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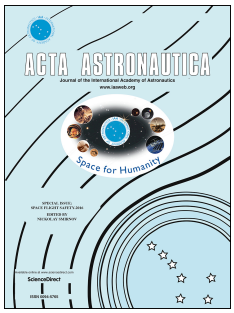

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Contact Dynamics and Control of a Space Robot Capturing a Tumbling Object

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Abstract

Capture of a free-floating space object in orbit is a challenging task especially when the object is tumbling. In this paper, the contact dynamics modeling and control problem for capturing a fast tumbling target object by a space robot are investigated. A generic frictional contact model is developed to represent the contact forces between the robot's end-effector and the target object. The frictional contact formulation is based on the compliance contact force and bristle friction model which can simulate intermittent frictional contact situations involving multiple-point contacts between contact interfaces with complex geometries. A resolved motion admittance control method is designed to realize a good tracking for a tumbling target object while increasing the compliance of the space robot. A simulation example of a 7-joint manipulator capturing a tumbling object in three dimensions is presented. The simulation results revealed that various contact scenarios during the capture process can be well simulated with the developed contact model and a good performance of the designed control method for capturing a fast tumbling target object.

Keywords

Contact dynamics; Space robotics; Robotic capture.

1. Introduction

Instead of human beings, space robots are increasingly playing a key role in on-orbit servicing operations. They can do many tasks such as maintenance, assembly, transportation, refueling, deployment and retrieval. When the object to be captured is a non-cooperative target, such as an out-of-control tumbling satellite, it will push the current space robotics technology beyond the limit. The contact dynamics modeling approach and the control strategy for such a capture task need to be further studied and matured before such a real mission can be conducted in space.

The operation of a space robot capturing a tumbling object is a complicated process which usually includes four phases [1,2]: observing and planning phase, approaching phase, grasping phase, and post-capture stabilization phase. In the first phase, the space robot is kept in station to observe motion information of the target object and plan the capture operation strategy. In the second phase, the space robot is controlled to make its end-effector approach and track the target object. In the third phase, the space robot is controlled to grasp the target object, which involves physical contact between the robot and the target. And the post-capture combined system including the target object, the robot and the servicing satellite is stabilized in the last phase. Among the four phases, the third phase (i.e., the gasping phase) is the most critical and risky operation phase because of the physical impact. In this phase, an excessive contact force between the end-effector and the target object may result in damage of the contact interface or instability of the servicing satellite, which can even lead to a failure of the

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