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REACTION CONTROL OF FLEXIBLE JOINT SPACE MANIPULATORS

Abstract

The stringent weight requirements of space manipulators make joint flexibility an important issue to be taken into account in their design and control. The classical inverse kinematic redundancy resolution schemes available in literature do not take into account the joint flexibility. This because the joint flexibility is usually taken into account by a flexible joint control block, which works after the kinematic control block. This paper presents the theoretical formulation and the experimental validation of an innovative solution for the inverse kinematics of flexible joint redundant space manipulators. A dynamically consistent redundancy resolution scheme is used, which minimizes the dynamic disturbances induced on the spacecraft during the manipulator manoeuvres. The advantage of this method, which can be applied to whatever dynamically consistent redundancy resolution scheme, is that the system dynamics which has been computed for the inverse kinematics solution can be used to compensate for joint flexibility directly inside the kinematic control block. In this way classical joint control schemes can be used instead of more computation-intensive flexible joint controls. The proposed method is composed of a two step solution. First the inverse kinematics is carried out neglecting the joint flexibility, as in the traditional methods, and then a compensation term is computed in order to correct the joint accelerations taking into account the joint stiffness and damping characteristics. The dynamic variables necessary to obtain the compensation term are available from the first step since the dynamics of the system has already been computed. The proposed solution has been first validated by means of software simulations and then tested on an experimental test-bed, using a 3D free-flying robot previously tested in an ESA Parabolic Flight Campaign. In the test campaign the 3D robot has been converted in a 2D robot taking advantage of its modular structure, and it has been suspended by means of air-bearings on a granite plane. In this way it is possible to perform planar tests, which have the advantage that it is possible to simulate a microgravity environment without time constraints. The comparison between the simulated and the experimental results allowed to validate the proposed solution, giving an insight on the importance of using accurate estimates of the joint stiffness and damping characteristics.