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Synchronization of nonlinear multi-agent systems using a non-fragile sampled data control approach and its application to circuit systems

Key words: Multi-agent systems (MASs); Non-fragile sampled data control (NFSDC); Time-varying delay; Linear matrix inequality (LMI); Asymptotic synchronization

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MOTIVATION

- Non-fragile control can adjust gain fluctuation in the design of the controller and is used to assure system stability when small disruptions occur in the design of the controller. A few noteworthy works on the non-fragile control problem in multi-agent systems (MASs) have been published.

- To a greater extent, the conditions for achieving asymptotic synchronization of nonlinear MASs with non-fragile sampled data control (NFSDC) have not been comprehensively addressed, which serves as a motivation for the investigation in this paper.

MAIN IDEA

➢In practical applications, neural network (NN) based circuit systems are modeled as MAS-based leader and follower systems for analyzing the synchronization issue, which is based on Lyapunov-Krasovskii functional with Kronecker product.

➢For MASs, NFSDC is designed, and then sufficient conditions of synchronization criteria are derived using Lemma 1. The derived conditions assure the asymptotic stability of the MAS error system.

➢The generality of our strategy in designing a controller distinguishes it from the past work in this area of research. Furthermore, it provides a broad framework for investigating synchronization difficulties that are related to the consistency of control strength over time, such as NFSDC.

➢The approaches in Ma et al. (2016) have been compared to confirm the efficacy of the suggested method in the numerical simulation.

MAIN IDEA

Lemma 1 (Seuret and Gouaisbaut, 2013) For a given matrix $\bar{Q} > 0$, the following inequality holds for $\omega : [c, d] \to \mathbb{R}^n$:

$$-\int_c^d \dot{\omega}^{\mathrm{T}}(\varsigma)\bar{Q}\dot{\omega}(\varsigma)\mathrm{d}\varsigma \leq -\frac{1}{d-c}(\omega(d)-\omega(c))^{\mathrm{T}}\bar{Q} \cdot (\omega(d)-\omega(c)) - \frac{3}{d-c}\mathit{\Pi}^{\mathrm{T}}\bar{Q}\mathit{\Pi},$$

where $\mathit{\Pi} = \omega(d) + \omega(c) - \frac{2}{d-c}\int_c^d \omega(\varsigma)\mathrm{d}\varsigma$.

METHOD

- A widespread synchronization for chaotic NNs was given, and numerous suitable conditions were found by employing a suitable Lyapunov-Krosovskii functional.
- The time-step sampled data from agent *i* are encapsulated in a packet of data, subsequently transferred to its controller and agent *j* over agent *i*'s communication network. Zero-order hold (ZOH) is used to update the input and output actuators of controller *i*. ZOH represents the outcome of keeping each sample value for one sample interval while converting a discrete-time signal to a continuous-time one.
- Here, cooperative synchronization implies that the two dynamic systems with the leader and followers will attain the same partial state. Generally, the leader uses channels to broadcast a communication signal that triggers the followers, and this signal induces the coordination between the leader and followers.

MAJOR RESULTS

Table 1 Comparison of the maximum allowable time delays

Method	ι
Ma et al. (2016)	1
Theorem 2	1.9
Corollary 1	1.7

Table 2 Upper bound ϱ and control gain matrix J corresponding to Example 1

Method	ϱ	J
Theorem 2	0.079	$\begin{bmatrix} 1.3326 & 0.4831 \\ 0.1367 & 0.2541 \end{bmatrix}$
Corollary 1	0.044	$\begin{bmatrix} -1.2336 & 0.0875 \\ 0.2390 & -2.4249 \end{bmatrix}$

MAJOR RESULTS

Table 4 Comparison of the maximum allowable time delays

Method	ι
Subramanian et al. (2019)	0.2
Ma et al. (2016)	1
Theorem 2	1.9
Corollary 2	1.5

Table 5 Upper bound ϱ and control gain matrix $\boldsymbol{J}$ corresponding to Example 2

Method	ϱ	J
Theorem 2	0.084	$\begin{bmatrix} 1.9542 & 1.3163 \\ 1.5364 & 2.8275 \end{bmatrix}$
Corollary 1	0.017	$\begin{bmatrix} 0.0327 & -1.1546 \\ 1.5810 & 0.4865 \end{bmatrix}$

CONCLUSIONS

- In this work, the MAS synchronization problem has been investigated using a non-fragile sampled data control (NFSDC) scheme. The suitable Lyapunov-Krosovskii functional has been constructed to derive the synchronization criteria for the proposed MASs, expressed in linear matrix inequality (LMI) forms.

- The proposed control scheme has achieved synchronization between the leader and follower systems with the derived sufficient conditions.

- Numerical validation has demonstrated the effectiveness of the presented method. As a future work topic, it will be exciting to explore the possibility of extending the NFSDC scheme to event-triggered control when unanticipated disruptions occur in MASs.

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