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Distributed containment control of fractional-order uncertain multi-agent systems☆

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Abstract

This paper investigates the containment control problem of uncertain linear multi-agent systems, where the dynamics of each agent is described by a fractional-order differential equation. Based on the stability theory of fractional-order systems and matrix theory, some sufficient conditions are presented to ensure that the states of the followers can asymptotically converge to the convex hull formed by those of the leaders, and the feedback matrix of the proposed protocol is also determined according to linear matrix inequalities. Two simulation examples are provided to demonstrate the effectiveness of the theoretical results.

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1. Introduction

Recently, consensus problem has received considerable attention. This is partly due to the fact that it has broad applications in many fields including formation control, cooperative control of unmanned airvehicles, attitude alignment, flocking. Among the research topics in consensus of multi-agent systems, there are mainly several classes such as leaderless consensus problem [1–4], leader-following consensus problem [5–8] and containment control problem [9–12].

In this paper, we focus on the containment control problem of multi-agent systems, which has been investigated from different perspectives. The main objective of containment control is to design appropriate protocol such that all the followers can converge to the convex hull spanned by the leaders. The containment control problem of double-integrator dynamics was studied in [9], where the dynamic leaders with identical velocity and the dynamic leaders with nonidentical velocities were considered, respectively. In [10], the containment control problem of continuous-time and discrete-time multi-agent systems with general linear dynamics were constructed based on the relative outputs of the neighboring agents. The impulsive containment control problems for the second-order multi-agent systems were investigated in [11], where the stationary and dynamic leaders were considered in a directed graph, respectively. In [12], the containment control problem with directed communication topologies and time delays was presented, in which a distributed PD-type protocol based on the information of neighbors was adopted.

On the other hand, it is noted that the multi-agent systems in the above-mentioned literature are mainly to be integer-order. However, it should also be noted that many systems are more suitable to be described by fractional-order dynamic equations rather than by the integer-order ones, such as viscoelastic systems, dielectric polarization, and electromagnetic waves. The synchronization problem of different fractional order chaotic dynamical system was investigated in [13], where the interrelationship between the order and synchronization was studied. By applying the pinning control and adaptive pinning control, cluster synchronization in fractional-order complex dynamical networks was presented [14,15], respectively. The distributed coordination of networked fractional-order systems over a directed interaction graph was studied in [16], where three different cases were summarized and the convergence spread of coordination for fractional-order system with that for integer-order systems was compared. The consensus problem of fractional-order uncertainty dynamics was investigated [17], in which a distributed static output feedback protocol was proposed. However, there is little study on containment control of fractional-order uncertain systems. In fact, to our best knowledge, containment control problem has not been investigated for fractional-order uncertain systems.

Motivated by the above discussions, this paper will investigate the containment control of fractional-order uncertain multi-agent systems, which is more challenging. Distributed containment controllers based on state feedback and output feedback are constructed, respectively. The states of the followers will asymptotically converge to the convex hull formed by those of the leaders if, for each follower, there exists at least one leader that has a directed path to that follower. By using the matrix analysis and the linear matrix inequality techniques, the sufficient conditions on the existence of these controllers are given. In summary, the main contribution of this paper is twofold. (1) Compared with the existing containment control problem, the agent in this paper is described by the fractional-order dynamic, not by integer-order dynamic. (2) An efficient way is provided to solve the containment control of fractional-order multi-agent system and the feedback gain matrices are easy to be determined.

The construction of this paper is organized as follows. In Section 2, we introduce the model to be studied. In Section 3, containment control problem of uncertain fractional-order linear