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ON COMPLIANCE CONTACT CONTROL FOR MULTI-ARM ROBOTIC CAPTURING OF LARGE TUMBLING SPACE DEBRIS

Abstract

When a multi-arm space chaser captures a large tumbling target, the chaser almost cannot manipulate the target effectively due to the characteristics of the large target inertia and dynamic motion of the anchor points. In this scenario, the target weighs more than chaser or even several times than it, and just like a human manipulates a free-floating car in the micro-gravity environment. In the capture process, the multiple arms of the chaser impact and grasp their corresponding handles, which present a great challenge for the uncertain impact impulses. In response to the challenge posed by this issue, we propose a multi-arm capture program for large targets. Firstly, a modular joint used for the space environment is designed, which is used to form a multi-arm space robot platform. Due to the microgravity application, all the joints in a space manipulator arm are the same with each other. Secondly, we model the kinematics and dynamics of tree-structured multi-arm free-floating space robot, which is the basis for subsequent research on capturing of large target. When the space robot capturing the target, the configuration of the robot changes from the free tree structure to the multiple kinematic close-loop chain one, and the model of multiple closed-loop chain kinematic constraint equation is established. Thirdly, a high-level controller is designed through the construction of mechanical impedance on CoM of chaser on orbit, which is output to a low-level one, and a low-level controller is designed based on the supporting arms to penalize deviation from desired compliance objectives. In this way, the multi-arm impacts and large drag force from the target can be compounded effectively. Fourthly, the programming objectives considering the joint motion manipulability measurement of the supporting and swing arms are designed, and the supporting arms are controlled to achieve the desired goals. Then, the singularity problems can be avoided degradation during the compliance contacts effectively. The developed control scheme is simulated on a four-arm chaser in 6-DoF on-orbit space, and experimentally tested on a dual-arm setup composed of two 3-DoF space manipulator on a 3-DoF air-bearing bed, which is dragged by a staff as an alternative to the drag force from the large tumbling target. Finally, the results show that the above method is effective.