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Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	Computer Science 系 Artificial Intelligence コース	申請学位（専攻分野）： Academic Degree Requested	Doctor of (Philosophy)
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Distributed coordinated control for multi-agent systems (MAS) due to widespread applications in many fields has attracted researchers from various areas including control, communications, signal processing, robotics, physics and so on. MAS are comprised of a number of autonomous agents that interact with each other over a shared network to reach a common goal. MAS provide higher redundancy and improved operational efficiency compared with a single autonomous agent. Moreover, this class of dynamical systems are known to exploit the advantages of having distributed sensing and actuation. A canonical problem in cooperative control of MAS is consensus, where the goal is that all agents eventually arrive at a group decision value. To this end, the agents locally communicate with each other in the neighborhood to exchange their state information. Effective distributed coordinated control schemes rely on sufficient information transmission among agents and efficient control protocol design.

This thesis focuses on developing distributed control protocols to effectively reduce transmission and update frequencies for the agents while guaranteeing consensus. We develop triggering-based protocols to facilitate opportunistic inter-agent communication and to alleviate communication and computational burden. We develop a unified framework for these protocols to solve the state consensus problems in the discrete-time domain for MAS with single-integrator dynamics as well as with general linear dynamics. Our approach for triggering-based protocols is to incorporate state information at each agent to determine the next event times for state updates and communication. This feature helps the agents take account of the consensus level locally and be responsive when they are close to reach their goals. Specifically, we develop two event-triggered protocols where the events occur in real time informing the agents to make updates in their states and broadcasts to transmit their state information to their neighbors. We also develop a self-triggered protocol where each agent estimates its next triggering times and broadcast them to their neighbors at the current triggering times.

The thesis consists of three parts to solve consensus problems of MAS in the discrete-time framework as follows:

(1) We focus on solving the average consensus problem of MAS with single-integrator dynamics. We propose three triggering-based protocols intending to reduce communication and update frequencies for agents while ensuring average consensus. Lyapunov-based design methods prescribe when agents should communicate and update their control so that the network converges to the average of agents' initial states asymptotically. Our general approach is to employ triggering protocols with threshold mechanism that is based on the state values received from neighbors. We begin with a static version of the triggering protocol to effectively reduce transmission and control update requirements for agents. When the agent is far from local consensus with its neighbors the threshold is large and the control need not be very accurate. This helps in reducing triggering instants without sacrificing convergence performance.

To further reduce the number of triggering instants, we employ an auxiliary state variable for each agent to regulate the threshold dynamically. The auxiliary variables take account of the state errors and can reduce the number of triggering instants compared with the static-triggering schemes. Moreover, to avoid continuous monitoring of the states to determine control update instants, we propose the self-triggered protocol where the next control update instant is determined using the current state and is sent together with the state information at the current triggering instant. Each agent only needs to make updates/broadcasts at its own triggering instants and listen to its neighbors at their announced triggering instants. Numerical examples are shown using MAS connected over a random network to illustrate these protocols in terms of reducing the frequencies of communication and control updates.

(2) We develop a unified framework for the triggering-based protocols to solve state consensus problems in MAS having general linear dynamics. We discuss three triggering-based protocols with different characteristics and advantages in terms of necessary computational resources and capabilities in reducing the frequency of communications and updates for each agent. In particular, we propose two event-triggered protocols with state-dependent thresholds. When agents are far from local consensus, less frequent communication suffices without sacrificing convergence performance. We start with a static triggering protocol and then generalize it so that it entails an internal auxiliary state variable to regulate the threshold dynamically for each agent. They are referred to as static and dynamic event-triggered protocols, respectively. The third protocol employs self-triggered control, where the agents in advance determine and broadcast to their neighbors their next triggering instants together with their state information. We discuss an application example of triggering-based protocol to solve the formation control problem of MAS. Through numerical simulations, we validate the efficacy of the proposed protocols.

(3) We further extend our proposed framework to solve the weighted consensus problems in MAS having integrator dynamics with directed topologies. We generalize the three protocols, namely, the static, dynamic and self-triggering protocols, for this case. We characterize their performances in reducing transmission and update frequencies for the agents. We also examine how our triggering-based protocols perform when adversaries are present and launch denial-of-service (DoS) attacks. Simulation examples are provided to demonstrate the efficiency of the methods and to confirm the theoretical analysis.