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A model of parameter adaptive law with time varying function for robot control

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Abstract

In this article, a model of adaptive control law for controlling robot manipulators using the Lyapunov based theory of guaranteed the stability of uncertain a system is derived. The novelty of obtained result is that the adaptive control algorithm is developed using a parameter estimation rule depending on manipulator kinematic, dynamic parameters and tracking error. This study is supported by a computer simulation and tracking performance has been improved.

Keywords: Adaptive control; Robot manipulators; Parameter estimation; System stability; Tracking performance

1. Introduction

Craig et al. [1] derived an adaptive inverse dynamic control law for rigid robot manipulators. The restriction of this algorithm is that joint accelerations have to be known and the inverse matrix of the estimated inertia parameters remains bounded. Middleton and Goodwin [2] overcome the difficulty in measuring joint accelerations by introducing a filter. Spong and Ortega [3] presented

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an alternative formulation of adaptive control algorithm so as to eliminate the second assumption on limitation for the inverse of the estimated inertia matrix. Slotine and Li [4] derived an adaptive control algorithm without using the joint accelerations and the inverse of inertia matrix. It consists of a PD feedback part and a full dynamics feed forward compensation part with the unknown manipulator and payload parameters. In another adaptive control approach of Slotine and Li [5], it is shown that position and velocity errors converge to zero but the Lyapunov stability was not established. Spong et al. [6] proved that the adaptive robot controller is stable in the sense of the Lyapunov, but, in the proof, the feedback gain matrix is assumed to be constant and diagonal. Egeland and Godhavn [7] assumed that the feedback gain matrix is to be uniformly positive defined, possible time varying and proved stability in the sense of the Lyapunov. Burdet and Codourey [8] compared nine different adaptive control algorithms, and as a result it is shown that the adaptive feed forward controllers are convenient for learning the parameters of the dynamic equation in the presence of friction and noise. Other comparative studies of adaptive control laws are given in [9,10]. Recently, a new robust-adaptive control law for n-link robot manipulators with parametric uncertainties has been derived from the Lyapunow theory [11]. The novelty of the adaptive-robust control algorithm is that manipulator parameters and adaptive upper bounding function are estimated to control the system properly, and the adaptive-robust control law is also updated as using exponential function of manipulator kinematics, inertia parameters and tracking errors.

In this paper, a new adaptive control law is derived for n-link robot manipulators based on the Lyapunov based theory. Parameter adaptation law is derived considering Slotine [4] and Sciavicco and Siciliano [12] approaches. Apart from the similar studies, the parameter estimation law is updated using an exponential function of manipulator kinematics, inertia parameters and tracking errors.

2. Parameter estimation in adaptive control law

In the absence of friction or other disturbances, the dynamic model of an n-link manipulator can be written as [13].

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + G(q) = T \tag{1}$$

where q represents generalised coordinates, T is the $(n \times l)$ vector of applied torques (or forces), $M(q)$ is the $(n \times n)$ symmetric positive definite inertia matrix, $C(q,\dot{q})\dot{q}$ is the $(n \times l)$ vector of centripetal and Coriolis terms and $G(q)$ is the $(n \times l)$ vector of gravitational terms. Eq. (1) can also be expressed in the following form associated with control purposes [12]:

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + G(q) = Y(q,\dot{q},\ddot{q})\pi \tag{2}$$

where π is a $(p \times l)$ vector of constant robot parameters and Y is an $(n \times p)$ matrix, which is a function of joint positions, velocities and accelerations. Consider the control law with K a positive definite matrix.

$$T = M(q)\ddot{q}_r + C(q,\dot{q})\dot{q}_r + G(q) + K\sigma \tag{3}$$