Paper ID: 64502
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student

19th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Post Mission Disposal and Space Debris Removal 2 - SEM (6)

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MOTION PLANNING WITH END-EFFECTOR ATTITUDE CONSTRAINTS FOR FREE-FLOATING SPACE ROBOT

Abstract

For capturing of space debris with Free-Floating Space Robot(FFSR), in order to ensure the effective observation of the target by the hand-eye camera, the End-Effector(EE) attitude of FFSR is required to be maintained within a certain range when FFSR is moving toward the target. This type of problem is called Motion Planning with End-Effector Attitude Constraints(EE-AC-MP). For motion planning problem with task constraints, the existing methods are mainly aiming at the Implicit Equality Task Constraints(IETC) of the fixed-base manipulator. The existing methods can handle the more stringent IETC, but existing methods are aimed at path planning that only considers geometry. EE-AC-MP of FFSR needs to consider differential constraints directly. Besides, EE-AC-MP of FFSR needs to consider not only Implicit Inequality Task Constraints(IITC), but also Explicit Inequality Task Constraints(EITC). EITC means that the attitude of FFSR base is required to be maintained within a certain range.

Taking into account above problems, this paper proposes RRT For FFSR with EE-Attitude-Constraints(RRT-for-FFSR-with-EEAC). The key of RRT-for-FFSR-with-EEAC is that the local trajectories generated by local planners should respect IITC and EICT. RRT-for-FFSR-with-EEAC catains two types of local planners: local planner for ectending toward goal and local planner for ectending randomly, and we call them Local Planner for Random-Configuration-Guiding Constraint-Growth(LP-RC-GCG) and Local Planner for Goal-EE-Pose-Guiding Constraint-Growth(LP-GEE-GCG) respectively. Firstly, when designing LP-RC-GCG and LP-GEE-GCG, we propose Control-Based Local Planner Designing Method(CBLP-DM). CBLP-DM is an iterative process, and the action is generated by using the pseudo-inverse of Jacobian matrix to project error in each iteration. CBLP-DM can consider differential constraints directly and respect EITC. Then, considering that the degree-of-freedom(DOF) of the manipulator joint is less than the sum of DOF of FFSR's configuration and the DOF of the EE attitude, we propose a principle named 'Adjust Base Attitude/EE Attitude When Necessary' for the action generation in each iteration of CBLP-DM. For each iteration of LP-GEE-GCG, only when the perturbation of the base attitude reaches a threshold, the base attitude is adjusted in the null-space of the Generalized-Jacobian-Matrix. For each iteration of LP-RC-GCG, only when the EE attitude reaches a threshold, the EE attitude is adjusted in the null-space of the Jacobian Matrix Related to State-Transition. With this principle, the problem of 'the DOF of constraints and task is more than the DOF of the actuator can be alleviated, and IITC can be satisfied.