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Intelligent Tracking Control of Redundant Robot Manipulators including Actuator Dynamics

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Abstract

In this paper, the trajectory tracking control problem of redundant robot manipulators at the actuator level is studied. In the proposed control scheme, RBF (Radial Basis Function) neural network and adaptive bound part is combined with the model based controller. All the existing uncertainties are learned with the RBF neural network without offline learning. The uncertain parameters, the bounded external disturbances and the neural network reconstruction error are approximated by the adaptive bound part. The hybrid controller is designed in such a way that both the trajectory tracking error and subtask task tracking error converges to zero as well as it controls the DC motors that are used to provide the required currents and torques. Finally, the Lyapunovs stability analysis is used to prove the overall closed loop system to be asymptotically stable.

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Keywords: Redundant manipulators, Radial basis function network, Lyapunov stability, Actuator dynamics, Tracking.

1. Introduction

At present, due to the fast robot motion, high velocity movements and high varying loads, actuator dynamics become an important part of the complete robot dynamics. For the various types of applications in mechanical systems, different types of actuators have been designed. The major effect of the actuator dynamics cannot be avoided in many of the resultant systems. The performance of the manipulator would be enhanced by including actuator dynamics.
Most of the progressive methods for the trajectory tracking are dependent on the full dynamic model of the manipulator. In case of model based controller, exact dynamic model and explicit parameters of the system are needed. To overcome the deficiency which is generated by the model errors and parametric uncertainty, a comprehensive research has been concerned on the design of adaptive and robust control schemes.
Dawson et al.[1] designed a corrective tracking control scheme for rigid link electrically driven manipulator with

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exact model knowledge. By using passivity techniques, Nawal et al.[2] developed position adaptive control scheme for electrically controlled two-link manipulator. A feedback control scheme with actuator dynamics was proposed by Kawamura et al.[3] for the improvement of the trajectory tracking performance of the manipulator and for the motion control of high order non linear systems. By considering uncertainties in electrical and mechanical subsystems, Homayounzade et al.[4] proposed trajectory tracking control scheme with actuator dynamics in backstepping manner. To overcome the uncertainties in kinematics and in the robot actuator dynamics, a newly task space plus robust controller was designed by Soltanpour et al.[5], which was based on back stepping method and on the Lyapunov stability. In present, neural network based technology has achieved much consideration due to its parallel distributed structure, learning capability and its property of approximation of any nonlinear function. There are many of the applications such as pattern recognition, information and graphics processing in which artificial intelligent technology has gained much popularity. For the trajectory tracking control problem with kinematic, dynamic and actuator model, Long et al.[6] developed an adaptive three layer neural network based controller. The controller was based on back stepping scheme and did not require the linearity in parameters assumption for the uncertain terms in kinematic, dynamic and actuator model of the manipulator. Liangyong et al.[7]developed a neural network based terminal sliding mode controller for the trajectory tracking of robot manipulator by integrating actuator dynamics. In the developed control scheme, a radial basis neural network was utilized for the approximation of non linear dynamics. For the highly precision performance of the joint position control of two-link robot, Wai et al.[8] developed four layer fuzzy neural network with projection algorithm by including actuator dynamics. Lyapunov stability was utilized for the convergence and better controller performance. Jafarian et al.[9] developed neural network based control scheme for the tracking control of dual robot manipulator by adding actuator dynamics. For the obstacle avoidance and for the trajectory tracking of redundant manipulator, Benzaoui et al.[10] developed fuzzy adaptive control scheme. In starting, obstacle avoidance was gained by generating self motion and after that self motion was integrated into adaptive fuzzy control scheme via ltered tracking error. The nonlinear tracking control problem of redundant robot manipulator was resolved by Kumar et al.[11] by using model free feed forward neural network based controller. By combining computed torque type controller, RBF neural network and an adaptive controller, Kumar et al.[12] developed a hybrid trajectory tracking controller for the redundant robot manipulator. In order to attain a high level position tracking, Wai et al.[13] developed an intelligent control system by including actuator dynamics that attains the properties of sliding-mode controller for the manipulator. In order to achieve high level position control of two-link manipulator by adding actuator dynamics, a Takagi Sugeno Kangtype fuzzy neural network control scheme was applied by Wai et al.[14]. For the stability of the closed loop system, the adaptive control law that was applied to the control scheme was determined in the form of the projection algorithm. In the presence of parameter perturbation and external disturbance, Chen et. al.[15] proposed robust tracking control scheme for the manipulator at the actuator level.

So far no research (to the best of authors knowledge) has been reported on trajectory tracking control of redundant robot manipulators by including actuators dynamics. Many of the trajectory tracking control schemes for the redundant robot manipulators have been considered in the literature that supplies torques directly to the robot without considering the actuator dynamics in the system. Moreover, Kumar et al.[11, 12] considered the different neural network based trajectory tracking control schemes for the redundant robot manipulators which does not take into account the effects of the actuator dynamics. To enhance the manipulator's performance, in the present paper, we have extended the control scheme proposed in [12] by integrating the robot dynamics with the actuator dynamics. With the integration of the DC motor dynamics with the robot dynamics, the actuator input voltage are control inputs that makes overall control system more rational.

The paper is organized into seven sections. Section 2, presents redundant robot manipulators kinematics, dynamics and actuator dynamics. Section 3, describes error system development. Section 4 presents RBF neural network based controller design. The stability analysis is presented in section 5. Section 6 deals with numerical simulation results with the conclusion in section 7.