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DYNAMIC MODELING AND ANALYSIS OF A SPACE ROBOT WITH A HYPER-REDUNDANT ROPE-DRIVEN MANIPULATOR

Abstract

Robotics are among the key technologies in space exploration activities. This paper studies the dynamics of a space robot. The concerned robot is designed for precise on-orbit servicing missions in a highly constrained environment. It mainly consists of a rigid platform and a rope-driven manipulator. The manipulator contains a large number of links which are driven complex rope network. The whole manipulator moves with a piecewise constant curvature. Such designs can enhance both the flexibility and controllability of the manipulator. When the manipulator is driven, the interacting forces between the links and ropes introduce complexity into the dynamic behavior of the manipulator as well as the space robot. Modeling the space robot appropriately is the key point of dynamic analysis of the space robot. This paper mainly makes three contributions. First, this paper proposes a dynamic model of the space robot based on methods of multibody dynamics. The ropes are simplified as linear elastic strings or torsional strings. The equations of motion are derived using space operator algebra. Second, the vibration of the space robot is investigated. The governing equations of the vibration are derived by applying the perturbation method to the proposed dynamic model. The values of the natural frequencies are investigated for the elasticities of the ropes. Third, the proposed dynamic model is applied in numerical simulation. The explicit fourth-order Runge-Kutta method is utilized to solve the equations of motion numerically. In numerical simulation, an upper bound of the time step is encountered. The value of upper bound is found to be related to the elasticities of the ropes. Such phenomena are studied by analyzing the stability region of the Runge-Kutta methods. The computational efficiency of numerical simulation is limited by the value of upper bound. Two modifications are introduced into the original dynamic model to relax the upper bound of the time step and improve computational efficiency of numerical simulation. The effects of the modifications are demonstrated by numerical results.