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Fuzzy sliding mode control design for a class of disturbed systems

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Abstract

This paper discusses the problem of the fuzzy sliding mode control for a class of disturbed systems. First, a fuzzy auxiliary controller is constructed based on a feedback signal not only to estimate the unknown control term, but also participates in the sliding mode control due to the fuzzy rule employed. Then, we extend our theory into the cases, where some kind of system information can not be obtained, for better use of our theoretical results in real engineering. Finally, some typical numerical examples are included to demonstrate the effectiveness and advantage of the designed sliding mode controller.

1. Introduction

Disturbance exists in real systems widely, which makes the corresponding control problem much more complicated. To solve this problem, the sliding mode control (SMC) provides a good solution. Up to now, many relevant researches have been carried out [1–13]. Based on SMC, the authors in [2] investigated the robust adaptive control problem for fuzzy systems with mismatched uncertainties. By using a high-gain observer, an output feedback model-reference variable structure controller is presented in [3] to achieve the

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global exponential stability with respect to a small residual set without generating peaking in the control signal. In [4], the subordinated reachability of the sliding motion is introduced to realize the control on a class of uncertain stochastic systems with time-varying delays. Through introducing a pseudo-inversion, the authors in [5] discussed the adaptive control for the uncertain discrete time linear systems preceded by hysteresis nonlinearity. In [6], a sufficient condition for existence of reduced-order sliding mode dynamics was derived to realize the SMC for a continuous-time switched stochastic system.

For SMC, the insensitivity to disturbances is due to its switching action between the different sliding mode surfaces. Conventionally, the general SMC method is based on the upper norm bound of the time-varying disturbance. The difference between the time-varying disturbance and its upper norm bound may lead to the serious chattering problem. The most effective solution is to obtain the precise estimation of the time-varying disturbance. Nowadays there are some feasible tools such as neural networks, genetic algorithm, wavelet series and piecewise polynomials, can be used to solve this problem. However, the balance among the accuracy of the estimation, the amount of the calculation, and the complexity of the control system is always a big concern. How to design a controller for the disturbed system with good overall performance is a very challenging topic, and this motivates our research.

Since the pioneering work from Zadeh in 1965 [14], fuzzy science has received more and more attentions, corresponding researches can be seen in [15–29] and the references therein. Especially in 1992, Wang proved that fuzzy systems are universal approximators [30], fuzzy method soon became a powerful approximation tool and has wide application areas, SMC is one of them.

In this paper, an auxiliary fuzzy controller based on one feedback signal will be built to not only estimate the unknown disturbances, but also participate in SMC, features simple structure and high efficiency; then, we will extend our theory into the cases that some kind of system information is not accessible, to make our researches possess more practical engineering value; these above are the main contributions of the paper. At last, some typical simulation examples will be included to demonstrate the effectiveness of the designed controllers.

Notations used in this paper are fairly standard. Let R^n be the n-dimensional Euclidean space, $R^{n\times m}$ represents the set of $n\times m$ real matrix, $*$ denotes the elements below the main diagonal of a symmetric block matrix, $(\cdot)^{(i)}$ denotes the ith derivative of $(\cdot)$, and the notation $A>0$ means that A is the real symmetric and positive definite.

2. Problem statement

In this paper, the following disturbed system is considered

$$\begin{aligned}&\dot{x}_i(t)=x_{i+1}(t), i<n\\&\dot{x}_n(t)=f(x,t)+\Delta f(x,t)+g(t)+\Delta u(t)+b\cdot u(t)\end{aligned}\tag{1}$$

where $x(t)=(x_1(t),\ x_2(t),\cdots,\ x_n(t))^T\in R^n$ is the system state vector, $f(\cdot,t)$ is the nonlinear function, $\Delta f(\cdot,t)$ is the system parameter uncertainty, $g(t)$ is the system disturbance, $\Delta u(t)$ is the control parameter uncertainty, b is the nonzero control coefficient, and $u(t)$ is the control input.

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