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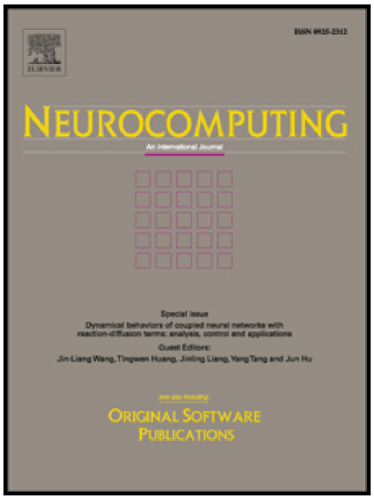

Bounded robust control design for uncertain nonlinear systems using single-network adaptive dynamic programming

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Bounded robust control design for uncertain nonlinear systems using single-network adaptive dynamic programming ☆

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Abstract

This paper is an effort towards developing an optimal learning algorithm to design the bounded robust controller for uncertain nonlinear systems with control constraints using single-network adaptive dynamic programming (ADP). First, the bounded robust control problem is transformed into an optimal control problem of the nominal system by a modified cost function with nonquadratic utility, which is used not only to account for all possible uncertainties, but also to deal with the control constraints. Then based on single-network ADP, an optimal learning algorithm is proposed for the nominal system by a single critic network to approximate the solution of Hamilton-Jacobi-Bellman (HJB) equation. An additional adjusting term is employed to stabilize the system and relax the requirement for an initial stabilizing control. Besides, uniform ultimate boundedness of the closed-loop system is guaranteed by Lyapunov's direct method during the learning process. Moreover, the equivalence of the approximate optimal solution of optimal control problem and the solution of bounded robust control problem is also shown. Finally, four simulation examples are provided to demonstrate the effectiveness of the proposed approach.

Keywords: Neural networks; Optimal control; Adaptive dynamic programming; Bounded robust control; Uncertain nonlinear systems

1. Introduction

As is well known, there exist lots of uncertainties arising from modeling errors, system aging and exogenous disturbances, which always result in the degradation of control system performance in practice. Therefore, it is necessary to design robust controllers to tackle these uncertainties for avoiding the deterioration of actual performance [1]. During the past several decades, various robust control approaches have been developed, including the H_∞ approach [2], the Lyapunov approach [3], the sliding model control approach [4] and others [5–7]. Although many robust control design methods have been studied for designing a control system, which guarantees robust stability, it is desirable to design a control system that is not only stable but also has better performances. Among these methods, it is worth noting that in [7], the robust control problem was solved by the solution to optimal control problem for the relevant nominal system, and the designed robust controller not only ensured the system to be asymptotically stable for all possible uncertainties, but also was optimal with respect to a meaningful cost. This could improve the system's performance to some extent, and also help to probe the relationships between robust control and optimal control.

When considering the optimality, i.e., the optimal control law for the nonlinear system, in addition to the stability alone, it makes the system have better performance. From a mathematical point of view, the optimal control problem of nonlinear system requires the solution of the Hamilton-Jacobi-Bellman (HJB) equation, which is generally difficult or impossible to solve due to its inherent nonlinearity [8]. Although dynamic programming (DP) is very useful in solving optimal control problems, it is often computationally untenable to run DP and get the optimal solution for high dimensional nonlinear systems, which is referred to as the "curse of dimensionality" [9]. Inspired by the principle of

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