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Global consensus of multiple integrator agents via saturated controls ☆

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Abstract

This paper investigates the problem of global leader-following consensus of multiple integrator agents subject to control input saturation. A weighted and saturated consensus algorithm is proposed to solve this problem. Both the case of an undirected communication topology and the case of a directed communication topology are considered. It is shown that global consensus of the multiple integrator agents can be reached under a general undirected graph or a detailed balanced directed graph provided that its generated graph contains a directed spanning tree. Numerical examples are provided to demonstrate the theoretical results.

1. Introduction

Consensus has received significant attention in the area of cooperative control of multiagent systems, which has potential applications in practice, including unmanned air vehicles [1,2], mobile robots [3,4], wireless sensor networks [5], bioinformatics [6,7], etc. Early works have been done by some researchers (see, e.g. [8–11]). Also, see the survey paper [12] and references therein for more details and developments.

The main idea of consensus is that each agent in a group converges to an agreement state by using only neighbors' information, which has been widely studied by different dynamics, such as single-integrator dynamics [13–15], double-integrator dynamics [16–18], linear dynamics [19–22] and nonlinear dynamics [23–28]. These works referred to the leader-following and the leaderless consensuses. Also, there were many works studied by switched dynamics or communication topologies

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(see, for example, [29–32]). By introducing a virtual leader, a group of agents can synchronize to the states of the virtual leader in [3]. Then the necessary and sufficient condition for consensus was given in [24]. By using the property of network, the authors [33] defined the concept of consensus region, and then it is pointed that consensus can be reached when all the nonzero eigenvalues of the corresponding Laplacian matrix lie in the stable region. Consensus of single input systems and undirected graphs was considered in [25], and then the paper [34] extended results to consensus of linear agents under a digraph using Riccati equations and also extended to the case of outside the unit disk.

While much efforts have been made towards studying the consensus of multiagent systems, the existing results do not consider the actuator saturation, which is ubiquitous in practical applications. Recently, by using the low gain feedback, [35] achieves semiglobal leader-following consensus for the multiagent system subject to input saturation. The results for consensus of multiagent systems with saturated controls are still lacking, though the leaderless and leader-following consensus for multiagent systems were achieved with their control inputs subject to actuator saturation in [36,37], respectively, where the design methods were inspired by Riccati inequality and the agents are ANCBC systems. It is also observed that the design of distributed controllers for multiagent systems depends on neighbors' information with explicitly known of the neighbors' information. However, it is not easy to explicitly obtain the precise values of the neighbors' information when the multiagent network is of a large scale. This motivates the global consensus problem in this paper without requiring that the values of the neighbors' information of each agent are explicitly known but saturated.

This paper aims to solve the problems of global leader-following consensus of multiple integrator agents subject to control input saturation under the case of an undirected communication topology and the case of a directed communication topology. A weighted and saturated consensus algorithm is proposed to solve this problem. It is shown that global consensus of the multiple integrator agents can be reached under a general undirected graph or a detailed balanced directed graph provided that its generated graph contains a directed spanning tree. Numerical examples are provided to demonstrate the theoretical results. The rest of the paper is organized as follows. Section 2 formulates the global consensus problem. Section 3 presents the main results on the global consensus problem. Section 4 provides simulation examples for verifying the theoretical results. Finally, some conclusion remarks are given in Section 5.

Before closing this section, some notations will be stated here. Matrices, if their dimensions are not explicitly stated, are assumed to be compatible for algebraic operations. The notation $P>0(\geq 0)$ means that P is a real symmetric positive (semi-positive) definite matrix. I and 0 represent, respectively, the identity matrix and zero matrix. The sign function sign (y) takes the value $+1$ if $y\geq 0$ and -1 if $y<0$. The standard saturation function can be defined as $\delta(y)=\text{sign}(y)\min\{|y|,1\}$. We use $[m]$, where $m>0$, to denote the integer part of m and use $\rho(A)$ to denote the eigenvalue set of matrix A.

2. Problem statement

Consider a group of N identical agents, and each agent, labeled from 1 to N, is described by a chain of n integrators

$$\dot{x}_i = Ax_i + bu_i, \quad i=1,2,\ldots,N, \tag{1}$$

with bounded input $|u_i|\leq u_{\max}$, where $u_{\max}$ is some known parameter representing the magnitude limitation on the control, and $x_i=[x_{i1},x_{i2},\ldots,x_{in}]^T\in\mathbb{R}^n$ and $u_i\in\mathbb{R}$ are the state and the control