of terrain obstacles, accidents including trajectory deviation, collision and bounce are likely to occur, which can adversely affect the implementation of subsequent detection activities. In the future missions, the selection of landing sites will be more focused on areas with high scientific values, leading to stricter requirements for the precision and safety of autonomous guidance.

To suppress bounce and tumble at surface touchdown, this paper proposes a novel landing scheme that adopts flexible structure and multi-actuator system to replace the traditional rigid landing structure. The flexible lander is more capable of absorbing collision energy, improving the dynamic system's tolerance to errors and disturbances, and increasing the adaptability to complex terrains. Since the flexible structure can hardly maintain its original shape under the control of a single actuator, a distributed control system with multiple actuators need to be applied to implement coordinated guidance. However, the existence of thrust errors can make the nominal control commands not uniformly distributed to each actuator, which leads to problems like deformation and attitude instability of the flexible lander. To fix the new problems, the dynamic characteristics of the flexible structure with distributed actuators are first analyzed. A dynamic model consisting of the stress among control nodes and the flexible material deformation is established, and the evolution of the lander's configuration under the control deviation is given. Then a multi-sliding surface cooperative guidance strategy is developed based on the high-order sliding mode theory, and a Lyapunov function is designed to verify its global stability. Both the tracking of nominal trajectory and the correction of the control deviation are considered, therefore the strategy is capable to restrain the deformation of the flexible structure while ensuring the landing precision with distributed control system. Finally, the method proposed is verified through numerical simulations. The result shows that the multi-sliding surface cooperative guidance strategy can effectively weaken the influence of control error on the flexible lander's kinestate, improving the safety of small body autonomous landing.