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Research Article

Algorithm for Identifying Minimum Driver Nodes Based on Structural Controllability

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Existing methods on structural controllability of networked systems are based on critical assumptions such as nodal dynamics with infinite time constants and availability of input signals to all nodes. In this paper, we relax these assumptions and examine the structural controllability for practical model of networked systems. We explore the relationship between structural controllability and graph reachability. Consequently, a simple graph-based algorithm is presented to obtain the minimum driver nodes. Finally, simulation results are presented to illustrate the performance of the proposed algorithm in dealing with large-scale networked systems.

1. Introduction

Advances in communications technology have opened up new challenges in the area of networked systems. Controllability of multiagent networked systems as a fundamental concept in this field has received considerable attention. The pioneer work in analysing controllability of multiagent systems with leader-follower architecture had been carried out by Tanner [1], where controllability conditions were provided for multiagent systems with undirected graph topology based on eigenvectors of the Laplacian matrix. In further development, some algebraic conditions for controllability of multiagent systems are presented in [2, 3]. Ji and Egerstedt [4] introduced network equitable partitions to present a necessary condition for the controllability of leader-follower multiagent systems. Inspired by [4], Rahmani et al. [5] proposed the controllability of multiagent systems with multiple leaders. Liu et al. [6] derived a simple controllability condition for discrete-time single-leader switching networks, which was further extended to continuous-time single-leader switching networks [7]. Ji et al. [8] derived a necessary and sufficient condition for the controllability of leader-follower multiagent systems, by dividing the overall system into several connected components. The other related topics in this area are leader-follower consensus [9, 10], leader-follower formation control [11–13], containment control [14, 15], and pinning-controllability of networked systems [16, 17].

The concept of structural controllability has been studied extensively since the classical work by Lin [18]. In [18], structural controllability of SISO linear systems was explored by introducing a notion of structured matrix whose elements are either fixed zeros or independent free parameters. Shields and Pearson [19] extended the results of [18] to structural controllability of multiinput linear systems. Since then various works have been carried out on the structural controllability of linear systems [20–22]. Recently, structural controllability of networked systems has emerged as a major interest in the network sciences. A notable work in this area is carried out by Liu et al. [23] which addressed the structural controllability of complex networks. Jafari et al. [24] studied structural controllability of a leader-follower multiagent system with multiple leaders. Sundaram and Hadjicostis [25] developed a graph-theoretic characterization of controllability and observability of linear systems over finite fields. Haghighi and Cheah [26] employed the concept of structural observability to examine the weight-balanceability of networked systems.