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Synchronization transmission of spatiotemporal chaotic signal in the uncertain time-varying network

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HIGHLIGHTS

- We present a new method for the synchronization transmission of spatiotemporal chaotic signal in the uncertain time-varying network.
- Lyapunov function of the network is constructed through designing a special function.
- The adaptive laws of uncertain parameters can identify effectively the uncertain parameters in the network.
- The adaptive laws of the time-varying coupling matrix elements can effectively replace the time-varying coupling matrix elements in the network coupling matrix.

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ABSTRACT

In this paper, a new method is presented for the synchronization transmission of spatiotemporal chaotic signal in the uncertain time-varying network. By designing a special function to construct the Lyapunov function of the network, it is sure that the uncertain time-varying network can effectively synchronize the spatiotemporal chaotic signal generated by the synchronization target. At the same time, we also design the identification laws of uncertain parameters and the adaptive laws of the time-varying coupling matrix elements. Especially in our work, the nodes of the uncertain time-varying network and the synchronization target are different. Obviously, this research has the reference value for the application fields.

1. Introduction

Synchronization is a common phenomenon in the nature [1–3]. Among them, the synchronization of complex network has been displayed the great application potential in many fields such as communication security, biological engineering, physics and automatic control, and it has aroused great interest of scholars at home and abroad. Many literatures have reported the problem of synchronization between nodes within a network, that is, the inner synchronization behavior of the network. As a kind of collective behavior in the network, the inner synchronization of the network has been widely researched [4–6]. At present, some mature techniques for network synchronization have been reported, including the Master Stability Functions (MSF) method [7], connection graph method [8], adaptive control [9,10], pinning technique [11,12] and impulsive synchronization [13], etc.

However, the actual network not only has the inner synchronization behavior, but also the synchronization among networks or between network and the external signal can be found everywhere. This synchronization is called the outer synchronization behavior of the network. To this end, Li et al. first proposed the outer synchronization as a new

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synchronization style, and theoretically and numerically demonstrated the possibility of synchronization between two coupled networks [14]. On this basis, many scholars put forward a variety of methods to achieve synchronization outer the network. For example, Al-Mahbashi et al. achieved the projective lag synchronization between chaotic systems in drive-response dynamical networks with nonidentical nodes [15]; Zhou et al. analyzed the outer synchronization between WS and NW small-world networks with different node numbers [16]; Lü et al. discussed outer synchronization between uncertain complex networks based on Backstepping design [17]; Ray and Roychowdhury investigated outer synchronization of networks with different node dynamics [18]; Sakthivel et al. obtained anti-synchronization conditions for BAM memristive neural networks with different memductance functions [19].

It is worth noting that in the current research, the network synchronization is mainly focused on the certain network, that is, the topology and network parameters are certain. However, the complex network contains a large number of interacting nodes, and these nodes in the process of actual connection can easily lead to the instability and uncertainty of the network parameters. These uncertainties will affect the network synchronization performance. Therefore, the determination of network topology and the identification of uncertain parameters have become an important research direction. As a new content, the problem of synchronization between uncertain networks has aroused great concern and has been widely researched. In the Ref. [2], the parameter estimation of complex network was discussed, and the tracking synchronization of the network was realized. Ref. [20] discussed the synchronization of complex dynamical networks with uncertain inner coupling and successive delays based on passivity theory. Ref. [21] researched the synchronization between uncertain nonidentical networks with quantum chaotic behavior.

In addition, the topological structure of the actual network in nature is often changed with time. Based on this kind of situation, Ref. [22] investigated the non-fragile synchronization for bidirectional associative memory (BAM) neural networks with time-varying delays. Ref. [23] was concerned with the problem of passivity analysis of neural networks with an interval time-varying delay. Ref. [24] researched synchronization of a dynamical complex network consisting of nodes being generalized Lorenz chaotic systems and connections created with transmitted synchronizing signals. The focus is on the robustness of the network synchronization with respect to its topology. Ref. [25] investigated the properties of a decentralized consensus algorithm for a network of continuous-time integrators subject to unknown-but-bounded time-varying disturbances.

Up to now, the research of network synchronization is mainly focused on the situation that the network nodes and synchronization target are same. But in practical applications, there are many the situations that the network nodes and synchronization target are different. At present, there are few reports about this kind of research. In this paper, a new method is presented for the synchronization transmission of spatiotemporal chaotic signal in the uncertain time-varying network. By designing a special function to construct the Lyapunov function of the network, it is sure that the uncertain time-varying network can effectively synchronize the spatiotemporal chaotic signal generated by the synchronization target. At the same time, we also design the identification laws of uncertain parameters and the adaptive laws of the time-varying coupling matrix elements. Especially in our work, the nodes of the uncertain time-varying network and the synchronization target are different. Obviously, this research has the reference value for the application fields.

The outline of the rest of the paper is organized as follows. In Section 2, a novel network synchronization technique is introduced. In Section 3, numerical example is provided to show the effectiveness of the proposed technique. The conclusions are summarized in Section 4.

2. Synchronization technique of uncertain time-varying network

The synchronization technique of uncertain time-varying network is analyzed in this section. Considering a spatiotemporal chaos system

$$\begin{aligned}\frac{\partial x(r,t)}{\partial t} &= F(x(r,t),k)\\ &= f(x(r,t)) + g(x(r,t))k \end{aligned} \tag{1}$$

where $x(r,t) \in R^n$ is state variable of system, k is the parameter.

The N-spatiotemporal chaos systems described by (1) are taken as nodes to constitute a network and node i satisfies the following state equation

$$\frac{\partial x_i(r,t)}{\partial t} = f(x_i(r,t)) + g(x_i(r,t))k_i + \varepsilon_i \sum_{j=1}^{N} c_{ij}^{(t)} x_j(r,t) + u_i(r,t) \quad (i = 1, 2, \ldots, N). \tag{2}$$

Here, it is to assume that the parameter k_i in state equations of the network nodes is uncertain and its identification is $\hat{k}_i$. ε_i is the coupling strength between the network nodes, $u_i(r,t)$ is the control input of the network. $c_{ij}^{(t)}$ is matrix element of the time-varying coupling matrix and it can represent the topological structure of network. If there is a connection between node i and node j, $c_{ij}^{(t)} \neq 0$, otherwise, $c_{ij}^{(t)} = 0$.

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