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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Coordination between individual interests and social interests have become essential for studying multiagent systems in the future smart society. This thesis provides a line of work on control problems of self-interested agents in pseudo-gradient-based noncooperative dynamical systems. In the first part, we focus on developing several utility-transfer frameworks for pseudo-gradient-based noncooperative dynamical systems to remodel agents' dynamical decision-making. Specifically, a zero-sum tax/subsidy approach, a hierarchical incentive framework, and a Pareto-improving incentive mechanism are constructed to deal with the control problems in the face of agents' private information, large-scale system, and Pareto improvement. In the second part, we investigate the influence of psychological considerations in noncooperative systems with the loss-aversion phenomena and the incorporation of cognitive predictions of agents into pseudo-gradient dynamics.

First of all, to deal with the control problem of noncooperative dynamical system where the sensitivity parameters of the pseudo-gradient dynamics are uncertain to the system manager, a zero-sum tax/subsidy approach is constructed to stabilize a possibly unstable Nash equilibrium. We first characterize the stability of the Nash equilibrium for arbitrary values of sensitivity and then investigate the zero-sum tax/subsidy framework without knowing the sensitivity parameters. In the proposed framework, the system manager defines the utility-transfer structure dividing the agents into subgroups so that the utility transfers are completed within the subgroups in a zero-sum and distributed manner. The amounts of tax (negative incentive) and subsidy (positive incentive) for each agent are determined by quadratic incentive functions with well-chosen control parameters.

For a noncooperative system with a large number of agents, the requirement for a single system manager to know all agents' payoff functions is extremely stringent. To handle this issue, in light of the hierarchical government structures in real society, we develop a hierarchical incentive framework for large-scale noncooperative dynamical systems to achieve social welfare improvement. In the proposed framework, the agents in the noncooperative system are divided into several groups and are influenced by the corresponding group managers via some intra-group incentives. We characterize the situation where group managers try to enhance the welfare of their groups by continually updating their own intra-group incentives to the group members. We explore the stability of group Nash equilibrium of the hierarchical noncooperative systems and derive conditions where the trajectory of agents' states converges to the group Nash equilibrium under group managers' intra-group incentives. Furthermore, the inter-group incentive mechanism for a system governor is proposed to reconstruct the group utility functions at the group managers level to move the group Nash equilibrium so that the social (entire) welfare is improved. To deal with the situation where the system governor may not know all the agents' individual payoff functions and all the agents' states, we present sufficient conditions to guarantee the convergence of agents' states towards a target (suboptimal but not optimal due to the lack of enough information) equilibrium using some macroscopic data.

Usually, the constructed incentive mechanisms are designed as coercion policies under which the agents cannot escape once in place. However, the agents may have the freedom to break away from the mechanism when they come across some undesired situations (e.g., when their payoffs decrease after the mechanism is executed). To address this problem, we develop a Pareto-improving incentive mechanism to remodel agents' dynamical decision-making to guarantee that all the agents are Pareto improving and their state converges to a Pareto-efficient Nash equilibrium. Considering the priorities among the agents, we construct a weighted social welfare function for the incentive mechanism and hence derive the socially maximum state as the target Nash equilibrium. With the well-designed incentive functions associated with the weighted social welfare function, the socially maximum state is ensured to be a Pareto-efficient Nash equilibrium in the incentivized noncooperative system. Several sufficient stability conditions are presented to guarantee that the agents are Pareto improving under the pseudo-gradient dynamics and their state converges to the socially maximum state with known or unknown sensitivity parameters. We reveal the fact that the Pareto improvement and potentialization do not have an inclusive relation with each other.

In light of psychological game theory and cognitive hierarchy theory, the conventional pseudo-gradient dynamics with static sensitivity by ignoring all psychological considerations and predictions about the likely actions of other agents seem unnatural to describe agents' behavior in real society. We connect the phenomenon of loss-aversion in prospect theory with the pseudo-gradient dynamics and focus on the stability problem of 2-agent noncooperative switched systems, which are characterized as payoff-driven piecewise linear systems for describing agents' dynamic decision-making with the quadratic payoffs and loss-aversion phenomena. Based on the transition analysis and mode analysis, the sufficient and necessary conditions under which agents' state converge to the Nash equilibrium are derived in accordance with the location of the Nash equilibrium. In the analysis, we observe an interesting phenomenon that we call a flash switching instant where a single agent's sensitivity transition makes the other agent immediately switch its sensitivity almost at the same time instant.

Finally, we connect cognitive hierarchy theory with the pseudo-gradient dynamics in noncooperative systems to extend the pseudo-gradient dynamics with some prediction behaviors under Level-k thinking. The modified pseudo-gradient dynamics under Level-k thinking are presented according to the knowledge network of the payoff functions so that the agents are allowed to base their decisions on the predictions about the likely actions (best-response states) of other agents with a bounded depth of reasoning. To deal with the uncertainties on the knowledge network of the payoff functions and sensitivity parameters, we characterize stability property with arbitrary knowledge network of the payoff functions for the cases with a pure population of the agents in the same level and the mixed population of the agents in different levels. In addition, we present the applications of the results in optical communication systems, homogeneous oligopoly markets, and differentiated oligopoly markets. It is observed that to ensure asymptotic stability of the differentiated oligopoly markets with Cournot competition, a larger market with more firms requires more differentiated products. In contrast, this phenomenon does not happen in Bertrand competition.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).