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Finite-time stabilization of switched linear systems with nonlinear saturating actuators

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Abstract

In this paper, finite-time stabilization of switched linear systems with saturating actuators is discussed by virtue of time domain approach. State feedback controllers are designed to make the closed-loop systems finite-time stable. If the state is unavailable, observer-controller compensators are used. The results not only give sufficient conditions for finite-time stabilization of switched linear systems with saturating actuator, but also show the effect of the switching signals on finite-time stabilization of the system. Moreover, based on average dwell-time technique, we present the average dwell-time of switching signals to guarantee finite-time stability of the closed loop system. An example is employed to verify the efficiency of the proposed method.

1. Introduction

A switched system consists of a family of subsystems described by differential or difference equations and a switching law that orchestrates switching between these subsystems [1]. Due to their success in practical applications and importance in theory development, switched systems have been attracting considerable attention during the last decades. Up to now, most of the existing literature related to stability of switched systems focuses on Lyapunov asymptotic

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stability [2–11], which is concerned with qualitative behaviour of its state variables over an infinite time interval. However, in many practical applications such as missile systems, analog computer systems, active and parametric networks, the main concern is the quantitative behavior of the system state variables over a fixed finite time interval [12]. In this case, finite-time stability could be used, which focuses its attention on the system behavior over a finite time interval rather than on the asymptotical behavior of a system response.

Some early results on finite-time stability problems date back to the 1960 s [12,13]. Recently, the concept of finite-time stability has been revisited in the light of linear matrix inequality theory. Many valuable results have been obtained for this type stability [14–23]. In [14–16,22,23] sufficient conditions for finite-time stability and stabilization of continuous-time systems or discrete-time systems have been provided. The authors of [18–21] have extended the definition of finite-time stability to the systems with impulsive effects or singular systems with impulsive effect, respectively, and derived some sufficient conditions for finite-time stability and stabilization problem. In addition, it should be pointed out, the authors of [24–29] present some results of finite-time stability for different systems, but the finite-time stability which consists of Lyapunov stability and finite-time convergence is different from that in this paper and references [12–15,17,16,18–22].

Recently, research work on finite-time stability of switched systems has attracted more and more attention. Finite-time stability of continuous-time hybrid and switching systems have attracted much attention and some results have been presented in many paper, such as [30–40]. Based on linear matrix inequalities, finite-time stability and stabilization conditions for switched systems without or with time-delay were developed in [31] and [36,38] respectively. It should be note that the feedback controller in those papers are all linear control (state feedback mainly). In practical control applications, actuators are often involved to follow the control signals emitted form the designed controllers [29,41]. Unfortunately, the physical limitation of actuator saturation is usually unavoidable in the operation of driving the actuator. Saturation nonlinearity existing can cause not only performance degradation but also instability of the overall system. Although linear control methods mentioned above have a wide range of applicability, those results cannot be applied directly to switched systems with saturation actuators. Hence, it motivates us to discuss the finite-time stabilization problem of switched systems with saturation actuators.

The stabilization of linear systems with saturating actuators has been investigated by many researchers. A representative result is the work of Chen and Wang using a time-domain approach [41]. The advantage of time domain analysis is intuitive and accurate, therefore in this note we resort to the time-domain method proposed by Chen and Wang [41] to investigate the finite-time stabilization for a class of switched linear systems with saturating actuators. It should be pointed out LMI(linear matrix inequalities) methods and other techniques have also been used to discuss the stabilization of switched systems with saturation actuators, such as [42,43]. It is an interesting topic that needs further research.To the best of the authors' knowledge, the proposed work in this paper on finite-time stabilization of switched linear systems with nonlinear saturating actuators is new in the current literature. A preliminary attempt to tackle this problem was reported in our recent conference paper [44].

The paper is organized as follows. In Section 2, some notations and problem formulation are presented. Section 3 main results of this paper are provided. Finite-time stabilization problem for switched linear system is dealt with. state feedback controllers and observer-controller compensators have been designed respectively to finite-time stabilize the switched linear systems. The important influence of switching signals on finite-time stability of switched linear systems has also been discussed. In Section 4, a numerical example is presented to illustrate the efficiency of the proposed result. Concluding remarks are given in Section 5.