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Output Consensus of Heterogeneous Linear Multi-Agent Systems
異構線性多智能體系統的輸出一致性

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Abstract

Multi-agent systems are usually used to describe a class of systems consisting of multiple subsystems, which have independent capabilities of computing, sensing, communicating, and are connected by communication networks, such as multi-robot systems, networked micro-satellite systems, mobile sensor networks, and so on. Benefiting from their advantages such as good scalability, high working efficiency, and fault tolerance, multi-agent systems have attracted great attention in their cooperative control from control community. Consensus is one of the cooperative control problems of multi-agent systems, and can be widely applied in the fields of formation control of Unmanned Aerial Vehicles (UAVs), environment surveillance, networking of multiple satellites, and so on.

In the past decade, great progress has been made for consensus of multi-agent systems. However, heterogeneity of agents, time-varying topology, disturbances, and system uncertainty still present some challenges for consensus protocol design. This thesis focuses on the cooperative output regulation problem and output consensus problem of heterogeneous multi-agent systems subject to different disturbances for individual agents under fixed or switching topology. General dynamics of high-order linear multi-agent systems are considered, and some novel distributed control laws are proposed. Furthermore, adaptive control techniques are applied to design feedback gains such that they will be independent of Laplacian matrix of the underlying system topology, and internal model principle is used to solve robust output consensus of discrete-time multi-agent systems with structural uncertainty. The main contributions of this thesis are summarized as follows:

Firstly, the cooperative linear output regulation problem of a class of heterogeneous multi-agent systems subject to different disturbances for individual agents is investigated. A novel distributed control law is presented based on dynamic mea-

surement output feedback. It is shown that the overall networked closed-loop control system is asymptotically stable and the output regulation errors asymptotically approach zero as time goes to infinity under a sufficient and necessary condition.

Secondly, since the feedback gains of high-order multi-agent systems are usually dependent on the Laplacian matrix of the underlying system topology, which is of global nature, we further apply adaptive control techniques to investigate the cooperative output regulation problem of heterogeneous multi-agent systems subject to different disturbances for individual agents. Two classes of distributed adaptive control laws are presented based on state feedback and dynamic output feedback respectively. It is shown that the outputs of all agents can track the reference input asymptotically under the proposed adaptive control laws.

Thirdly, we further investigate the cooperative output regulation problem of heterogeneous multi-agent systems with periodic switching topology, which has only a subgroup of agents accessing to the information of the exosystem. A novel distributed adaptive control law is presented based on dynamic state feedback with the feedback gain independent of the Laplacian matrix of the underlying system communication topology. It is shown that the overall networked closed-loop control system is asymptotically stable and the regulation errors approach zero as time goes to infinity.

Fourthly, the output consensus problem of heterogeneous multi-agent systems without a common reference input is further studied. A distributed control law is first presented for leaderless output consensus based on internal reference models, which are designed to generate a virtual reference input. It is shown that the internal reference models of agents can achieve consensus to a common trajectory which is determined by the underlying system topology and the initial states of the internal reference models. Then a necessary and sufficient condition is presented for the leaderless output consensus. Moreover, the approach is extended to leader-following output consensus of heterogeneous linear multi-agent systems with the leader also being subject to a disturbance.

Finally, the output consensus problem of heterogeneous discrete-time multi-agent systems with individual agents subject to structural uncertainty and different disturbances is investigated. A novel distributed control law based on internal ref-

erence models is first presented for output consensus of heterogeneous discrete-time multi-agent systems without structural uncertainty, where internal reference models embedded in controllers are designed with the objective of reduced communication costs. Then based on the internal reference models and the well-known internal model principle, a distributed control law is further presented for output consensus of heterogeneous discrete-time multi-agent systems with structural uncertainty. It is shown in both cases that the consensus trajectory of the internal reference models determines the output trajectories of agents.

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