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Containment control for heterogeneous nonlinear multi-agent systems under distributed event-triggered schemes

Key words: Multi-agent systems; Distributed event-triggered control; Containment control; Heterogeneous nonlinear systems; Zeno behavior

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Motivation

1. To date, a great deal of work has been put into cooperative control for multi-agent systems (MASs) based on the behaviors of animal groups in nature and their wide practical applications such as consensus control.

2. Containment control has attracted enormous concern and it is absolutely essential to study nonlinear MASs because most real systems are nonlinear.

3. In the view of continuous communication among agents which may cause excessive data and waste embedded processor resources, the event-triggered method is more favorable when designing protocols.

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Main idea

1. A distributed event-triggered control scheme is proposed, which ensures that the output for each follower converges to the convex hull spanned by multi-leader signals within a bounded error. In addition, no agent exhibits the Zeno behavior.

2. To avoid continuous monitoring of state errors, the results in the event-triggered control case are extended to the self-triggered control case.

3. Two numerical simulations are presented to verify the correctness of the obtained results.

Method

1. By applying the backstepping method, Lyapunov functional approach, and neural networks, a distributed event-triggered control scheme is proposed to achieve the containment control objective and avoid the Zeno behavior.

2. To avoid continuous monitoring of state errors, a self-triggered scheme is developed based on the results in the event-triggered control case.

Major results

1. Event-triggered scheme

The control protocol is as follows:

$$\dot{x}_i^r = \boldsymbol{A} x_i^r + \boldsymbol{B} \boldsymbol{K} \boldsymbol{\rho}_i \left(t_k^i\right), \quad t \in \left[t_k^i, t_{k+1}^i\right)$$

$$u_i = -\left(k_n + \frac{1}{2\mu_n} + \hat{\vartheta}_{i,n}\right) \xi_{i,n}$$

$$\dot{\hat{\vartheta}}_{i,n} = \xi_{i,n}^2 - \eta_n \hat{\vartheta}_{i,n}$$

The triggered condition is given as

$$t_{k+1}^i = \inf\left\{t > t_k^i \,|\, \|\boldsymbol{\omega}_i\| \geq \Delta_i\right\}, \ \Delta_i > 0$$

Major results

1. Event-triggered scheme

Theorem 1 Consider MAS (4) under the protocols given in Eqs. (7), (51), and (52), and the triggered condition is designed as Eq. (8). If Assumptions 1 and 2 hold, then the practical containment control objective can be achieved.

Theorem 2 Consider MAS (4) under the protocols given in Eqs. (7), (51), and (52), and the triggered condition is designed as Eq. (8). If Assumptions 1 and 2 hold, no agent exhibits Zeno behavior.

Major results

2. Self-triggered scheme

The self-triggered rule is as follows:

Suppose that the last triggered instant of agent i $(i \in \Gamma_1)$ is t_m^i, and define $t^* = t_m^i + \ln\left(\frac{\Delta_i}{\varphi(t_k^i)+g_i h}+1\right)$, where $\Delta_i > 0$ and $g_i = \sum_{k=N+1}^{N+M} a_{ik}$. If no neighbor is triggered before t^*, then $t_{m+1}^i = t^*$. If at t_{p_1} $(t_{p_1} < t^*)$ one neighbor p_1 is triggered, let $\Delta_i' = \Delta_i - [\varphi(t_k^i) + g_i h](\mathrm{e}^{t_{p_1} - t_m^i} - 1)$. If $\Delta_i' \leq 0$, the next triggered instant is t_{p_1}; otherwise, recalculate $\varphi(t_k^i)$ by substituting $\rho_{p_1,1}(t_{p_1}), \rho_{p_1,2}(t_{p_1}), \ldots, \rho_{p_1,n}(t_{p_1})$ into Eq. (63). Then we can determine that $t^* = t_{p_1} + \ln\left(\frac{\Delta_i'}{\varphi(t_k^i)+g_i h}+1\right)$. If at t_{p_2} $(t_{p_2} < t^*)$ another neighbor p_2 is triggered, let $\Delta_i'' = \Delta_i' - [\varphi(t_k^i) + g_i h](\mathrm{e}^{t_{p2} - t_{p1}} - 1)$. If $\Delta_i'' \leq 0$, $t_{m+1}^i = t_{p2}$; otherwise, update $\varphi(t_k^i)$ by substituting $\rho_{p_{2,1}}(t_{p_2}), \rho_{p_{2,2}}(t_{p_2}), \ldots, \rho_{p_{2,n}}(t_{p_2})$ into Eq. (63), which makes $t^* = t_{p_2} + \ln\left(\frac{\Delta_i''}{\varphi(t_k^i)+g_i h}+1\right)$. This process will be repeated until no triggering exists among the neighbors of agent i before t^*. Then, the next triggered instant t_{m+1}^i can be finally determined as $t_{m+1}^i = t^*$.

Theorem 3 Considering MAS (4) under the self-triggered rule, if Assumptions 1 and 2 hold and the protocols are given in Eqs. (7), (51), and (52), practical containment control can be achieved and no agent exhibits Zeno behavior.

Major results

3. Simulations

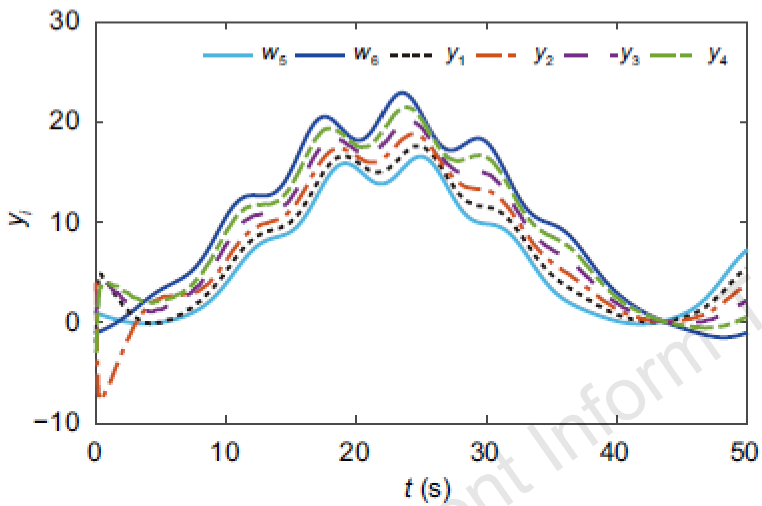

Fig. 3 Outputs of the followers under the event-triggered scheme

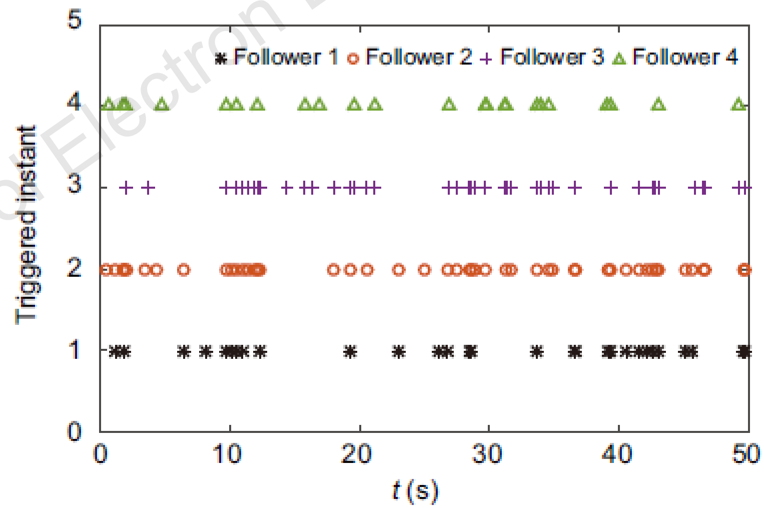

Fig. 5 Triggered instants of the followers under the event-triggered scheme

Major results

3. Simulations

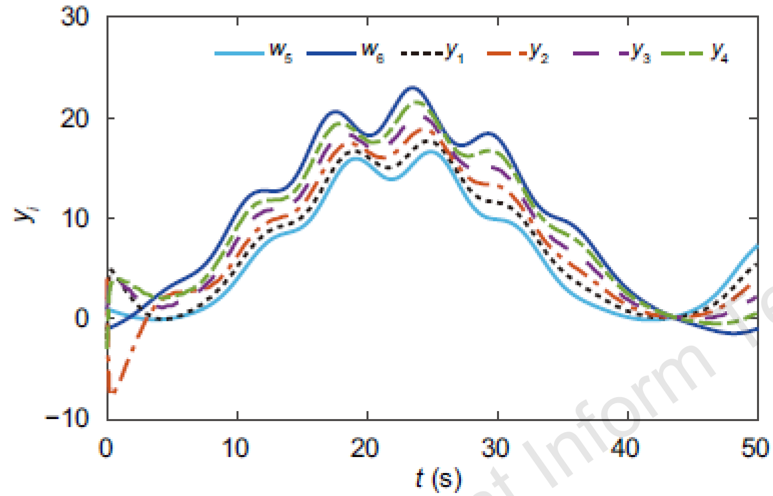

Fig. 7 Outputs of the followers under the self-triggered scheme

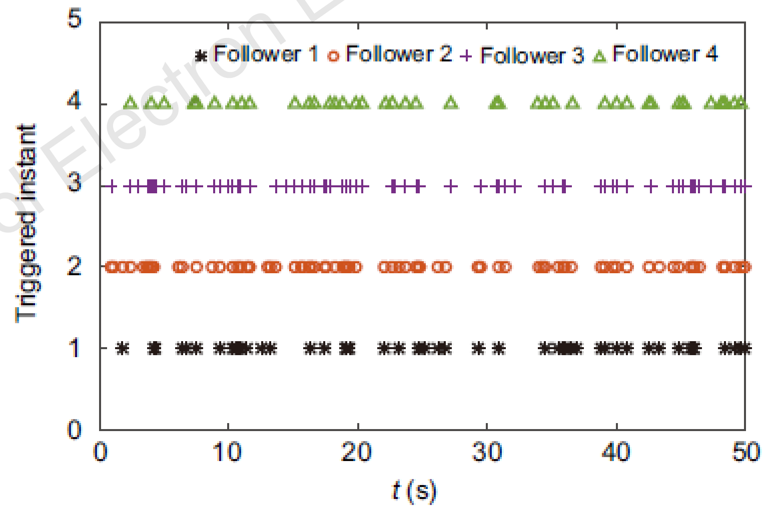

Fig. 9 Triggered instants of the followers under the self-triggered scheme

Conclusions

1. The containment control problem for a class of high-order heterogeneous nonlinear MASs with the distributed event-triggered mechanism was studied.

2. By developing an appropriate distributed event-triggered control scheme, the practical containment control objective was achieved and Zeno behavior was avoided. Then a distributed self-triggered control scheme was proposed.

3. Two simulation examples were provided to validate the correctness of the main results.

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