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MULTI-OBJECTIVE OPTIMIZATION OF ATTITUDE MANEUVER PLANNING FOR FLEXIBLE ASTEROID LANDER USING POPULATION EVOLUTIONARY ALGORITHM

Abstract

In soft landing mission on asteroids, concerning obstacle avoidance, environment constraints on payloads and selection of landing site, asteroid lander faces various scenarios requiring attitude maneuver with optimized performance, such as minimum maneuvering time during surface imaging. During attitude maneuver operations, including sun avoiding, slew for communication and optical navigation observation, multiple constraints and optimization objectives needs to be considered to solve maneuver paths in attitude planning. In this paper, for the sake of safer design under the risk of bounce and turn-over by rigid spacecraft during asteroid landing, a novel type of flexible lander with three thruster units and connecting deformable material is selected. Each unit is regarded as an under-actuated rigid unit with thrusters providing control forces. Attitude maneuver of flexible lander causes deformation of relative displacement and angles between units, which generates internal forces and torques. This makes attitude planning a problem of solving the maneuver path of a configuration-attitude-coupled three-body system, while satisfying constraints of payload pointing and bounded thrusts. To reduce difficulty of tracking control, less flexible deformation of each thruster unit is preferred, that is, attitude planning is transformed into a constrained optimization problem with objectives of minimal flexible disturbance as well as minimum maneuvering time. An approach to multi-objective optimization of attitude maneuver path planning for flexible lander is proposed. Firstly, an improved rapidly-exploring random tree method is used as global planner, in which flexible constraints based on the lander's equivalent model, double-zero constraints and pointing constraints are satisfied. The method generates trajectories of three units, which are then converged to path of spacecraft pointing nodes. Subsequently, multi-objective optimization model considering engineering bounded constraints, e.g., thruster saturation, is designed. To meet the optimization objectives of minimum maneuvering time and minimal flexible disturbance of relative angle between units, a multi-objective fruit fly optimization algorithm based on non-dominated sorting is adopted to produce Pareto frontier, in which initial maneuver path from former step is substituted into population evolutionary process. Obtaining a global optimal solution set, the three-unit velocities and control thrusts are thus calculated by inverse dynamics. Proposed attitude planning method are applied in simulation cases to present a good performance of global optimization ability and searching eciency. By comparing the results to those from optimal control method, the comprehensive optimization effect is validated.