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A singular perturbation approach for tracking control of a parallel robot including motor dynamics

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The tracking control problem of a parallel robot, including the electrical actuator dynamics, is addressed. The inverse dynamic model of the mechanical part is obtained using Lagrange and the geometric properties of the robot. For electrically actuated robots we design a nonlinear control law in the armatures' input voltages. The model obtained is in a standard form that allows the application of the singular perturbation method. To validate the proposed corrective controller, the passicity concept and the singular perturbation techniques are used. Computer simulations are performed on the model of a real electrically driven six degrees-of-freedom parallel robot where the friction model is incorporated. The results show the robustness of the proposed controller with a good trajectory tracking performance.

1. Introduction

For parallel or serial robot manipulators, various control methods have been developed for robot motion control (Nguyen *et al.* 1993, Lebret *et al.* 1992, Spong and Vidyasagar 1989, Dombre and Khalil 1989). The principal limitation of many of these schemes is that controllers are designed at the torque input level and the actuator dynamics are not considered. However, actuator dynamics constitute an important part of the complete robot dynamics; furthermore, the actuators cannot be controlled directly in forces or torques. In this context, for a rigid-link electrically driven (RLED) robot, Tarn *et al.* (1991) develop a feedback linearizing control. The RLED manipulator is transformed to a third-order dynamic model that requires acceleration measurements. Dawson *et al.* (1992) use the assumption of exact model knowledge and propose a corrective tracking controller for RLED robots. Taylor (1989) for a RLE direct-drive (RLEDD) robots propose a composite control law and consider the RLEDD manipulators as a singularly perturbed model. In the presence of unknown parameters of a RLED robot, an adaptive controller scheme was designed by Stepanenco and Su (1994). Marino *et al.* (1990) develop a feedback linearizing control for an induction motor which includes both electrical and mechanical dynamics. The tracking control of a RLED robot is addressed by Mahmoud (1993) where a third-order differential model is obtained. For a hydraulically actuated serial robot, the tracking control problem is addressed by Abichou (1993) and d'Andréa-Novel *et al.* (1994) using singular perturbation method, where the hydraulic part is the fast subsystem.

The incorporation of the motor dynamics into the robot dynamic leads to a third-order differential equation (see for example Tarn *et al.* (1991), Vucobratovic

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