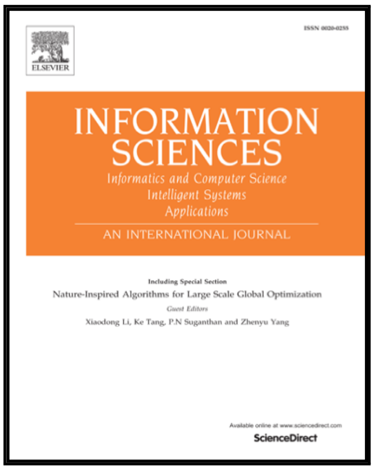

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Data-based robust adaptive control for a class of unknown nonlinear constrained-input systems via integral reinforcement learning ☆

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Abstract

This paper presents a data-based robust adaptive control methodology for a class of nonlinear constrained-input systems with completely unknown dynamics. By introducing a value function for the nominal system, the robust control problem is transformed into a constrained optimal control problem. Due to the unavailability of system dynamics, a data-based integral reinforcement learning (RL) algorithm is developed to solve the constrained optimal control problem. Based on the present algorithm, the value function and the control policy can be updated simultaneously using only system data. The convergence of the developed algorithm is proved via an established equivalence relationship. To implement the integral RL algorithm, an actor neural network (NN) and a critic NN are separately utilized to approximate the control policy and the value function, and the least squares method is employed to estimate the unknown parameters. By using Lyapunov's direct method, the obtained approximate optimal control is verified to guarantee the unknown nonlinear system to be stable in the sense of uniform ultimate boundedness. Two examples are provided to demonstrate the effectiveness and applicability of the theoretical results.

Keywords: Adaptive dynamic programming; Input constraint; Neural networks; Optimal control; Reinforcement learning; Robust control

1. Introduction

Due to exogenous disturbances or other unforeseen changes often involved in practical control systems, it is necessary that controllers are designed to avoid the deterioration of the closed-loop performance. To address this problem, the theory of robust control is developed. Over the past several decades, great progress has been made in this field (see insightful surveys [44] and [46]). Many methods are proposed to design robust controllers for nonlinear systems, such as the H_∞ approach [3], the Lyapunov method [19], and the geometric approach [34]. A common feature of these methods is that the prior knowledge of system dynamics needs to be completely known or partially available. Nevertheless, in real control systems (such as systems in chemical engineering, aeronautics and astronautics, electric power, traffic and transportation), it is often intractable to construct appropriate mathematical models, let alone to get the prior knowledge of system dynamics. There are only a huge amount of data available, which are generated from the operation of systems. Moreover, in light of physical characteristics of actuators or safety consideration in applications, actuators generally have limitations on their magnitude [5, 6, 8]. Therefore, robust control problems of data-based methods for unknown nonlinear constrained-input systems are significant in both theories and applications.

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