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Microgravity Experiments from Sub-Orbital to Orbital Platforms (3)

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REACTION CONTROL OF MULTI DEGREES OF FREEDOM SPACE MANIPULATORS: THEORY AND SIMULATED MICROGRAVITY TESTS

Abstract

The problem of controlling the reactions transferred to the spacecraft during manipulator manoeuvres is of particular interest in space robotics because reduced reactions result in reduced energy consumption and longer operating life of the Reaction Control System. In this paper the performance of a novel reaction control method recently introduced by some of the authors is analyzed in the case of hyper-redundant space manipulators. The proposed method locally minimizes the base reactions transferred by the manipulator to the base spacecraft by exploiting its redundancy, and has some important advantages with respect to the previous ones presented in the literature: a simple mathematical formulation, the possibility to use simple least-squares real-time routines for the solution, and the possibility to take into account the joint limits and the joint velocity and acceleration limits of the manipulator. Different test cases are analyzed in order to evidence the interesting performances that can be achieved with a high level of redundancy. The first test case is set up in order to show that a higher minimization performance can be obtained by increasing the degrees of freedom of the manipulator, in the case that the redundant degrees of freedom are less than the reaction components to be minimized. On the other hand, if the redundant degrees of freedom are equal to the reaction components to be minimized, a zero reaction solution is possible, and the number of reaction components that can be controlled increases as the redundant degrees of freedom increase. Then, the Zero Reaction Workspace of different space manipulators with increasing degrees of freedom has been computed, showing that the workspace in which a zero reaction is possible is significantly increased by increasing the available degree of redundancy. Simulations are carried out in order to demonstrate the proposed concepts, and then the experimental validation of the proposed solutions is carried out by means of a planar three degrees of freedom manipulator, which is fixed to ground by means of a dynamometer in order to measure the reactions, and suspended by means of air-bearings on a granite plane in order to perform tests in simulated microgravity without time constraints.