Coexistence of competing strategies in evolutionary games

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Chapter 7

General Conclusions

Summarize the past, anticipate the future.

This final chapter summarizes the main results that have been presented in this thesis and provides recommendations for future research.

7.1 Conclusions

Cooperation is a cornerstone of social organization and commonplace in human societies. Altruism refers to a costly behavior that benefits others. However, mutual cooperation is often found in nature even when selfish behavior is apparently rational for individuals. Why and under what circumstances, presumptively selfish agents cooperate is a question of longstanding interest to multidisciplinary research. In investigating this cooperation dilemma problem the standard framework utilized is evolutionary game theory. Evolutionary game theory is an interdisciplinary mathematical tool which seems to be able to embody several relevant features of the problem and, as such, is used in much cooperation-oriented research. Vast theoretical mechanisms for emergence and maintenance of cooperation in social dilemma games have been reported thus far.

Rooted in biology and reaching out to complex networks and control engineering, this thesis thoroughly investigates the competition and coexistence of competing strategies in gaming population in the framework of evolutionary games.

Chapter 2 develop a general model for the updating of states in a network that allows us to derive conditions for the steady-state coexistence of strategies. The analysis reveals that coexistence crucially depends on the number of agents consulted for updating. We conclude that updating rules are as important for evolution on a network as network structure and the nature of the interaction.

Chapter 3 extends the model to a more general one for the updating of states in a network. We introduce individual player's switching probabilities between competing partners, not only competing strategists. It allows us to derive conditions for the steady-state coexistence of competing strategies. New theoretical models and results developed in this thesis are useful for probing into how strategies are being taken in structured populations. It provides an original and novel approach for studying evolution dynamics, while also pave feasible ways for possible robotic study in future. The results imply that strategy updating deserves more attention in empirical and theoretical studies.

Chapter 4 presents the dynamic outcomes of gaming populations when the diversity of time scales is introduced in the strategy update process. We have break with the traditional assumption concerns that nature selection acts on the population at the same time scale, i.e. players have the same frequency in updating their strategies. We eliminate this restriction by dividing the population into two groups (fast ones and slow ones), and investigate the evolutionary dynamics in finite populations with time scales on updating and study the influences of different composition of the two groups on fixation probabilities. Numerical and analytical calculations are performed to study the evolution dynamics of strategies in the special classes of two-player games (Prisoner's dilemma game, Snowdrift game and Stag-hunt game). Results show that the decoupling of time scales on updating leads to dramatic changes in the dynamics of strategies. We give a proximation formula of fixation probability of mutant types in finite populations and investigate the outcome of evolution under weak selection. This work is a preliminary study on time scales on updating and more attention is required on this topic in future.

Chapter 5 shows the strategy dynamics in threshold public goods games in which players can buy insurance for their contribution. A threshold public goods game requires a minimum amount of contributions to be collected from a group of individuals for provision to occur. If the threshold is not achieved, the loss can be covered. Our analytical results show that when agents face the potential aggregate risk in threshold public goods games, more contributions occur with increasing compensation from insurance. Moreover, insurance significantly enhances individual contributions and facilitates provision, especially when the required threshold is high.

Chapter 6 bases our analysis of the evolutionary game on replicator dynamics for four strategies: C (cooperators), D (defectors), S (speculators) and L (nonparticipants). For simplicity we assume that punishment of a given effectiveness is externally imposed upon the defectors in a public goods game. We do not consider the question how the punishment system is established or who carries the costs of punishment. Results suggest that the evolutionary fate of the system depends on special assumptions of model parameters. The corresponding results highlight the kinds of model parameters for which evolution favours cooperation, and those in which it does not. Moreover, the observed domination of some strategy or a rock-paper-scissors type of cycle suggests that the additional strategic options can radically alter the evolution of cooperation, and, the coexistence of competing strategies are possible under some conditions.

7.2 Further research topics

All the above phenomena indicate that there are possibly many ways or factors to influence and enhance the competition or coexistence of strategy behaviors among selfish populations. Further investigations would be required to clarify the distinguished role of multiple strategies, appearance of different subpopulation structures, and inhomogeneities of games in these networked populations. Here we only identify three possible directions for subsequential research, servings as a modest spur to induce others to come forward with their valuable contributions in future.

Game Competition among multiple strategies. An interesting future direction would be to address whether the presence of more strategy options altogether affect the dynamics of behaviors in the field of human cooperation. This thesis has dealt with four strategies available for the gaming populations: cooperation, defection, loner and speculation. More candidate strategies will be taken into consideration in network models in future research. For example, the insured cooperation, insured defection strategy, which means strategy players can get some insurance when the game. This is more plausible when the success of the game depends on some threshold point, or the defectors will suffer some punishment in the evolutionary game playing. In addition, this thesis has focused on the synchronization or consensus problem, under the condition that all the agents update their states synchronously. To mimic the real social systems and probe the origin of altruistic behaviors in nature, this motivates extending the study in this thesis to the case with competition among multiple strategies . That is to say, each agent is provided with a multiple-strategy profile, and can choose any one from it when playing games with others. However, accordingly the evolutionary dynamics will really a complicated because it will be closely related with multiple game parameters led by the various strategies. It is a challenging problem if one considers a combination of different communication constraints.

Competing among players situating on different topologies. Many tools to foster cooperation and solve the social dilemma in an efficient way have been designed and tested. It is well known that the evolution of cooperative behavior is dependant upon certain environmental conditions. One such condition that has been extensively studied is the use of a spatially structured population. The key concept of spatially structured populations is: agents are assigned to the vertices of a network, which can be a regular lattice or has a more complex structure. The edges denote links between players in terms of game dynamical interactions. Then, agents are constrained to interact only with their adjacent neighbors to play evolutionary games in which more successful strategies spread on the system. This thesis has studied some structured population situating ont the complex networks. To simplify the research work, we only focus on the case that the whole population situates on a single complex network. The multiple structures among the gaming population can be further investigated when the population can be divided into several groups with their respective networks. For this idea, the correlationship between multiple networks is the key problem needed to be solved. This kinds of investigation can help us get more hints about the potential relationship between evolutionary dynamic process and the characteristics (e.g. population structure, individual heterogeneity) of gaming population.

Competing among players playing different games. Almost most past studies, including the work mentioned in this thesis, focus on the simple case where only one game model (e.g. prisoner's dilemma game, snowdrift game, or public goods game, and so on) is employed as the metaphor to describe the conflicting tension between the short-term benefits of defection and the long-term benefits of cooperation. Everyday experience told us that large heterogeneity between agents is common in real social systems. Individuals are probably involved in complex interacting networks, where they join different games within different gaming groups. For example, they may are asked to participate in a public goods game in a collective group, such as with their colleagues or neighbors for a public goods project. Meanwhile, they may join a prisoner's dilemma game with only one partner in some gaming situations. To focus on the main research object in each work, this thesis has only considered the mentioned simple case where only one game is employed in the large gaming population. Actually, studying the competing among players playing different games is also a challenging project in this field, because the evolutionary process will be complicated or difficult to gain the results. For example, we should wrestle with the challenging calculation of payoffs gained in different games. In the future, we can pay more attention to the multiple games mentioned here.

An Application issue-Competing among different gaming 'players'. The current work in this thesis studies the competing strategies among the population by the means of theoretical analysis and numerical simulation. The robotics (e.g. E-pucks in our group) has also attracted plenty of attention from researchers in many fields, and many works have been proposed and published, suggesting that robotics to study the collective dynamics is a promising direction. Along this thriving research line, we could first try to investigate evolutionary problems among the robotic populations, to verify the theoretical analysis results. It is of interest to study a mixed population consisting of robotics and real agents, and focus on the behaviors of these different 'players'.