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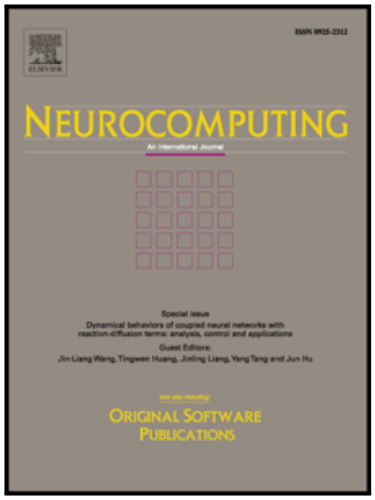

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Consensus control for multi-agent systems with distributed parameter models

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Abstract

This paper addresses the consensus control problem for a class of multi-agent systems with distributed parameter models, and all the agents in the considered systems are governed by the one-dimensional parabolic equations or the one-dimensional second-order hyperbolic equations. The main contribution of this paper is to apply Lyapunov functional approach to the multi-agent systems with distributed parameter models, and solve the consensus control problem of such multi-agent systems on an appropriate Sobolev space. The distributed consensus-based feedback control protocols are obtained based on the virtual leader approach, and when the feedback control laws are applied to the systems, consensus on $L^2(0,1)$ space (corresponding to the parabolic equations) or on $W^{1,2}(0,1)\times L^2(0,1)$ space (corresponding to the hyperbolic equations) is achieved for all the directed communication graphs with spanning trees. Simulation examples illustrate the effectiveness of the proposed method.

Keywords: Multi-agent systems, Parabolic equations, Hyperbolic equations, Consensus protocols, Directed graphs

1. Introduction

Distributd parameter systems (DPSs), which are composed of partial differential equations (PDEs), come commonly from the studies of many engineering practice problems, such as wave motion, heat conduction and so on. The control problem for DPSs is of great research significance and has aroused widespread concern in the recent years [1-10]. Up to date, two main methods are often used for DPSs control: one of them is the distributed control [1-6] and the other one is the boundary control [7-10]. This paper considers the distributed control problem of DPSs.

In the last decade, there has been a rapid development in the field of multi-agent systems (MASs) and a lot of research results about coordination control of MASs [11-20] have been gained. In general, MASs can be fallen into two categories: leaderless MASs [11-15] and leader-follower MASs [16-18]. As one important topic of leaderless MASs, the consensus problem [11-15], which considers how to design the distributed protocols so that all agents converge to a common value as time increases, plays an important role in the distributed coordination of MASs, see [21] for detailed results. On the other hand, since the variables of DPSs are related to infinite dimensional space, studies of consensus control for the MASs with distributed parameter models are limited and there have been only a few works reported on consensus control for the MASs with PDEs, while consensus control has been widely investigated for the MASs with ordinary differential equations (ODEs) [11-15]. Furthermore, most of the research results were obtained by using the operator theory and the consensus problems were solved by transforming the PDE problems into ODE problems on a Hilbert space [22-25]. As is well known, there are two main approaches applied in solving the distributed control problem of DPSs: one is the operator theory approach [22-25] and the other is the Lyapunov functional approach [3-6]. Compared with the results obtained by the operator theory approach, the results obtained by the Lyapunov functional approach are more practical (see [26]). This observation motivates our current study.

In this paper, the Lyapunov functional approach is applied to solve the consensus control problem for a class of MASs with distributed parameter models, and all the agents in the considered MASs are governed by the one-dimensional parabolic equations (heat equations) or the one-dimensional second-order hyperbolic equations (wave equations), which are two kinds of the most important PDEs. A distributed consensus-based feedback control law is proposed based on the virtual leader approach in [15], and when the feedback control law is applied to the MASs, consensus on $L^2(0,1)$ space (corresponding to the parabolic equations) or on $W^{1,2}(0,1)\times L^2(0,1)$ space (corresponding to the hyperbolic equations) is achieved for all the directed communication graphs with spanning trees.

2. Preliminaries and problem statement

Some usual notations are adopted in this paper. I_n represents the $n\times n$ dimensional identity matrix. $\mathbf{1}_n = [1 \quad 1 \quad \cdots \quad 1]^{\mathrm{T}} \in R^n$. For a vector or matrix Y, we use Y^{T} to denote its transpose, use Y^{-1} to denote its inverse matrix if Y is nonsingular. For a function $z(\varsigma)\in L^2(0,1)$, we denote $\|z(\cdot)\|_{L^2(0,1)} = \sqrt{\int_0^1 z^2(\varsigma)\mathrm{d}\varsigma}$ and use $W^{l,2}(0,1)$ to represent the Sobolev space

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