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ScienceDirect

Procedia Computer Science 125 (2018) 42–49

Procedia Computer Science

www.elsevier.com/locate/procedia

6th International Conference on Smart Computing and Communications, ICSCC 2017, 7-8 December 2017, Kurukshetra, India

Design of Intelligent Hybrid Force and Position Control of Robot Manipulator

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Abstract

This work considers the Hybrid Force/Position control of robot manipulator in the presence of uncertainties and external disturbances. The proposed controller contains the model based term, Radial Basis Function neural network term plus an adaptive bound part. The Radial basis function neural network is functioning to learn a non linear function with no requirement of off line training. An adaptive bound part is developed to guess the unknown bound on the unmodeled disturbance, neural network reconstruction error and friction term. The Lyapunov function approach is used to the stability of the system. In the end simulations results are presented for two link robot manipulators.

Keywords: *Hybrid Force and Position control; Interection force; RBF neural network; Lyapunov Stability;*

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1. Introduction

There are many industrial applications such as grinding, fine polishing, contour following, deburring and assembly in which the robot end effector comes in the contact with the environment. During the implementation of

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10.1016/j.procs.2017.12.008

such types of tasks robot contact forces and robot position should be controlled. The Hybrid Force and Position control of robot manipulators has been studied by many researchers. Robert and Craig [1] proposed the hybrid force/ position control scheme in which dynamic decoupling among each of the robot joints is neglected. They designed the controller within the frame work of robot joint control system. Lozano and Brolioto [2] presented an adaptive controller for robot manipulator with redundant degree of freedom. This approach does not require measurement of the joint acceleration and the force first derivative. Yoshikwa and sudou [3] extended the work of Raibert and Craig. They consider the dynamics of manipulator and constraint on the end effector and designed a control algorithm. Kwan [4] designed the robust adaptive controller to control force/motion of the constrained rigid robot together with motor dynamics. In the robust approaches, the controller has fixed structure that produced an suitable performance for dynamics. Kouya et al. [5] has given an adaptive force/position controller by utilizing the strict feedback back-stepping method, depended on passivity. De Queiroz et al. [6] developed adaptive force/position controller for robot manipulator through the constrained motion with no velocity measurement. Cheah et al. [7] developed a motion/ force controller for robot with unsure dynamics and kinematics. Roy and Whitcomb [8] gave an idea of an adaptive force control method by low level position/velocity controller for robot arm in contact with surface of unidentified linear compliance. Filaretov and Zuev [9] created a method by not using force/moment sensor and supplementary device to manage the force used by robot end effect on the environment. Kouya [10] designed a hybrid force/position controller for robot manipulators with uncertainty which comes in the contact of environment. We find that this techniques need the information of complex regression matrices and problems are faced by unmodeled disturbances.

In recent times, neural networks have all-round characteristics for example learning ability and nonlinear mapping due to these it have achieved great popularity among community of control system. The initiative for neural network based control is that it is able to compensate unknown dynamics. Various approaches based on neural network are available in the literature for control of robot manipulators [11–12]. Karayiannidis et al. [13] presented a neuro adaptive controller of robot manipulator interacting with a flat surface when there exists many non parametric uncertainties in the dynamics. Bechlioulis et al. [14] designed an adaptive force/position controller based on neural network with the uncertainties in the dynamical model and bounded disturbances. Kumar et al. [15] designed an adaptive controller by taking into consideration the decomposition of dynamics of robot. Neural network was used to find out the unknown dynamics. Singh and Sukavanam [16] designed the robust adaptive controller based on neural network to achieve the stability of system. Li et al. [17] developed a hybrid position/force control scheme based on adaptive neural network for a constrained reconfigurable manipulator. For reducing the complication of the dynamic model a reduced model for reconfigurable manipulators is designed. Gajhar et al. [18] presented hybrid position/force controller for a constrained robot manipulator. The controller is made of two parts in which one part fulfils the objective of motion and force tracking and another part is used to compensate for the deficiencies of the CT controller.

In this paper, neural networks based hybrid force/position control method is developed for a constrained rigid robot manipulators in the presence of uncertainties. Generally, all hybrid force/position controllers which are based on neural network assume no prior knowledge about the dynamics of the system. Actually, some information is always available about the system dynamics. By using this facts of robot dynamics, we design the controller in which unknown dynamics part is compensated by using the RBF neural network. The whole system attains the stability in the sense of Lyapunov.

The paper is prepared as follow. We present the dynamical form of rigid robot manipulator and its decomposition along with two assumptions and useful properties related to dynamics in Section 2. In Section 3, the RBF neural network plus model based controller is created. The stability testing for the closed-loop error system is presented in Section 4. The simulation results are presented in Section 5.

2. Dynamical Model for Rigid Robot Manipulators

The general equation describing the dynamics of n link revolute rigid robot manipulators with environment contact is given by [16]

$$M(q)\ddot{q} + V_m(q,\dot{q})\dot{q} + F_e(\dot{q}) + G(q) + T_d = \tau - \tau_e \tag{1}$$

Where $M(q) \in R^{n\times n}$ is the inertia matrix. $V_m(q,\dot{q}) \in R^{n\times n}$ stands for the centripetal coriolis matrix. $G(q) \in R^n$ is the gravity effect. $F_e(\dot{q}) \in R^n$ is the friction effects. $\tau \in R^n$ represents the torque input vector. $T_d \in R^n$ represents