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Stabilization and destabilization of nonlinear systems via intermittent stochastic noise with application to memristor-based system

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Abstract

This paper considers the stabilization and destabilization of a given nonlinear system by an intermittent Brownian noise perturbation. We give some distinct conditions and conclusions on almost sure exponential stability and instability, which are related to the control period T and the noise width δ. These results are then exploited to examine stabilization and destabilization via intermittent stochastic perturbation and applied to the stabilization of a memristor-based chaotic system. Two numerical examples are presented to illustrate the theoretical results.

1. Introduction

It is well known that noise can be employed to stabilize a given unstable system, to make a system even more stable when it is already stable or to destabilize a given stable system.

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As the development of the theory of stochastic systems, the stochastic noise stabilization has been applied to many practical fields, such as engineering [1–3], finance [4,5] and ecosystems [6] (Chapter 11). Besides these, plenty of literature reported stabilization and destabilization by noise (see [7–9] and the references therein). The noise in stabilization most refers to the deterministic periodic "noise" in the previous works [10–12]. However, the pioneering work on random noise stabilization was studied by Khasminskii who adopted two white noise sources to stabilize a system [1]. Subsequently, a great number of works concerning stochastic stabilization and destabilization have emerged [1–9,13–18]. Mao [9] presented a general theory on the stabilization and destabilization by Brownian motion. The references [7,17,18] generalized the theory of Mao [9]. The hypothetical conditions are weaken in [7], i.e. the nonlinear function f and the noise perturbation coefficient g only satisfy local lipschiz condition and $f(0)=0,\ g(0)=0$. Huang [17] obtained extensive conclusions which imply the theory of [7], while Zhao and Deng [18] generalized the works of [7,17] to the time varying case under weaker and more general assumptions. Based on the theory of Mao [2,3,9] investigated stochastic stabilization and destabilization of hybrid systems. Moreover, the theories and methods of stochastic stabilization and destabilization were extended to investigations of some new problems, e.g. noise suppresses or expresses exponential growth [19].

Then let us turn to another field, viz, intermittent control. The so-called intermittent control refers to that the control of the system is intermittent rather than continuous. Due to the characteristics of the intermittent control, it can efficiently reduce the control cost in this sense just like the sample-data control and impulsive control. Therefore, in recent years, much attention has been drawn to the research works of the intermittent control [20–31] From the point of view of control time, the intermittent control is divided into the periodic intermittent control and the non-periodic intermittent control. Here the periodic intermittent control means that the control time is periodic and each period is composed of working time (or control time) and rest time. The study of the periodic intermittent control has gained wide popularity in the control field, e.g. [20–30]. The periodic intermittent control has achieved great developments in theory, meanwhile, has been also generalized extensively in model. The periodic intermittent control has been widely used in the synchronization of chaotic systems and neural networks, e.g. Huang and Li [29] investigated the synchronization of chaotic systems with time delay via intermittent linear state feedback strategy. Nevertheless, the periodic intermittent control is difficult to implement in some special practical systems, for example, the generation of wind power in smart grid depends on the change of the real environment, which is clearly non-periodically intermittent. Thus, it is also very meaningful to study the non-periodic intermittent control. Non-periodic intermittent control is rare in the present literature except that Chen and Liu [31,32] studied the problem of synchronization of the linear coupled networks and the nonlinear coupled networks by using the non-periodic intermittent pinning control.

Inspired by the idea of the intermittent control, we have a question whether a given nonlinear system can be stabilized or destabilized by an intermittent stochastic perturbation. The answer, which is shown in the following sections, is positive. The main contributions of this paper are to apply the intermittent stochastic noise to stabilize and destabilize nonlinear systems for the first time, and establish a class of theories on stabilization and destabilization by intermittent stochastic perturbation based on the aforementioned theories of stochastic stabilization and destabilization. The theoretical results obtained are applied to the stabilization of a memristive system and the corresponding simulation results are provided to illustrate the effectiveness of the theories. Hence, we fill the gap that there is rare literature investigating