

A Cascaded Feedback Control Scheme for Robot Manipulator Systems with Actuator Dynamics

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Recently, various kinds of nonlinear actuator systems, such as pneumatic actuators and SMA (Shape Memory Alloy) actuators with the high power to mass ratio, are adopted for the robot manipulating systems. However, generally, it is difficult to make accurate models of such actuators and estimate the parameters due to the nonlinear characteristics.

For the robot systems with the above nonlinear actuator dynamics, the entire system becomes a high-order system. Therefore, improper gain tuning based on the linear control theory can make the system be unstable. Although the adaptive control scheme can be applied to specific nonlinear actuator systems calculating feedforward input by estimating of the system parameters, however it is not be applicable for many complex nonlinear actuator systems because of the difficulty of parameter estimation.

In this thesis, a cascaded feedback control scheme for the robot manipulator with nonlinear actuator dynamics is proposed in order to assure trajectory tacking performance theoretically. Furthermore, the trajectory tacking performance with the increase of the feedback gains can be assured as long as the gain setting fulfills some conditions which are apparent in the theoretical analysis.

At first, the trajectory tacking performance with high accuracy can be assured if the actuator dynamics is given by a 1st-order nonlinear differential equation. Next, when the desired velocity of the robot motion is zero, the suitable structure of the actuator dynamics and the implementation of the proposed scheme for asymptotic stability are explained. One of the purposes of this thesis is to make clear the range of the applicable actuator dynamics or some conditions to apply the proposed control scheme. Firstly, the redundantly actuated robot system is considered, where the respective actuator output force is converted through a constant coefficient matrix into the driving torque of the robot. Secondly, the actuator dynamics given by a higher-order nonlinear differential equation is investigated.

Finally, it is shown that the proposed control scheme can be applied to flexible joint robot systems and pneumatically driven systems for the trajectory tracking. Furthermore, the usefulness of the proposed control scheme on a pneumatically driven actuator system is demonstrated through both of simulation and experimental results.