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ON-ORBIT MANIPULATION OF A PASSIVE OBJECT BY 'PITCH', 'HIT' AND 'CATCH' IN CONTACT-RICH ENVIRONMENT FOR SWARM SPACE ROBOTICS

Abstract

Space robotics play an important role in space tasks such as on-orbit servicing and active debris removal. With the development of the robotic technology, small modular swarm robotics are attracting more attention of space community. Compared with the traditional large manipulator system, such as the Canadarm, the swarm robotic has the advantages of high overall stability, maintainability, extensibility, and low cost. The contact-rich environment of swarm robotics is a new challenge for on-orbit cooperated manipulation. However, most state-of-the-art techniques of cooperated manipulation focus on the post-contact phase, assume that contacts have been established and are stable enough from easily break. This assumption narrows the range of problems that can be solved. We are interested in a manipulation scenario that a passive object is moved by 'pitch', 'hit', and 'catch' by different robotics to save the total fuel of swarm system (or balanced fuel cost of each robotic). This scenario is obviously with a lot of contacts and breaks, which can not be solved under the mentioned assumption. In this paper, we introduced a direct trajectory optimization method for on-orbit manipulation by swarm robotics, considering contacts make and break between robots and the passive object. From a geometric constraint point of view, contacts are formulated as linear complementarity constraints, which are suitable for direct method formulations. The direct method searches over states and controls simultaneously, with dynamics of the system imposed as constraints. The resulting optimization problem is a large sparse mathematical program with complementarity constraints, which can be solved by large-scale sparse SQP solvers like SNOPT. With the trajectory optimization method, we demonstrated a planar cooperated manipulation by three robotics in numerical simulation. A passive object with rotational velocity is detumbled while moved from initial point to target point. If the object's rotational velocity is not too fast, the optimized trajectory shows a motion quite like 'pitch', 'hit' and 'catch'. In another task with a fast spinning object, swarm robotics come to the object and push it together for a while to reduce it rotational velocity in time.