Coexistence of competing strategies in evolutionary games

Zhang, Jianlei

Summary

The emergence and existence of cooperation in real societies continues to intrigue researchers from multiple areas, and is basking in a great boom as a multi-disciplinary field of research. A dilemma based on universal Darwinism derives from the fact that defectors gain an advantage over cooperators, whenever cooperation is costly so consequently, not cooperating pays off. However, cooperative behaviors abound in nature. To delve into this problem the widespread framework utilized is game theory along with its extensions involving evolutionary process. The selfish behavior here is manifested by a defective strategy, aspiring to obtain the greatest benefit from the gaming interactions with others. Vast theoretical or experimental mechanisms for emergence and maintenance of cooperation in social dilemma games have been reported thus far.

As mentioned earlier, the cooperative dilemma problem draws attentions of researchers from various disciplines, and one of the reasons may probably lies on the fact that it is really an interdisciplinary and cutting-edge topic. And, cooperative dilemmas in which the self-interest may at odds with the collective interest actually constitute a significant form of vast societal problems, where the maximum payoffs led by the mutual or collective cooperation are in great need. Up to now a great deal of research is aimed at pointing out the way to breakthrough it, by virtue of the viewpoints or methods from several different branches of the sciences, such as biology, physics, sociology, computer science, economics, etc. Each discipline has dealt with this problem differently, and meanwhile each may have much to learn

from the other.

Inspired by the research focus in the two groups ('Theoretical Biology Group' and 'Network Analysis and Control Group' in Groningen University) where I carried out my PhD study, I establish the theoretical study of this topic from the biological or sociological perspective, at the same time, with the help of the simulations in the framework of complex networks under more realistic assumptions. The central topic of this thesis is the competing and coexistence of different agents, since not only one type of strategist actually exists in conflicting situations often encountered in natural and social sciences. Attracted and also bewildered by this social diversity, the main research focus we have in mind is to theoretically and experimentally investigate the conflict and coordination of multiple competing behaviors, as summarized in this thesis.

First and foremost, the research project is related with our proposed switching probabilities between players. What is noteworthy is that the evolution dynamics of involving strategies are the core of the employed evolutionary game theory. A commonly used approach to strategic interaction is combing game theory and population dynamics in a replicator equation or imitation dynamics. This framework or structure is frequently employed in most existing literatures, whereas requires the specific values of payoffs as an indispensable factor. However, in many situations of decision-making under conflicting interests, the information about strategies or payoffs are not easy to acquire, especially for the capacity-constrained players. In a real case of games for benefits, there is normally no easy way for players to know of the ongoing performance of their partners.

In our work, the general situation is modeled here as a repeated game played in a sequence of periods, and strategy update are led by the so-called individual player's switching probabilities, as discussed in Chapter 2. We restrict our analysis to the case where switching only occurs between competing strategies. Results help us to find a causal link between the coexistence of competing strategies and the number of agents consulted for updating. This new theoretical model and the results are also beneficial for investigating how strategies are being taken in structured populations. Considering the complicated strategy decision process and the involved factors, strategy updating still deserves more attention in empirical and theoretical studies.

However, do strategy revisions merely occur between different strategists? In many competitive games, strategy revisions also emerge when two same strategists encounter. This is in line with some real-world mimicry, where decisions or actions of each player may be less directly linked to or affected by the actions of the other players. In this case, strategy revisions also occur in social contexts where players interact and happen to adopt the same strategy concurrently. To answer these questions, we design a general paradigm to study the strategy switching probabilities between competing players, and the related results are summarized in Chapter 3. The results reveal that the evolutionary fate of the coexisting strategies can be calculated analytically, and provide novel hints for the resolution of cooperative dilemma problems in a competitive context.

Then, it is understandable that the speed or frequency of strategy update may vary in each individual in real social societies. Previous studies have focused mainly on the assumption of homogeneous times scales in strategy updating of the populations. Because participants had varying reaction times or frequencies in strategy updating, we reported the modulation of player behavior attributable to different time scales in strategy updating, as summarized in Chapter 4. Our approach can be interpreted as individual heterogeneity regards to time scales.

To dissociate between slow and fast opponents, we divide the population into two groups endowed with respective time scales. And, we extend our analysis to three representative dilemma models (Prisoner's dilemma game, Snowdrift game, and Stag-hunt game). In sum, we have gained a sequence of approximation formulas that determine the fixation probabilities under variations of the initial conditions. Results suggest that the different time scales result in much richer evolutionary dynamics, and some inspirations can be gained to control the fall or rise of cooperative behaviors. To more convincingly show the individual diversity, our work lends itself to several extensions, such as an immediate and feasible one, one more type of players that updates with median time scales can be taken into account.

Next, with a view to the significance and diversity and strategy choices, we extend the general two-strategy profile by adding a third strategy, called insured cooperation, which corresponds to buying an insurance covering the potential loss resulted from the unsuccessful public goods game. We focus our study on the threshold public goods games. Particularly, only the contributing agents can opt to be insured, which is an effort decreasing the amount of the potential loss occurring. Our results in Chapter 5 show that permitting the adoption of insurance significantly enhances individual contributions and facilitates provision, especially when the required threshold is high.

Finally, a large majority of the current evolutionary game studies that shed light on the mechanism behind many cooperative phenomena in gaming systems concentrated on pair-wise interactions between individuals. It is tempting to introduce and investigate the individual diversity in terms of strategy in a competitive context. Thus it is conceivable that participants face the following options: cooperation, defection, speculation and being a loner. The traces of all of these forms of actions could be spotted in everyday life. In the analysis shown in Chapter 6, we identify specific characteristics of the game parameters in public goods games that conceptually mark the transitions among various steady states of the system.

Summarizing, modeling the characteristics of individual diversity, involves exploring the heterogeneous factors of individuals, from strategy choice to time scales of strategy updating and more practical forms that exist in societies. At the core are the issues of how reasonable assumptions are required to propose based on these realistic considerations, and the degree that individual decisions are influenced by regard for others. Hope our work can offer inspirations and references for the sustainable cooperative behaviors, avoiding the free riding phenomenon in some situations, and promoting high efficient transactions and cooperates in society finally.