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IMPLEMENTING MODEL-BASED VARIABLE-STRUCTURE CONTROLLERS FOR ROBOT MANIPULATORS WITH ACTUATOR MODELLING

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ABSTRACT

A model-based control scheme for robot manipulators employing a variable structure control law has previously been found to perform well provided that the design parameters are carefully chosen. Refinement to the system model of this original scheme is studied ~~in this paper~~ in which the actuator dynamics is taken into consideration. The practical experiments are carried out on a commercial revolute-joint robot manipulator.

1. INTRODUCTION

Because of the wide variations of the robot parameters particularly under high-speed operations and with possible payload changes, there has been a great deal of interest in adaptive control to overcome robot tracking problems associated with the coupled, nonlinear and time-varying dynamic system [1].

Various models have been used for the adaptive control purpose. One extensively investigated approach [2] adopts the full nonlinear model as used in the computed torque method [3]. The 'uncertain' parameters in the model are continuously adjusted according to a theoretically convergent adaptation process. As a consequence of the comprehensive compensation thus included in the system, independent PD joint-control will tend to be more robust and effective with respect to any arbitrary trajectories chosen. Unfortunately the successful application of this model-reference adaptive control method relies on persistent excitation [2,4] and the convergence rate cannot be prescribed by design. By applying a specially developed variable structure control law [5], it is no longer necessary to provide persistent excitation and exponential convergence can be ensured. The formulation of the control law [5,6] assumes the actuator and drive for each joint to be simply described by an amplification gain. It is the purpose of this paper to examine in detail the modification involved in considering the actuator dynamics in the overall system model and to present the results of practical implementation using a digital controller based on the refined model.

2. DEVELOPMENT OF NEW MODEL-BASED CONTROL

The robot dynamic equation is given by [4]

$$\mathrm{T} = M\ddot{\Theta} + H\dot{\Theta} + G + R \tag{1}$$

where T is the joint torque, M is the inertia matrix of the manipulator, Θ is the joint variable vector, $H\dot{\Theta}$ is the Coriolis and centrifugal torque, G is the gravitational torque and R is the viscous and Coulomb friction.

We define the relations for the error and filtered error vectors as follows:

$$\begin{aligned} \Theta' &= \dot{\Theta}_d + \Psi E = \dot{\Theta} + S \\ \Theta'' &= \ddot{\Theta}_d + \Psi \dot{E} = \ddot{\Theta} + \dot{S} \end{aligned} \tag{2}$$

where

$$S = \dot{E} + \Psi E \tag{3}$$

$$E = \Theta_d - \Theta \tag{4}$$

Θ_d is the desired joint trajectory and Ψ is a diagonal matrix.

Rearranging (2) gives

$$\begin{aligned} \dot{\Theta} &= \Theta' - S \\ \ddot{\Theta} &= \Theta'' - \dot{S} \end{aligned} \tag{5}$$

Using (5), equation (1) is linearly parameterized [2] to give

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