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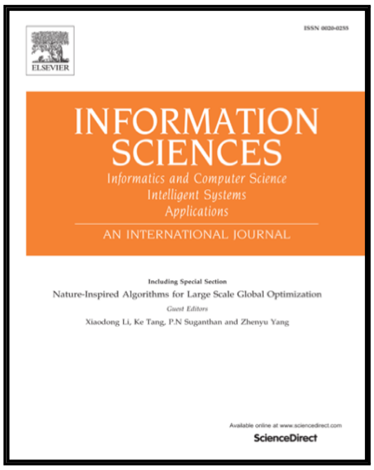

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Observer Based Adaptive Dynamic Programming for Fault Tolerant Control of a Class of Nonlinear Systems ☆

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Abstract

This paper develops a novel fault tolerant control (FTC) scheme for a class of nonlinear systems with actuator failures based on adaptive dynamic programming (ADP). The estimated actuator failure from a fault observer is utilized to construct an improved performance index function that reflects the failure, regulation and control simultaneously. By employing a proper performance index function, the FTC problem can be transformed into an optimal control problem. By using policy iteration, the Hamilton-Jacobi-Bellman equation can be solved by constructing a critic neural network. Then, the approximated optimal controller can be derived directly. The closed-loop system is guaranteed to be uniformly ultimately bounded via the Lyapunov stability theorem. The effectiveness of the developed FTC scheme is demonstrated by two simulation examples. The significant contribution of the proposed strategy lies in that the well-known ADP method is extended to solving the FTC problem.

Keywords: Adaptive dynamic programming; Fault tolerant control; Policy iteration; Nonlinear systems; Fault observer; Neural network

1. Introduction

Modern industries are becoming increasingly complex and large-scale to satisfy the requirement of the improving production efficiency [40]. Consequently, the demands for reliability and safety of sophisticated control systems are urgent. As we know, various components such as actuators, sensors and processors may undergo abrupt failures individually or simultaneously during operation, which may lead to serious damages [28]. Among all kinds of malfunctions, actuator failures significantly account for the degradation of control performance. Hence, it is important to develop fault tolerant control (FTC) methods to deal with such failures and maintain acceptable system performance.

In recent decades, many FTC approaches have been developed to solve the aforementioned problems through different theories and methods. In early stages of research, hardware redundancy based FTC was achieved by installing some backup components, which increased the weight, volume and cost. In contrast to hardware designs, analytical redundancy based FTC was distinguished for its low cost and flexible structures, and therefore, it attracted many researchers' attention. In general, analytical redundancy based FTC schemes could be categorized into passive approaches and active ones. By passive design, Zhou *et al.* [50] proposed an architecture that included two parts, i.e., the feedback control system was solely controlled by the performance controller, and the model uncertainties and external disturbances were handled by the robustness of the controller. Wang *et al.* [33] investigated a robust fault-tolerant H_∞ control of active suspension systems with finite-frequency constraints. The scheme considered actuator faults, suspension deflection and actuator saturation simultaneously. In fact, the insensitivity

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