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SELF-TUNING TRAJECTORY CONTROL OF SMALL BODY LANDING MISSION BASED ON RISK PREDICTION

Abstract

The small body landing technology is the key to the success of sample return missions, as well as implementation of in-situ detection, obtaining high-resolution surface images and high-precision terrain data. Increasing mission complexity has brought higher requirements for the landing accuracy and safety. In implemented small body landing missions, a combination of on-board auto-navigation and Earth-based command has been used in trajectory control during the landing phase. Due to the exist of communication delay, the Earth-based command cannot cover the final part of the landing process, which lasts for several minutes, and the lander has to control its landing trajectory autonomously. The terrain of small bodies is usually complex, with ridges, valleys, pits, and hills widely distributed. For obstacle avoidance problems, existing solutions include adding terrain constraints in the nonlinear programming of trajectory parameters, or controlling the trajectory to maintain a convex curvature shape in a closed-loop guidance law, which can reduce the collision probability of terrain obstacles. However, these methods cannot be flexibly adjusted according to the actual terrain and lack generality. Aiming at the technical requirement of autonomous terrain obstacle avoidance during small body landing missions, this paper designs a self-tuning control method of landing trajectory based on the prediction of terrain obstacle risk. Firstly, a point cloud of the lander's reachable area under the maximum thrust is calculated in real time. According to the conflict between the point cloud and the surface terrain of the small body, the threat of terrain obstacles is determined, the shape and distribution of the terrain obstacles in front of the lander are predicted, and the optimal thrust direction can be calculated. All these results are transmitted to the self-tuning controller. The self-tuning control system is designed on the basis of an analytical optimal guidance law, including three thrust coefficients of the lander's three-axis thrust component. The thrust direction distribution of the engine can be adjusted by changing the thrust coefficients, meanwhile the shape of the landing trajectory can be flexibly changed to avoid terrain obstacles. The simulation results show that the landing trajectory control method proposed is able to fulfill the terrain obstacle avoidance requirement during small body landing missions and improve landing safety compared to existing methods. There are reasons to believe that the method has positive significance for establishing a full-process active control system for small bodies.