A Study on Complex System: From the Perspectives of Traffic Flow Theory and Evolutionary Game Theory

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Title:　　A Study on Complex System: From the Perspectives of Traffic Flow Theory and Evolutionary Game Theory (複雑系に関する研究：交通流理論と進化ゲーム理論の観点からの考察)

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論 文 内 容 の 要 旨

Thesis Summary

The rapid development of modern society has also brought about a series of social dilemmas. For instance, the increasingly severe traffic jam not only slows economic progress but also creates a poor social experience for humanity. Another example is the frequent breaches of global agreements on energy saving and emission reduction, which involve the conflict between individual and collective interests under the backdrop of social dilemmas. This thesis explores how to alleviate or even solve these social dilemmas, drawing from the fields of traffic flow theory and evolutionary game theory. In traffic flow theory, we focus on the car-following model, proposing a more realistic improved model. Based on this improved model, we explore key factors contributing to traffic jams, providing a theoretical foundation for mitigating or even eliminating traffic jams. In evolutionary game theory, we focus on network reciprocity, examining from three perspectives—incentives, types of strategies, and types of game participants—how cooperation can be maintained in groups despite severe social dilemmas. Regarding incentives, we introduce a third strategy type to the traditional 2 by 2 game: the super cooperator, who rewards cooperators and punishes defectors. We also allow defectors to be more speculative, giving them a probability to know whether their opponent is an unconditional cooperator or a super cooperator; they choose to defect against the former and cooperate with the latter. Our new model surprisingly finds that speculative defectors cooperate with super cooperators, forming active isolation layers to prevent super cooperators from being exploited by unconditional cooperators, and the formation of these active layers is closely related to the level of information and the degree of rewards and punishments. As for the types of strategies in games, we argue that the traditional discrete strategy, which allows only cooperation or defection, does not accurately depict more intricate real-world scenarios. Therefore, we propose the continuous strategy and mixed strategy. Under the context of the prisoner's dilemma, we conducted extensive simulations with three types of strategies across well-mixed and structured populations, finding that, compared to discrete and continuous strategies, mixed strategies result in significant uncertainties. We clarify the factors influencing this uncertainty and elucidate the causes. Regarding the types of game participants, we break from the traditional

limitation of participants being solely biological by introducing bot players, which are pre-programmed. We compare the effects of cooperative bots on the cooperation level of ordinary players under discrete, continuous, and mixed strategies, exploring the reasons behind their differences. Based on the results obtained from these two research fields, we provide a solid theoretical basis for alleviating or even solving social dilemmas.