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MODELING AND DIRECT ADAPTIVE CONTROL OF A MANIPULATOR WITH VARIABLE-SPEED CONTROL MOMENT GYROSCOPES

Abstract

This paper addresses the problem of adaptive trajectory control of space manipulators with variable-speed control moment gyroscopes as actuators that exhibit elastic vibrations in their flexible links and that are subject to parametric uncertainties and modeling errors. First, it presents a study of flexible manipulators models, to propose a dynamic formulation that captures nonlinear interactions between the actuators and the flexibilities of the structures. Second, it develops an adaptive composite control scheme for tracking the end effector of a two-link flexible manipulator based on the singular perturbation theory. The control scheme consists of a slow adaptive control term and a fast control. The slow adaptive control term is a direct model reference adaptive system designed to stabilize the rigid kinematics and the fast control is a correction term to suppress the vibration using variable-speed control moment gyroscopes. Lyapunov stability of the controller is analyzed. It proposes the adaptive control law to stabilize the slow adaptive control. The performance of the adaptive controller is compared with its nonadaptive version in the context of a square trajectory tracking. The overshoot of adaptive control occurring at each direction switch is smaller than that of nonadaptive control. Moreover the adaptive controller settles rapidly to a steady state, such that tracking is close to a straight line along each side of the trajectory. Results obtained with the adaptive control strategy also show an increased robustness to modeling errors and uncertainties compared with the nonadaptive strategy by changing the uncertain parameters. The control torque of adaptive strategy is also compared with nonadaptive control, which shows that the improved tracking accuracy provided by adaptive controller is obtained at the detriment of greater control torque efforts.