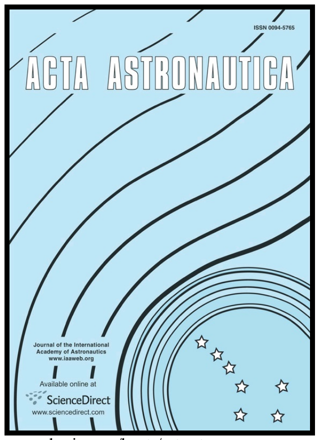

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Reactionless Camera Inspection With a Free-Flying Space Robot Under Reaction Null-Space Motion Control

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Abstract

The possibility of implementing reactionless motion control w.r.t. base orientation of a free-flying space robot in practical tasks is addressed. It is shown that such possibility depends strongly on the kinematic/dynamic design parameters as well as on the mission task. A successful implementation of a camera inspection task is reported. The presence of kinematic redundancy and the manipulator attachment position are shown to play important roles. More specifically, for a manipulator arm with a typical seven degree-of-freedom (DoF) kinematic structure, it is shown that two motion patterns, wrist reorientation and folding/unfolding of the arm, result in almost reactionless motion. The orientation pattern is adopted as the main task for camera inspection, while the remaining four DoFs are used to ensure complete reactionless motion and to minimize the position errors. Since the composition of these tasks introduces the so-called algorithmic singularities, **two methods** are suggested to alleviate the problem. Furthermore, it is shown that other types of singularities may also be introduced in case of an inappropriate choice of the manipulator attachment position. At the end, numerical analysis is provided to show that reactionless motion provides an advantage in terms of kinetic energy as well.

Keywords: Free-flying space robot, Reactionless motion control, Practical application

1. Introduction

The development of free-flying space robots (FFSR) has been steadily advancing since their first appearance about almost three decades ago [1]. These robots are envisioned to perform a few sophisticated space missions such as space debris removal, repairing/refueling of satellites and construction of large space structures [2]. A FFSR comprises a satellite base with attitude control devices, such as reaction wheels, and one or more manipulator arms. The controller has to deal with base rotation arising from the dynamic coupling between the manipulator(s) and the floating satellite base [3]. Because of the base rotation, control methods which are used in terrestrial manipulators cannot be directly applied.

One possible approach to solve the above problem is to implement a controller based on the Generalized Jacobian [4]. Thereby, the momentum conservation law is used as a constraint to eliminate the base rotation resulting from the differential relationships in the system. Thus, similar to terrestrial robots, the end-effector velocity can be represented in terms of joint velocity only, without the need of base angular velocity/acceleration measurement. Methods of analysis and control developed for terrestrial robots can then be implemented by replacing the fixed-base Jacobian matrix with the generalized one [5, 6].

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