Abstract

Multi-agent systems have been extensively studied in modern control theory due to its wide applications in robotics, transportation networks, smart grid, etc. In this thesis, we investigate the multi-agent system from the perspective of *robust coordination, distributed optimization and game algorithm design, and network controllability.* Specifically, in the practical applications of multi-agent systems, uncertainties and disturbances are always surrounded. Therefore, it is of great significance to consider the influence of these uncertain factors when designing distributed control algorithms. In addition, optimization and game theory have wide applications in industry. This thesis focuses on distributed optimal algorithms design in multi-agent systems. Lastly, controllability of networked multi-agent systems is another important issue that helps to organize a network such that the control and interactions are more effective and amenable.

In the first part of this thesis, we study *robust cooperative control of multi-agent systems.* To deal with model uncertainties and disturbances in the agent dynamics, we propose a continuous *filter-based* control protocol for a class of *high-order multi-agent systems*. Sufficient conditions are given to guarantee asymptotic consensus. An output feedback control algorithm is further proposed by using only position information. Then, we consider robust finite-time connectivity-preserving consensus and formation tracking problems. We propose an integral sliding mode based framework to simultaneously achieve *disturbance rejection, finite-time convergence,* and *connectivity preservation* for double-integrators with bounded disturbances and a virtual leader. The result is further extended to the formation tracking case.

In the second part, we study *distributed optimization and game algorithm design*. First, we consider a class of distributed quadratic optimization problem where the optimal solution and the objective functions are both assumed to be *time-varying*. When there is no constraint on the decision variables, gradient-based searching methods are proposed to track the unknown optimal solution. The tracking errors are proven to be asymptotically stable. We further consider the case where there exists a local compact convex constraint set for each agent. By using projected gradient methods, we prove that the tracking errors are uniformly ultimately bounded with arbitrarily small bound. Next, we consider the distributed Nash equilibrium seeking problem for a *nonsmooth generalized convex game*. Each player has a convex cost function and is subject to multiple shared constraints. The objective is to design a Nash equilibrium seeking law such that each player minimizes its own cost function in a distributed way. Both class-C_2 objective functions and locally Lipschitz objective functions are studied.

In the third part, we consider the *controllability problem of multi-agent systems.* Specifically, we study the controllability of a class of *antagonistic networks* with not only positive weights but also negative ones. This kind of network model is common in social network science. Nodes connected with a positive edge can be viewed as “friends” and linked with a negative edge can be viewed as “enemies”. We present necessary conditions to characterize the controllability and analyze the relationship between an antagonistic network and an all-positive network.