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Bipartite asynchronous impulsive tracking consensus for multi-agent systems

Key words: Bipartite tracking; Multi-agent systems; Asynchronous impulsive; Consensus

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Motivation

- It should be noted that most of the works on tracking consensus are focused on multi-agent systems with all cooperative communication links. As already known, in the communications among multiple agents, cooperative and antagonistic interactions may exist simultaneously.
- It is noted that the works on impulsive control of multi-agent systems were carried out under the synchronous setting; that is, the impulsive jumps of all the agent states occur with respect to the same time sequence. Due to the limitation of current hardware, asynchronous impulsive control is widely used in practical applications.

Multi-agent mathematical model

$$\dot{x}_p(t) = Ax_p(t) + Bu_p(t),\ p = 0, 1, \cdots, N$$

- Agent labeled 0 is the leader, while the remaining agents represent the followers.
- A link edge $\varepsilon_{pq} \in \varepsilon$ is denoted by (v_p, v_q). c_{pq} could be positive or negative if v_p can send information to agent v_q.
- If the leader is a neighbor of node k (k=1, 2, · · ·, N), then $c_{k0} > 0$; otherwise, $c_{k0} = 0$.

Asynchronous impulsive control protocol

- The impulsive effects for agent p are proposed as follows:

$$\begin{cases} u_p(t) = d_1 H\Big(\sum_{q=1}^{N} |c_{pq}|(x_p(t) - \operatorname{sign}(c_{pq})x_q(t)) \\ \qquad\qquad + c_{p0}(x_p(t) - m_p x_0(t))\Big),\ t \in [t_k^p, t_{k+1}^p), \\ x_p(t) = x_p(t^-) - \mu g_p(t^-),\ t = t_k^p, \end{cases}$$

- Assume that asynchronous impulsive time instants $T_p = \{t_1^p, t_2^p, \cdots\}$ have no finite accumulation points.

Main results

Theorem 1 If Assumption 1 holds, there exists a constant η such that $0 < \eta < 1$ and $\frac{\ln \eta}{\mathcal{T}} + \omega < 0$. For the impulsive sequence $T^\star = \{t_k\} = \bigcup_{p=1}^{N} \{t_k^p\}$, suppose that the average impulsive interval is less than $\mathcal{T}$ ($\mathcal{T} > 0$), and

$$\begin{pmatrix} s\eta(I_N \otimes Q) & \Theta^{\mathrm{T}}(I_N \otimes Q) \\ (I_N \otimes Q)\Theta & (I_N \otimes Q) \end{pmatrix} > 0. \qquad (11)$$

Then MAS (1) achieves bipartite asynchronous impulsive tracking consensus, where $\omega = \tau(\Lambda)\lambda_{\min}(Q^{-1})$.

Theorem 2 If Assumption 1 holds, (A, B) is stable, the control parameter satisfies $\eta_2 > 1$, and for the impulsive sequence $T^\star = \{t_k\} = \bigcup_{p=1}^{N} \{t_k^p\}$, suppose that the average impulsive interval is less than $\mathcal{T}$ ($\mathcal{T} > 0$) and

$$-\lambda_{\max}(PA + A^{\mathrm{T}}P - 2PBB^{\mathrm{T}}P)\lambda_{\min}(P^{-1}) > 0,$$

$$\omega_2 - \frac{\ln \eta_2}{\mathcal{T}} > 0,$$

$$\begin{pmatrix} \eta_2(I_N \otimes P) & \Theta^{\mathrm{T}}(I_N \otimes P) \\ (I_N \otimes P)\Theta & (I_N \otimes P) \end{pmatrix} > 0, \qquad (21)$$

then MAS (1) achieves bipartite asynchronous impulsive tracking consensus, where $\omega_2 = -\lambda_{\max}(PA + A^{\mathrm{T}}P - 2PBB^{\mathrm{T}}P)\lambda_{\min}(P^{-1}) > 0$.

Simulations

- In our simulations, we consider systems with a leader marked 0 and five followers marked from 1 to 5, and parameters are taken as

$$x_p(t) = \begin{pmatrix} x_{p1}(t) \\ x_{p2}(t) \end{pmatrix}, A = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}, B = \begin{pmatrix} 1 \\ 0 \end{pmatrix},$$

p=0, 1, 2, 3, 4, 5.

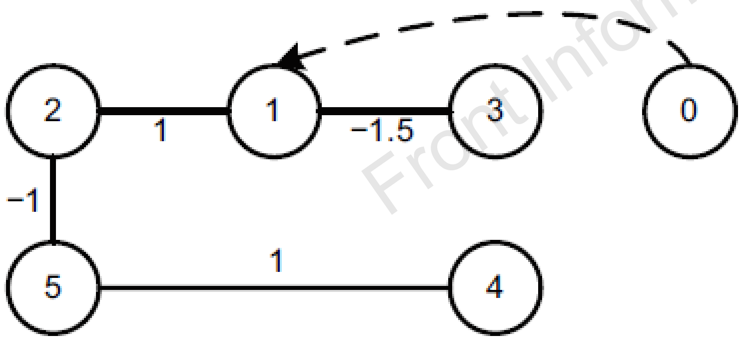

Fig. 1 Communication topology of six agents

The adjacency matrix:

$$\mathcal{C} = \begin{pmatrix} 0 & 1 & -1.5 & 0 & 0 \\ 1 & 0 & 0 & 0 & -1 \\ -1.5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & -1 & 0 & 1 & 0 \end{pmatrix}$$

Simulations

- The states of the followers and the leader with positive impulsive effects are shown in Fig. 2.
- The trajectories of tracking errors with positive impulsive effects are shown in Fig. 3.

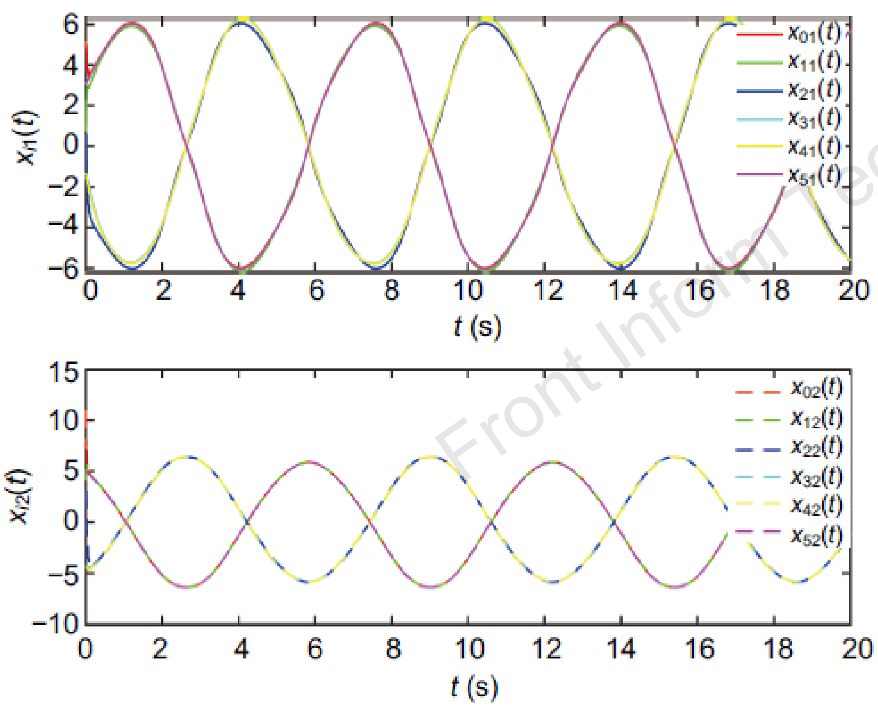

Fig. 2 States of $x_p(t)$ for $p = 0, 1, \ldots, 5$ under the positive impulsive effects in Example 1

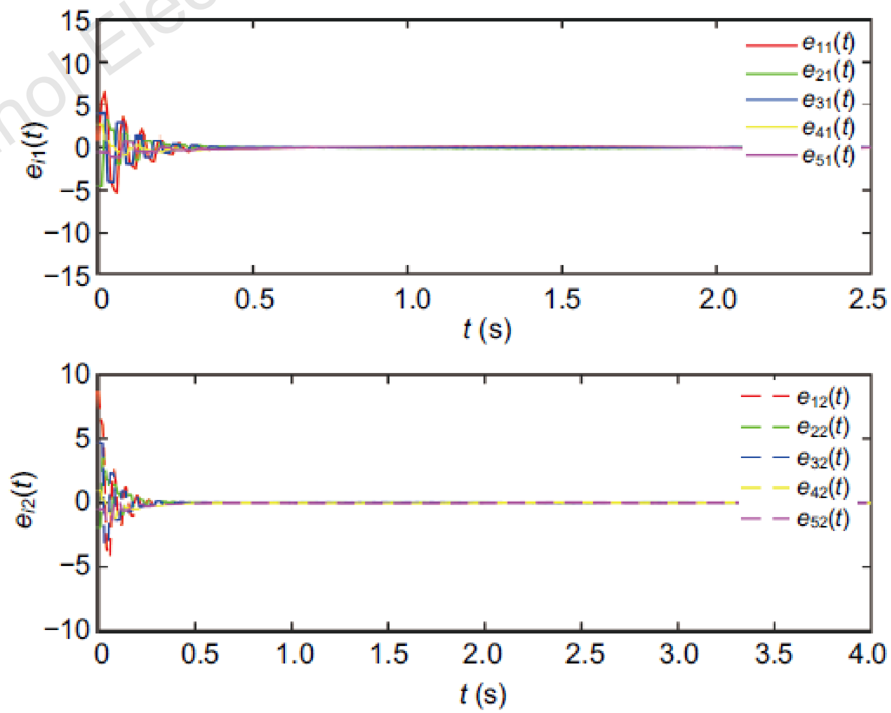

Fig. 3 Tracking errors $e_p(t)$ for $p = 1, 2, \ldots, 5$ under the positive impulsive effects in Example 1

Conclusions

- The signed grapy is considered, and the proposed asynchronous impulsive control approach does not require the impulse to occur simultaneously for all the agents.
- Using the relative information from a neighboring agent, a new distributed impulsive control protocol with positive or negative impulsive effects is designed.
- The leader's control input is nonzero, and sufficient conditions are obtained to achieve bipartite asynchronous impulsive tracking consensus in closed-loop multi-agent systems.

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