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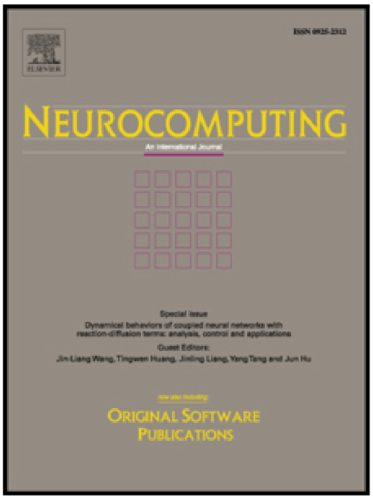

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Robust adaptive neural tracking control for a class of nonlinear systems with unmodeled dynamics using disturbance observer[☆]

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Abstract

This paper is concerned with an adaptive neural tracking control for a class of strict-feedback nonlinear systems subject to unmodeled dynamics, system uncertainties, completely unknown external disturbance and input dead zone. An adaptive neural control method combined with backstepping technique and the radial basis function neural networks (RBFNNs) is proposed for the systems under consideration. In recursive backstepping designs, a dynamic signal is introduced to cope with the unmodeled dynamics, a disturbance observer is employed to approximate the unknown disturbance and the dead zone equalled to the sum of the simple linear system and the partial bounded disturbance. It is shown that by using Lyapunov methods, the developed control scheme can ensure semi-globally uniformly ultimately bounded (SGUUB) of all signals within the closed-loop systems. Simulation results are presented to illustrate the validity of the approach.

Keywords: Adaptive backstepping control, Unmodeled dynamics, Dead zone, Disturbance observer, Radial basis function neural networks(RBFNNs)

1. Introduction

The problem of nonlinear exists in almost all physical systems, and it is impossible to simplify into a linear model. Therefore, much attention has paid on the control of nonlinear systems during the past few decades, and some significant results have been obtained in the literature, for instance, [1–6]. A variety of remarkable control methods have been proposed for both theoretical significances and engineering applications, including an adaptive backstepping technique [7–9], fuzzy control [10–14], fault tolerant control [15–17], and intelligent control [18–24]. Recently, as an effective control method, the adaptive backstepping technique has played an important role in the control of nonlinear systems with parametric uncertainty [25–28]. In particular, for a class of complex nonlinear systems with unknown functions, a variety of control schemes were explored by combining adaptive control and functional approximators. It is konwn that neural networks [22, 29–31] and fuzzy-logic systems [32, 33] are very effective approaches in control of highly uncertain nonlinear systems. Thus, by using neural networks, great efforts have been focus on nonlinear systems affected by these unknown functions. To list a few, in [34] and [35], based on the neural networks, the adaptive control methods was developed for nonlinear systems with unknown virtual control coefficient functions. In [22], an effective neural network control is developed for Bimanual Robots systems with unknown uncertainties. In [23], an intelligent controller was designed on the basis of extreme learning machine for uncertain robot manipulators with unknown nonlinearity, and a neural learning law was designed to ensure finite-time convergence of the neural weight. Then, in [36–39], the research is extended to multiinput multioutput (MIMO) nonlinear systems. Alternatively, some fuzzy adaptive control researches are studied for uncertain nonlinear systems containing unknown functions [14, 30, 40–42].

It is particularly important to point out that the input dead-zone problem should be considered in control synthesis of many practical systems because the existence of input dead-zone may degrade system performances and even cause instability. Thus, a variety of control schemes have been developed for nonlinear systems affected by input dead-zone [43]. In [44], the authors investigated the problem of actuator dead-zones by using an adaptive robust control method for a class of nonlinear systems in pure-feedback form. A class of nonlinear uncertain systems with dead-zone has been solved in the work [45], where the dead-zone was treated to disturbance in a same way. Moreover, the author in [46] solved the chattering problems by proposing a smooth adaptive dead-zone inverse algorithm and a different adaptive compensation scheme for unknown dead-zone is derived in [47]. The aforementioned results, however, neglected the effect of unmodeled dynamics.

On the other hand, the unmodeled dynamics and unknown external disturbance exist in nearly all practical systems, since it is impossible to describe exact mathematical models. Therefore, some valuable results have been presented in[30, 31, 48–53] affected by these two issues. In [30], an adaptive neural output-feedback control method was presented for a class of

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