

Finite-time stabilization and boundedness of switched linear system under state-dependent switching

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Abstract

In this paper, finite-time stabilization and boundedness (FTSB) problems are investigated. Unlike the existing approach based on time-dependent switching strategy, in which the switching instants must be given in advance, largest region function strategy, i.e., state-dependent switching strategy, is adopted to design the switching signal. Based on multiple Lyapunov-like functions method, some sufficient conditions are provided for FTSB of switched linear system and the corresponding sliding motion problem is also considered. Finally, two examples are given to verify the efficiency of the proposed methods.

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1. Introduction

A switched system is a dynamical system that consists of a finite number of subsystems and a logical rule that orchestrates switching between these subsystems [1]. Due to the success in practical applications [2,3], switched systems have been attracting considerable attention during the last decades. For recent progress, readers can refer to survey papers [4–6] and the references therein.

The issues of stability and stabilizability are the basic problem for switched system and have attracted most of the attention [7–13]. The multiple Lyapunov functions [14] and the

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single Lyapunov function methods [15] have been proven to be powerful and effective tools for finding such a switching signal, which includes time-dependent switching signal [16–18] and state-dependent switching signal [19,20].

Up to now, most of the existing literature related to stability of switched systems focuses on Lyapunov asymptotic stability, which is defined over an infinite time interval. However, in many practical applications, the main concern is the behavior of the system over a fixed finite time interval. Some early results on finite-time stability can be found in [21–23]. Finite-time stability and finite-time bounded problems of linear systems subject to parametric uncertainties are discussed in [24]. In [25] a dynamic output feedback controller is designed for the finite-time stabilization problem. In [26], the problem of observer-based H_∞ finite-time control for switched systems with time-varying delay is investigated. Finite-time boundedness and stabilization problems for a class of switched linear systems with time-varying exogenous disturbances are studied in [27], and a class of state-dependent switching signals are designed such that switched system is finite-time bounded. But in [27], the results on state-dependent switching signals are based on single Lyapunov-like function.

The existing methods of investigating the finite-time stabilization and boundedness are based on time-dependent switching strategy. There is no available result on FTSB based on multiple Lyapunov functions for switched systems under state-dependent switching signal. Therefore, the main contribution of this paper is that a different approach, largest region function strategy (i.e., state-dependent switching strategy), is adopted to study the problem of FTSB for switched systems. Based on multiple Lyapunov-like functions, some sufficient conditions are given, and the corresponding problem of sliding motion is also considered.

The remainder of the paper is organized as follows. In Section 2, two definitions and problem formulations are presented. In Section 3, sufficient conditions that can ensure finite-time stabilization and boundedness of switched linear systems are proposed. Then, two examples are presented to illustrate the efficiency of the proposed method in Section 4. Conclusions are given in Section 5.

The notations used in this paper are standard. Let $\mathbb{R}$, $\mathbb{R}^+$, and $\mathbb{Z}^+$ denote the field of real numbers, the set of non-negative reals, and the set of non-negative integers, respectively. The notation $P > 0$ means that P is a real symmetric and positive definite; the superscript “ T ” stands for matrix transposition; $\mathbb{R}^n$ denotes the n -dimensional Euclidean space. $\lambda_{\min}(P)$ and $\lambda_{\max}(P)$ denote the minimum and maximum eigenvalues of matrix P , respectively.

2. Problem formulation

Consider a class of switched linear control systems of the following form:

$$\dot{x}(t) = A_{\sigma(t)}x(t) + B_{\sigma(t)}u(t) + G_{\sigma(t)}\omega(t) \quad (1)$$

where $x(t) \in \mathbb{R}^n$ is the state, $u(t) \in \mathbb{R}^m$ is the control input and $\omega(t) \in \mathbb{R}^r$ is the exogenous disturbance. $\sigma(t) : [0, \infty) \rightarrow \mathcal{I} = \{1, 2, \dots, N\}$ is the switching signal which is a piecewise constant function depending on state $x(t)$ in this paper. A_i , B_i and G_i are constant real matrices for $i \in \mathcal{I}$. In this paper, we assume B_i , $i \in \mathcal{I}$, are full column rank.

The following switching state feedback controller

$$u(t) = K_{\sigma(t)}x(t) \quad (2)$$

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