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論文審査の要旨 (2000 字程度)

This dissertation is entitled "Control of Self-Interested Agents in Noncooperative Dynamical Systems" and composed of 7 chapters, wherein a regulation framework of noncooperative dynamical multiagent systems is developed. The underlying dynamics considered throughout the dissertation are pseudo-gradient dynamics with a scalar state for each of the agents. Furthermore, in order to regulate the system, the existence of the system manager is assumed so that it can collect the entire/part of the state information and the payoff dependencies of the agents.

In Chapter 1 (Introduction), current incentive frameworks for game theoretic situations and noncooperative systems are overviewed, and the motivation and the goals of this research is stated. Specifically, fundamental issues of regulating the noncooperative multiagent systems are characterized in terms of the incentive design principles and psychological considerations.

In Chapter 2 (Control of Uncertain Noncooperative Dynamical Systems: A Tax/Subsidy Approach), a zero-sum tax/subsidy approach for stabilizing unstable Nash equilibria is proposed. Specifically, without the information of agents' personal sensitivity parameters, several sufficient conditions for guaranteeing stability of an unstable Nash equilibrium are characterized. Based on these conditions, it is claimed that by constructing a framework with a zero-sum tax/subsidy incentive structure, the system manager can ensure that a Nash equilibrium can be stabilized by collecting taxes from some agents and giving the same amount of subsidy in total to other agents so that the agents' payoff structure is properly modified.

In Chapter 3 (Control of Large-Scale Noncooperative Dynamical Systems: Hierarchical Incentive Framework), a framework for hierarchical noncooperative multiagent systems is developed. In this framework, agents in each group are incentivized by a corresponding second-level system manager who represents the benefits of group utility via an intra-group incentive mechanism. These second-level system managers are further incentivized by the first-level system manager in the hierarchy. The update rules for the second-level system managers are proposed based on the local state and the payoff information with continual and intermittent observation on the state of the agents from the other groups. To deal with the uncertain information on agents' personal payoff functions for the first-level system manager, sufficient conditions are presented to guarantee convergence of agents' state to the target equilibrium.

In Chapter 4 (Control of Noncooperative Dynamical Systems With Pareto Improvement: Pareto-Improving Incentive Mechanism), a Pareto-improving incentive mechanism to improve the weighted social welfare and achieve continual Pareto improvement for a noncooperative multiagent system is developed. In the proposed approach, the system manager remodels agents' dynamical decision making with a sustainable budget constraint. Sufficient conditions are derived under which agents' state converges towards the socially maximum state associated with a weighted social welfare function depending on the priority ratio of the agents and the initial state. It is elucidated that the potentialization of the payoff structure has a non-inclusive but strong relation to generating Pareto-improving system trajectories.

In Chapter 5 (Stability Analysis of Loss-Aversion-Based Noncooperative Switched Systems), the stability property of the loss-aversion-based noncooperative switched systems with quadratic payoffs is investigated. In this switched system, each agent is modeled to adopt the lower sensitivity parameter in the myopic pseudo-gradient dynamics for the case of losing utility than gaining utility, and both system

dynamics and switching events depend on agents' payoff functions. As a consequence, some sufficient conditions are derived to guarantee that agents' state converges to the Nash equilibrium in accordance with the location of the Nash equilibrium. In the analysis, the mode transition sequence and its resulting phenomena are also observed.

In Chapter 6 (Incorporation of Predictions of Other Agents' Behavior into Pseudo-Gradient Dynamics), first the incorporation of cognitive hierarchy theory to the pseudo-gradient dynamics in noncooperative systems is discussed. In the characterized framework, all the agents are allowed to base their decisions on the predictions about the likely actions of other agents with a bounded depth of reasoning. Each agent believes that he/she is the most sophisticated agent in the noncooperative system and makes the decision according to some strategic reasoning of the other agents' likely actions. Depending on a knowledge network of payoff functions, the modified pseudo-gradient dynamics are presented under the assumption that the agents may be able to infer the other agents' best-response states and use these predicted states in his/her own pseudo-gradient dynamics. Some sufficient conditions are presented to guarantee stability of a Nash equilibrium with uncertain sensitivity parameters or uncertain knowledge network.

Finally, in Chapter 7 (Concluding Remarks and Future Research Recommendations), the results of each chapter are summarized and discussed. In addition, concluding remarks for each chapter as well as the dissertation as a whole are drawn. Lastly, future extensions are discussed.

In summary, this dissertation develops a framework for stabilizing Nash equilibria of the noncooperative multiagent systems composed of the pseudo-gradient-based agents. The contribution of this dissertation in the field of control of noncooperative multiagent systems is scientifically significant in that the dissertation shows a new framework for obtaining deep insights of incentive structure of the payoff dependencies between the agents and provides guaranteed conditions of state convergence to the target Nash equilibrium. Consequently, it is concluded that this dissertation is of sufficient merit as a doctoral thesis, deserving the degree of doctor of philosophy.