Consensus Control for Dual-rate Multi-agent Systems

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Abstract

The present study discusses the consensus control multi-agent systems. In such systems, the consensus is achieved through the exchange of information between neighboring agents. In order for mobile systems to consensus with each other, they must be designed with power consumption in mind. Therefore, since communication consumes power, it is important that the communication interval be as long as possible. The present study proposes a design methodology for the consensus achievement of dual-rate multi-agent systems, where the update period of agents is shorter than the communication period.

Keywords: Multi-agent System, Dual-rate, Consensus Control

1. Introduction

With the development of information and communication technology, Internet of Things (IoT), which uses communication to connect devices, is attracting attention. The control method for a group of devices connected to a network can be a centralized management style using a central control terminal or an autonomous decentralized control method. This study investigates the consensus control of multi-agent systems [1] are designed in a dual-rate system, where the communication period differs from the update interval. Networked predictive controller [2], quantized control [3], strict feedback control in a sampled-data system [4] have been reported as studies of dual-rate multi-agent systems. Network topology design [5], state-dependent graph Laplacian [6], and pinning consensus [7] are studies of convergence of multi-agent systems. The present study examines the convergence of dual-rate multi-agent systems.

2. Problem Statement

All agents are assumed to be integrator systems as follows:

$$\dot{x}_i(t) = u_i(t) \tag{1}$$

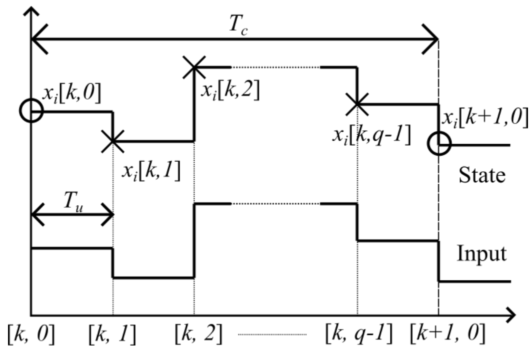


Fig. 1 Communication and input update periods in a dual-rate system; ○: communication with adjacent agents, ×: non-communication

$$(i = 1,2,\cdots,n)$$

where $x_i(t) \in \boldsymbol{R}$ and $u_i(t) \in \boldsymbol{R}$ are the state and input of agent i, respectively, and n is the number of agents. The goal of this study is to achieve the consensus that is defined as follow:

$$x_1(t) = x_2(t) = \cdots = x_n(t). \tag{2}$$

To this end, the control inputs are determined based on the states of its own agent and its neighboring agents that can communicate with its own agent. The following assumption is made about communication between agents.

Assumption 1

As shown in Fig. 1, the communication period of agents, $T_c \in \boldsymbol{R}^+$, is an integer multiple of $T_u \in \boldsymbol{R}^+$, the update period of control input, and

$$T_c = qT_u, \tag{3}$$

where $q \in \boldsymbol{N}^+$. Therefore, the control input is updated q times during the communication interval, and time $t \in \boldsymbol{R}^+$ is described using T_c and T_u as follows:

$$t = kT_c + mT_u, \tag{4}$$

where $k \in \boldsymbol{N}$ is the communication step, and $m \in \boldsymbol{N}$ is the update step ($0 \leq m < q$). Assuming $T_u = 1$, without loss of generality, the dynamics in the discrete time are given as follows:

$$x_i[k, m+1] = x_i[k, m] + u_i[k, m], \tag{5}$$

where $x_i[k, m]$ and $u_i[k, m]$ denote the state and input of the mth step from the communication of the kth step, respectively.

3. System Design

The input of agent i is updated by different control laws for single-rate and dual-rate systems. The control law of the single-rate system is:

$$u_i[k, m] = h \sum_{j=1}^{n} a_{ij}\left(x_j[k, 0] - x_i[k, m]\right), \tag{6}$$

and that of the dual-rate system is:

$$u_i[k, m] = h \sum_{j=1}^{n} a_{ij}\left(x_j[k, m] - x_i[k, m]\right), \tag{7}$$

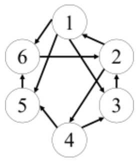


Fig. 2 Directed graph

where $h \in \boldsymbol{R}$ is a controller gain, and $a_{i,j}$ is the i,j element of an adjacency matrix A.

4. Numerical Example

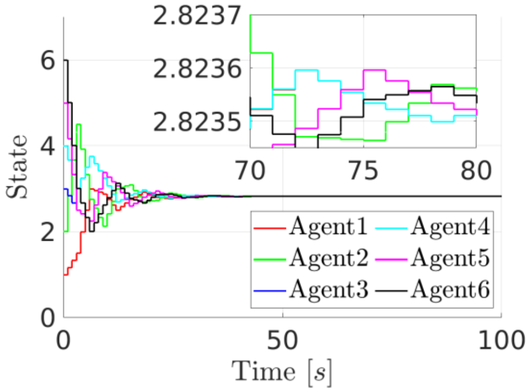
Consider a directed graph as shown in Fig. 2, where the number of agents is 6. The communication period T_c is 3, hence q is 3. The controller gain h is 0.1666 which stabilizes both the single-rate and dual-rate systems. The initial values of the agents are $x_1(0) = 1$, $x_2(0) = 2$, $x_3(0) = 3$, $x_4(0) = 4$, $x_5(0) = 5$, and $x_6(0) = 6$. Fig. 3 and Fig. 4 shows the simulation results of the single-rate and dual-rate systems, respectively. The consensus condition is defined as follows:

$$\max x_i(t) - \min x_i(t) \leq 10^{-4}, \tag{8}$$

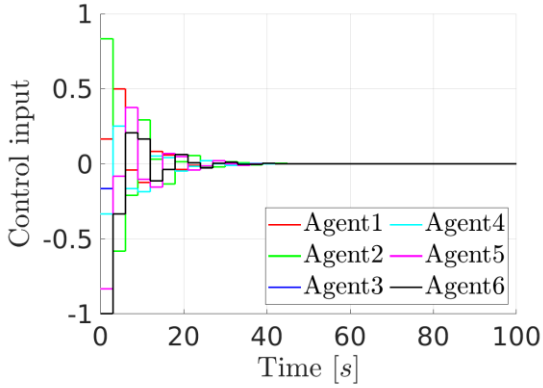
and the consensus time of the single-rate and dual-rate systems are 75s and 57s, respectively. Therefore, the performance of the dual-rate system is superior to that of the single-rate system.

5. Conclusion

The present study has proposed a design method of multi-agent systems in dual-rate system, where the communication period is longer than the input update period.

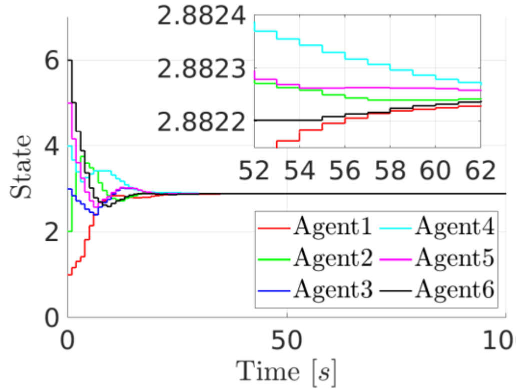


(a) State

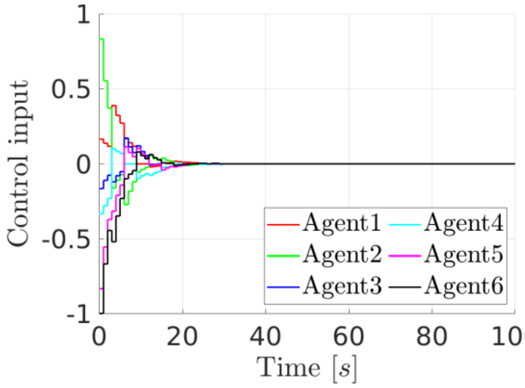


(b) Input

Fig. 4 Simulation results in the single-rate system



(a) State



(b) Input

Fig. 3 Simulation results in the dual-rate system

References

1. S. Azuma and M. Nagahara (Eds.): Control of Multi-agent Systems, CORONA Publishing (2015) (in Japanese).
2. C. J. Li, X. R. Yang, and J. Zhao: Multi-rate Design of Networked Predictive Controller and Its Application for Consensus of Networked Multi-agent Systems with Delays; Proceedings of the 38th Chinese Control Conference, pp. 5474–5479(2019).
3. T. Furusaka, T. Sato, N. Kawaguchi, N. Araki, and Y. Konishi: Consensus Control of Dual-Rate Multi-Agent Systems with Quantized Communication; IEEE Access, Vol. 48, No. 1, pp. 97557–97563(2020).
4. H. Katayama: Multi-rate Design of Consensus Controllers for Multi-rate Sampled-data Strict-Feedback Multi-agent Systems; IFAC-PapersOnLine, Vol. 48, No. 18, pp. 157–162(2015).
5. M. Rafiee and A. M. Bayen: Optimal Network Topology Design in Multi-Agent Systems for Efficient Average Consensus; 49th IEEE Conference on Decision and Control, pp. 3877–3883(2010).
6. Y. Kim and M. Mesbahi: On Maximizing the Second Smallest Eigenvalue of a State-dependent Graph Laplacian; 2005 American Control Conference, pp. 99–103(2005).
7. D. Xu, A. Sakaguchi, T. Ushio: Dynamic Pinning Consensus Control of Discrete-time Multi-agent Systems; Proceedings of the 37th Chinese Control Conference, pp. 6937–6942(2018).

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