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Sliding mode control for stochastic Markovian jumping systems subject to successive packet losses

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Abstract

In this work, the problem of sliding mode control is considered for a class of Markovian jumping systems. The packet dropout may happen when the state information is transmitted from the sensor to the controller. By means of an estimator for lost signals, an integral-like sliding function is constructed. And then, a sliding mode controller involving in dropout probability is designed such that the effect of packet losses can be effectively attenuated. Besides, the analysis on both the stability of sliding mode dynamics and the reachability of sliding surface are made. Finally, the numerical simulation results are given.

1. Introduction

Markovian jumping systems (MJSs) have received considerable attention in the past decades, since many real-world systems with abrupt variations in their structures can be effectively represented by MJSs, where the abrupt variations may happen due to random failures or repairs of components, changing of subsystem interconnections, abrupt variations in the operating point, etc. More importantly, different from the traditional single controller, the control strategy designed for MJSs is based on the idea of switching to improve the performance of closed-loop system. Up to now, many results on the stability and stabilization of MJSs have been obtained, see [1–5] and the reference therein.

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Sliding mode control (SMC) has been recognized as an effective robust control approach due to its excellent advantage of strong robustness against model uncertainties, parameter variations, and external disturbances [6,7]. Over the past few decades, a variety of SMC methods have been developed for various types of dynamical systems [8–10]. More recently, the application of SMC has been also extended to MJSs in [11–15]. Among them, the SMC problem of MJSs was first considered by Shi et al. [11]. By using a transformation, a set of linear sliding surfaces and a reaching motion controller were designed in [11], respectively. Niu et al. [12] further extended SMC method to Itô stochastic systems with Markovian switching, and both the reachability and the stability of sliding mode dynamics were established. More recently, the problem of SMC for MJSs with unmeasured states were also considered, respectively, by Wu et al. [13] and Zhang et al. [15]. These above works have shown the effectiveness of SMC method for MJSs. Nevertheless, it is worthy noting that all of the aforementioned works were considered under the assumption that system signals could be successfully transmitted to the controller or actuator, i.e., there did not happen packet losses. Actually, this case might only be true for those traditional point-to-point controlled systems.

As is well known, with the rapid advances in communication network, more and more system information is transmitted via communication networks. The insertion of communication networks in feedback control loops not only brings great advantages, e.g., low cost, reduced weight and power, etc., but also yields some detrimental phenomena. Among them, the *data packet dropout*, termed as *data missing* [16,17], is a potential source of instability and poor performance for the controlled systems. Hence, the problem of packet dropout has recently received increasing attention, and many results have been reported in, to mention a few [18–25] and the reference therein. However, to the authors' best knowledge, there exist little work reported on the design problem of SMC for MJSs subject to *packet losses*. Especially, due to the complexity of the structure of MJSs *with stochastic perturbation*, these existing methods on SMC without packet dropout cannot be trivially extended to such class of systems.

Motivated by the above discussions, the problem of SMC is investigated in this work for a class of MJSs with stochastic perturbation. It is assumed that the transmitted information may be lost, and the probability distribution of packet dropout obeys Bernoulli process. In this work, an estimation method is proposed to cope with the packet losses, based on which an integral-like sliding surface is chosen, and a dropout-probability-dependent SMC law is designed. Moreover, by means of the stochastic Lyapunov method dependent on sliding variable and system state, the analysis on the reachability is made, simultaneously, with the stability of system states, and some sufficient conditions are derived.

It should be pointed out that the main contribution in this paper is to provide a design method of sliding mode control for Itô stochastic Markovian jumping systems subject to *successive packet losses*. In fact, it is difficult to investigate this issue due to the effect of both the Markovian switching and the data missing. Thus, some existing works cannot be simply extended to the systems under consideration in this work. Firstly, in the design of sliding mode control, what is the connection among different sliding functions under Markovian switching for SMC systems? Remark 2 in this work gives a deeper investigation on the problem. Secondly, it is highly desirable to synthesize a SMC law so as to ensure the attraction of the switching surface when the switching surface changes from one to another under Markovian switching. Thirdly, the effect of packet losses must be considered in