



Synchronization of second-order chaotic systems via adaptive terminal sliding mode control with input nonlinearity

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Abstract

In the presence of system uncertainties, external disturbances and input nonlinearity, this paper is concerned with the adaptive terminal sliding mode controller to achieve synchronization between two identical attractors which belong to a class of second-order chaotic system. The proposed controller with adaptive feedback gains can compensate nonlinear dynamics of the synchronous error system without calculating the magnitudes of them. Meanwhile, these feedback gains are updated by the novel adaptive rules without required that the bounds of system uncertainties and external disturbances have to be known in advance. Some sufficient conditions for stability are provided based on the Lyapunov theorem and numerical studies are performed to verify the effectiveness of presented scheme.

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1. Introduction

Chaotic system is a very complex dynamical system. It is well known that the response of a chaotic system possesses many characteristics, such as the excessive sensitivity to initial conditions, fractal properties of the motion in phase space, and board spectrums of the frequency response. Due to the potential applications in the control of complex physical, mechanical, and biological systems, synchronization between two chaotic systems has emerged as an attractive researched field. The goal of chaotic synchronization is to synchronize states of the slave system with states of the drive system. There were many

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researchers focused on the topic and developed several efficient technologies for chaotic synchronization, such as robust active-passive decomposition scheme [1], active control method [2,3], adaptive method [4–10], passive control method [11], back-stepping control method [12,13], time-delay feedback control [14,15], and sliding mode control [16–20].

Because system uncertainties and external disturbances are ubiquitous in reality, the sliding mode control is the well known scheme for its robustness and applied to various control systems. However, there are two main drawbacks in the previous studies [16–20] by utilizing the sliding mode control approach. First, the used sliding modes were linear types in nature. For a linear type sliding mode, the convergence of system states to the equilibrium point is asymptotical. It means that the system states can not tend to the equilibrium point within the limited time duration. To improve this point, the terminal sliding mode (TSM) [21] was developed by introducing the fractional power item into the sliding mode, which offers some superior properties such as fast, finite time convergence and better tracking precision. The second drawback is that nonlinear dynamics of the synchronous error system have to be actively canceled by the sliding mode controller. Basically, this directed elimination makes the controller to be complex and unsuitable for practical implementation. To cope with the hindrance, the adaptive neural network sliding mode controls were introduced to compensate the nonlinear dynamics [22,23]. However, in these previous studies [16–20,22,23], the input nonlinearity was not considered in the design procedure.

In applications, the control inputs of practical systems are usually subject to input nonlinearity as a result of physical limitations. Recently, chaotic synchronization subjected to control input nonlinearity is attracted many attentions [24–27]. In the literature, it is shown that the presence of nonlinearity in control input may cause a serious degradation of the system performance and decrease the system response. Moreover, the input nonlinearity of control may induce the chaotic attractor led to unpredictable situations. Therefore, the development of control scheme by taking account of input nonlinearity is one of the important problems [25–27]. By motivated the aforementioned concept, the problem of synchronization between two chaotic systems by utilizing a sliding mode controller with input nonlinearity was addressed in [25]. Furthermore, robust and adaptive sliding mode control schemes with input nonlinearity to synchronize two chaotic systems by considering bounded system uncertainties were introduced in [26,27].

For synchronization of second-order chaotic systems, to the best knowledge of the Author, the TSM control scheme associated with input nonlinearity is infrequently discussed in the literature. Therefore, the main goal of this paper is to propose the adaptive TSM controller subjected to input nonlinearity for synchronization between two identical attractors, which belong to a specific class of second-order chaotic system, in the presentations of system uncertainties and external disturbances. Different to the previous studies [25–27] required to compute the magnitudes of overall mismatched nonlinear dynamics for compensation, the proposed adaptive TSM controller includes adaptive feedback gains can tackle the nonlinear dynamics. Meanwhile, these adaptive feedback gains are updated according to the novel adaptive rules which including the product terms of absolute value of sliding mode and fractional power term of the synchronous error state. The implementation of the adaptive TSM controller is not required that the bounds of system uncertainties and external disturbances should be provided beforehand. Some sufficient conditions are given based on the Lyapunov stability theorem and numerical studies are provided to verify the effectiveness of presented scheme.

The rest of this paper is organized as follows. Dynamics of a class second-order chaotic system and synchronized problem formulation are introduced in Section 2. In Section 3,

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