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Event-triggered distributed cross-dimensional formation control for heterogeneous multi-agent systems

Key words: Heterogeneous multi-agent systems; Formation control; Cross-dimensional event-triggered mechanism

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Motivation

1. In practical scenarios, agents are usually governed by non-identical kinetic equations. In this sense, heterogeneous systems are more applicable than homogeneous systems. Different from homogeneous systems, where all agents share similar characteristics, heterogeneous systems bring together a diverse ensemble of agents, each possessing unique capabilities, roles, and attributes.
2. The problem of distributed cross-dimensional formation control for heterogeneous multi-agent systems (HMASs) using event-triggered communication mechanisms has not been studied.

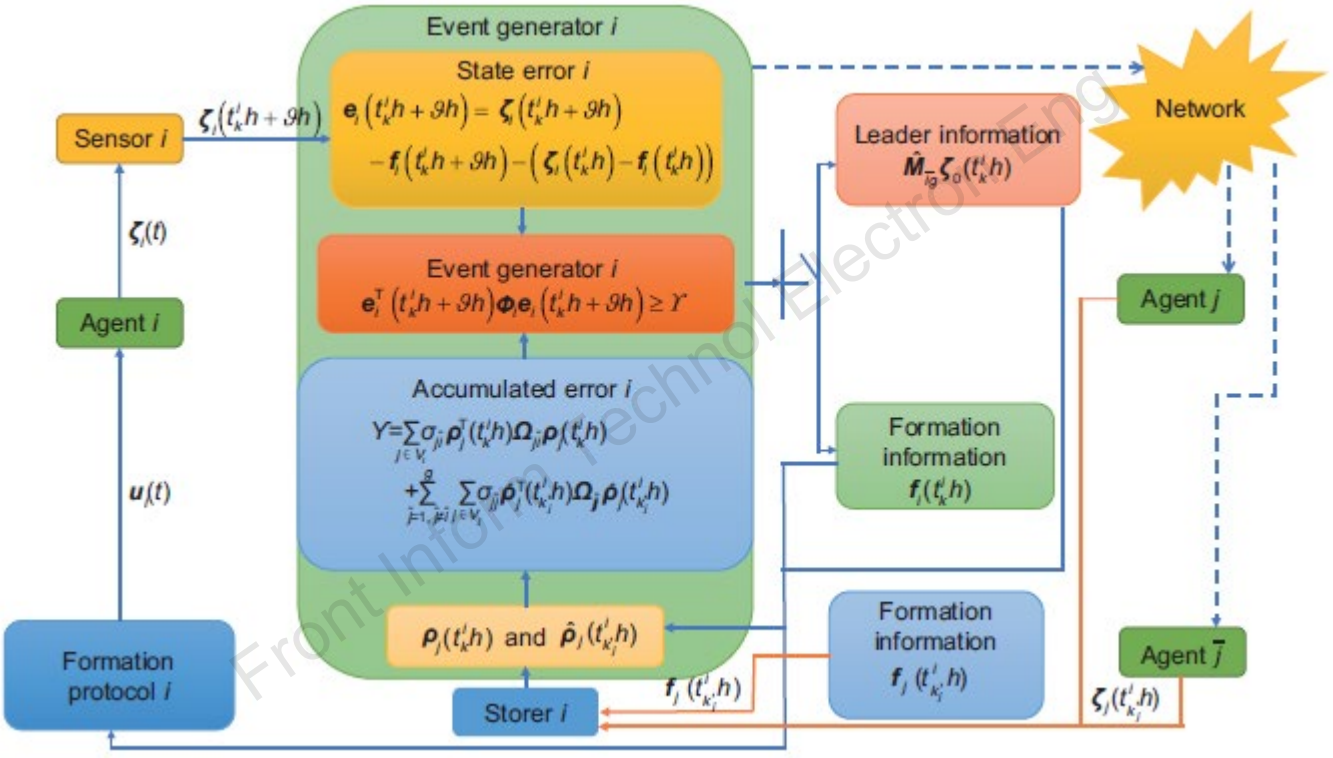
Main idea

1. A complete HMAS is proposed where the agents in the same and different groups are all heterogeneous in the proposed HMAS.

2. A cross-dimensional event-triggered communication mechanism is designed, where the leader's information is included in the state response errors among the neighboring agents in both the same and different groups.

3. Under the proposed event-based communication mechanism, the problem of HMAS cross-dimensional formation control is transformed into the asymptotic stability problem of a closed-loop error system.

Framework



In this event-based communication mechanism, the state errors of one agent between its neighbors in the same subgroup and different subgroups are considered.

Method

1. A multi-dimensional HMAS is first developed, where a group of agents are assigned to several subgroups based on their dimensions.

2. To mitigate the excessive consumption of communication resources, a cross-dimensional event-triggered communication mechanism is designed to reduce the information interaction among agents with different dimensions.

3. The stability criteria for designing a cross-dimensional formation control protocol are provided and the effectiveness of the proposed control protocol is validated by simulation.

Main results

Theorem 1 For given scalars $\sigma_i \in [0,1)$, τ_{m}, τ_{M}, and $\rho_a > 0$, the resulting closed-loop error system (15) under the proposed cross-dimensional event-triggered communication protocol (9) is asymptotically stable, if there are real matrices $\hat{\boldsymbol{P}}_i = \hat{\boldsymbol{P}}_i^{\mathrm{T}} > 0$, $\hat{\boldsymbol{Q}}_{ai} = \hat{\boldsymbol{Q}}_{ai}^{\mathrm{T}} > 0$, $\hat{\boldsymbol{R}}_{ai} = \hat{\boldsymbol{R}}_{ai}^{\mathrm{T}} > 0$, $\hat{\boldsymbol{\Phi}}_i = \hat{\boldsymbol{\Phi}}_i^{\mathrm{T}} > 0$, $\hat{\boldsymbol{\Omega}}_i = \hat{\boldsymbol{\Omega}}_i^{\mathrm{T}} > 0$, $\hat{\boldsymbol{S}}_i$, and $\hat{\boldsymbol{K}}_i$ ($i \in \mathcal{V}$ and $a = 1, 2$) with appropriate dimensions such that

$$\begin{bmatrix} \hat{\boldsymbol{R}}_2 & \hat{\boldsymbol{S}} \\ \hat{\boldsymbol{S}}^{\mathrm{T}} & \hat{\boldsymbol{R}}_2 \end{bmatrix} > 0, \tag{17}$$

$$\begin{bmatrix} \hat{\boldsymbol{\Theta}} & \tau_{\mathrm{m}}\hat{\boldsymbol{\Gamma}}^{\mathrm{T}} & \delta\hat{\boldsymbol{\Gamma}}^{\mathrm{T}} \\ * & -2\rho_1\hat{\boldsymbol{P}} + \rho_1^2\hat{\boldsymbol{R}}_1 & \boldsymbol{0} \\ * & * & -2\rho_2\hat{\boldsymbol{P}} + \rho_2^2\hat{\boldsymbol{R}}_2 \end{bmatrix} < 0 \tag{18}$$

Main results

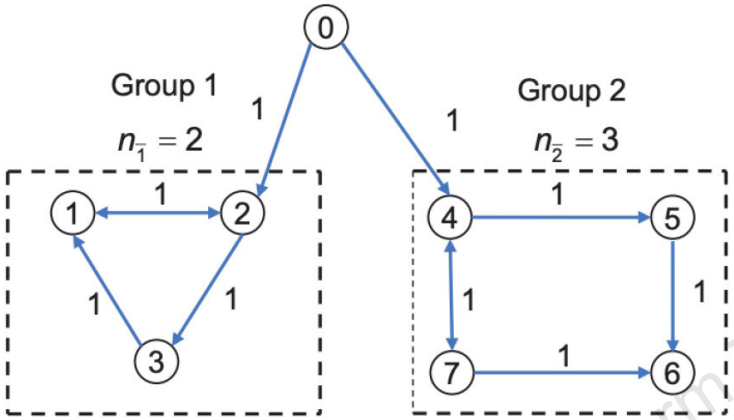


Fig. 3 Communication topology

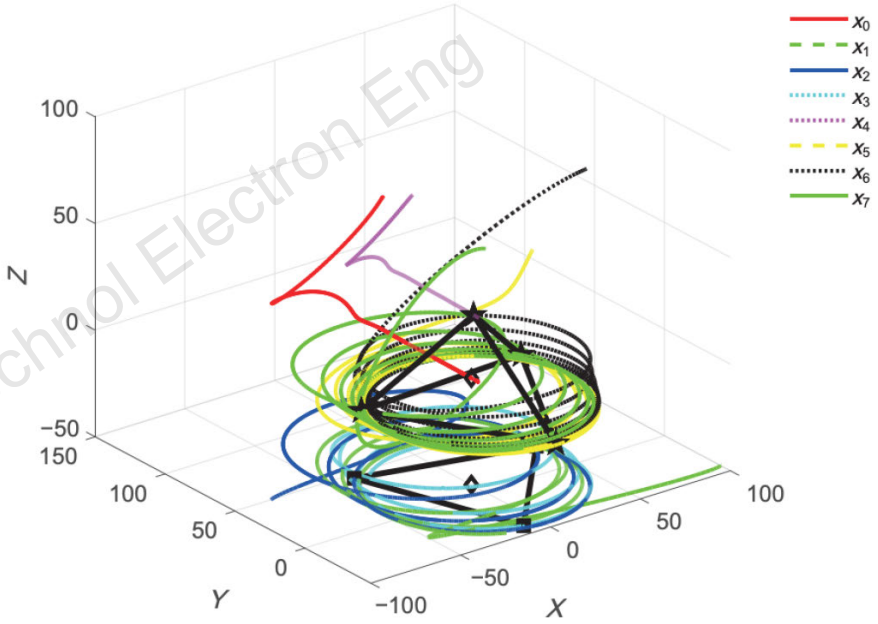


Fig. 4 Trajectories of followers and the leader

Main results (Cont'd)

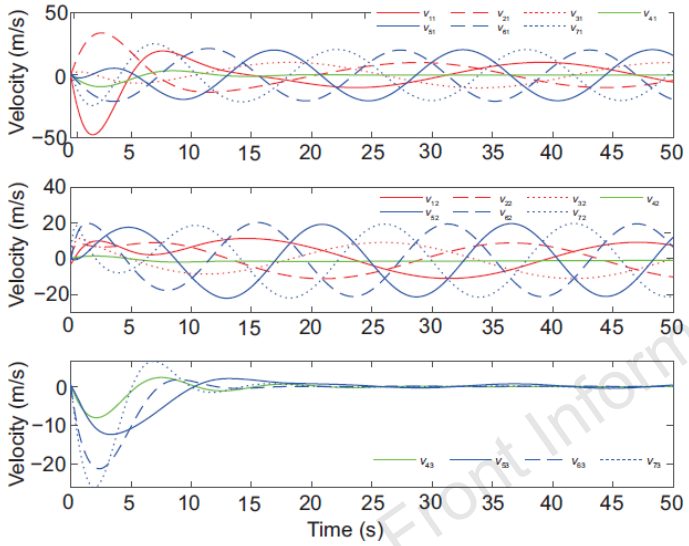


Fig. 5 X-velocity, Y-velocity of followers 1–7 and Z-velocity of followers 4–7

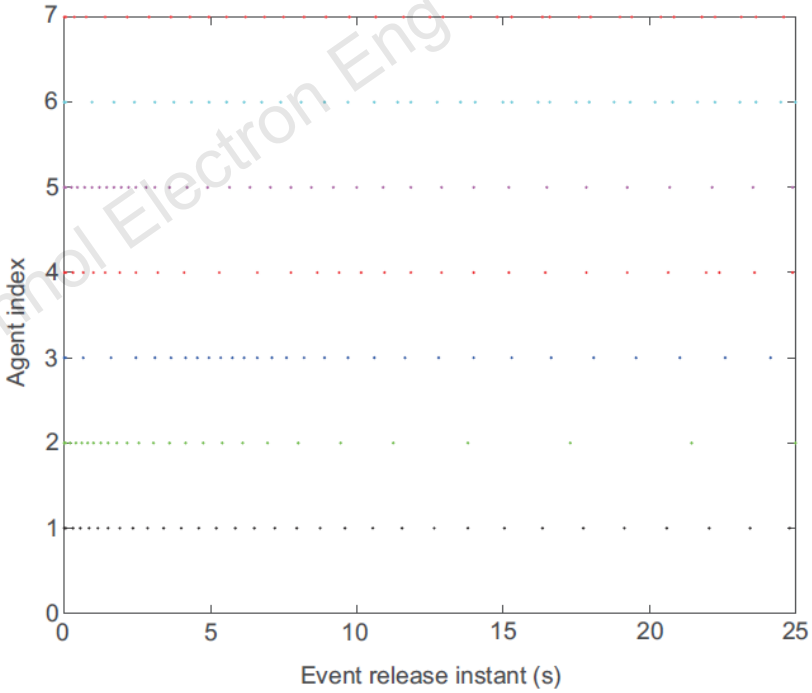


Fig. 6 Event release instants of followers 1–7

Conclusions

In this paper, to save limited communication resources, a cross-dimensional event-triggered data transmission protocol has been proposed to schedule communication among agents with different dimensions. Leveraging the proposed protocol, the cross-dimensional formation of an HMAS has achieved the asymptotic stability of a closed-loop error system. Then, to facilitate the design of a cross-dimensional formation control protocol and event-triggered weighting parameters when there is no information interaction between follower agents with different dimensions, several criteria have been proposed. Finally, a simulation study case has been implemented to substantiate the efficacy of the designed protocol.

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