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Decentralized adaptive neural control for interconnected stochastic nonlinear delay-time systems with asymmetric saturation actuators and output constraints

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Abstract

This paper investigates the problem of decentralized adaptive backstepping control for a class of large-scale stochastic nonlinear time-delay systems with asymmetric saturation actuators and output constraints. Firstly, the Gaussian error function is employed to represent a continuous differentiable asymmetric saturation nonlinearity, and barrier Lyapunov functions are designed to ensure that the output parameters are restricted. Secondly, the appropriate Lyapunov–Krasovskii functional and the property of hyperbolic tangent functions are used to deal with the unknown unmatched time-delay interactions, and the neural networks are employed to approximate the unknown nonlinearities. At last, based on Lyapunov stability theory, a decentralized adaptive neural control method is proposed, and the designed controller decreases the number of learning parameters. It is shown that the designed controller can ensure that all the closed-loop signals are 4-Moment (or 2 Moment) semi-globally uniformly ultimately bounded (SGUUB) and the tracking error converges to a small neighborhood of the origin. Two examples are provided to show the effectiveness of the proposed method.

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1. Introduction

It is well known that large-scale systems are widely found in practical systems, such as traffic systems, transportation networks, power systems and multiagent systems. Stochastic disturbances and time delays lead to performance degradation, and even system instability [1,2]. In the control design process, the effect of input and output constraints should be appropriately considered. Therefore, this paper will present decentralized adaptive constrained control for large-scale stochastic nonlinear systems subject to unknown unmatched time-delay interconnections.

Recently, fuzzy logic systems and neural networks have been extensively used in the modeling and control design for various nonlinear systems [3]. In [4], adaptive fuzzy backstepping control was presented for a class of nonlinear systems via fuzzy logic systems. The distributed fuzzy H_∞ filtering problem was addressed in [5] for networked industrial processes. Based on the neural networks approximation in [6,7], dynamic learning from the adaptive control was proposed via deterministic learning theory. In [8], neural network approximator was applied in vibration control of a flexible robotic manipulator. Fuzzy-model-based nonlinear networked control systems were considered in [9] subject to various network-induced limitations. By employing radial basis function neural network, the data-based optimal control for networked industrial processes was investigated in [10]. In [11], an efficient hybrid feedback feedforward adaptive approximation-based controller was designed for uncertain Euler–Lagrange systems. Adaptive fuzzy control was studied in [12] for nonstrict-feedback systems, and observer-based fuzzy control was developed in [13,14] for nonstrict-feedback systems. Output-feedback fault-tolerant control strategy was further used in reliable control of piecewise affine systems [15] and network-based industrial processes [16]. The control of the switched stochastic nonlinear pure-feedback systems was presented in [17] with unknown backlash-like hysteresis, and in [18], the approximation-based adaptive tracking control was investigated for multi-input multi-output (MIMO) nonlinear systems. In [19], MIMO pure-feedback nonlinear time-delay system was considered for adaptive neural tracking control. Robust H_∞ state estimation was investigated in [20] for a class of continuous-time nonlinear systems via fuzzy logic. In [21], output-feedback robust fuzzy H_∞ control was presented for a class of nonlinear spatially distributed systems. In particular, decentralized control for the interconnected and complex systems has long been a very active research area in the control community. In the decentralized control scheme, one of the main obstacles is how to deal with the interconnections. In [22], decentralized adaptive fuzzy control for large-scale nonlinear systems was proposed, and [23,24] studied the neural network decentralized stabilization problem for large-scale stochastic nonlinear systems. Wang et al. [25] considered a class of stochastic nonlinear strong interconnected systems, and proposed an adaptive neural tracking control scheme. Choi and Yoo [26] employed one function approximator to achieve the local controller for interconnected time-delay systems. In [27], the observer-based decentralized controller was designed for interconnected stochastic nonlinear time-delay systems. In [28], the switched uncertain nonlinear large-scale systems were considered subject to unmeasurable system states. Decentralized adaptive tracking control for interconnected non-affine nonlinear systems was developed in [29] with arbitrary switches. It should be noted that the input and output constraints are factors that affect the performance of the practical control system. Especially in the control design of practical engineering, input and output constraints need to be taken into account.