The Effect of Occasional Rational Decision on the Cooperative Relationship between Groups

Tetsushi Ohdaira[†1], **Hirotada Ohashi**[†]

[†]Department of Quantum Engineering and Systems Sciences,
Graduate School of Engineering, University of Tokyo,
2-11-16 Yayoi, Bunkyo-ku, Tokyo, 113-0032 Japan
Tel / Fax: +81-3-5841-6991
[1]ohdaira@crimson.q.t.u-tokyo.ac.jp.

Abstract

Prisoner's Dilemma Game is one of the most common game theory treating a conflict of interest. In this research, we set a new model for simulating a conflict of interest between groups. It has mainly two features. First, the game player is not affected by the previous move of the opponent because it makes more difficult to build and keep cooperative relationship. Second, the structure of strategy takes a form of sequential array so that it can evolve through the interaction with the other.
Using this model, we show the rapid collapse of cooperative relationship induced by only a few times of rational decision.

Keywords: Social Simulation, Conflict of Interest, Decision Making Problem, Evolutionary Game Theory, Prisoner's Dilemma Game.

1 Introduction

Prisoner's Dilemma Game (PDG) and its repeated form, Iterated Prisoner's Dilemma Game (IPDG) are very popular and often used for modeling a conflict of interest between nations, companies, animals, human beings and so on.

An eminent work of IPDG is the Robert Axelrod's tournament which was held twice about 20 years ago [1]. In the study, he found the toughness of Tit-for-Tat (TFT) strategy and the factor for the development of mutual cooperation.

In the study of PDG, there are two important topics. First, what a method is effective for the emergence of cooperation. Second, if you observe a cooperative relationship, how stable it is. These topics have been discussed for a long period, but they're still inconclusive.

This research is like common one-to-one IPDG, but our model does not have any memory in a strategy of agent and includes a method of updating strategy with an evolutionary computation. We offer the model as a new candidate to deal with the matter about a conflict of interest between groups. The main purposes of this research are summarized below.

- Creating a new PDG model with an evolutionary strategy update mechanism.
- Proposing irrational decision as a new element essential for cooperation.
- Demonstrating that only a few rational decisions seriously unravel favorable relationship.

2 The Model

2.1 Prisoner's Dilemma Game (PDG)

We intend to devise a model for discussing a conflict of interest between two groups and an effect of irrational decision by each group. To attain this goal, we introduced a novel structure about the strategy.

The following is a well-known PDG scenario. 1. There are two Players and they can choose their strategies (Defection or Cooperation). 2. They are separated each other, so that each of them can not know the strategy of the opponent. 3. After choosing strategies, they get their payoff according to the payoff matrix (Table1).

The strategy of Defection is the undefeated one in PDG. However, if PDG is repeated many times, defection is no longer the optimum. There is no 'unbeaten' strategy in the repeated PDG, which is called Iterated Prisoner's Dilemma Game (IPDG). The effectiveness of strategy depends on the strategy of the opponent.

As noted before, the remarkable work of IPDG is the Robert Axelrod's contest with computer simulation. From the result, he picked up the important points for cooperation as follows [1,2]: 1. Player needs to remember the previous strategy of the opponent (Memory). 2. Player must give profit each other, that is, they have to take the same action as the past move of the opponent (Reciprocity).

Table 1: Prisoner's Dilemma Game Payoff Matrix

Player B / Player A	Defection	Cooperation
Defection	(**P**: 1, **P**: 1)	(**T**: 5, **S**: 0)
Cooperation	(**S**: 0, **T**: 5)	(**R**: 3, **R**: 3)

Every capital bold alphabet means:
T - **T**emptation to defect,
R - **R**eward for mutual cooperation,
P - **P**unishment,
S - **S**ucker's payoff.
In Prisoner's Dilemma Game,
The condition **T**>**R**>**P**>**S** is necessary,
and about Iterated Prisoner's Dilemma Game,
additional condition 2**R**>**T**+**S** should be satisfied.
This payoff matrix meets both conditions.

2.2 Sequential PDG

In this research, we investigate a conflict of interest between two groups using the idea of PDG. Our goal is not searching the prevailing strategy. We intended to reveal the dynamics between groups through the interaction. To achieve this purpose, a new scenario is devised for simulation, that is, there is no fixation of strategy and strategy itself evolves based on the decision of each group. We name this advanced PDG as "Sequential PDG". The main features are listed below.

- There are two different groups which have eight agents respectively.
- Agents of each group have an ID (from no.1 to 8) and one strategy.
- The strategy regulates the behavior of the agent in each round of PDG. Therefore agents can not change its move during Sequential PDG.
- Every strategy of agents (that will be simply noted as strategy) is a sequential array whose length is 30 characters as mathematical expression (1) convenient for the evolutionary process (described later). Each character represents a strategy of one round (D: Defection, C: Cooperation).
- Every agent plays Sequential PDG using their strategy against the opponent of identical ID belonging to the other group.

$$S_{g\_u}(u) = \left\{\alpha^{n}_{g\_u}(u) \,\middle|\, \alpha_{g\_u}(u) \in \{D, C\}, 1 \le u \le 8, n = 30\right\} \quad (1)$$

D or C means the component vector, it is expressed as (0, 1) or (1, 0). The former represents that the selection at one round is defection, the latter means the agent chooses cooperation.

The payoff of each agent in the group at the generation g is numerically expressed in this way (2). If we focus the group i whose opponent group has the ID j, the agent u in the group i get its payoff $P_i^g(u)$ respectively. A denotes the payoff matrix, and α_i^k and α_j^k means the element of strategy (1).

$$A = \begin{pmatrix} 3 & 0 \\ 5 & 1 \end{pmatrix}$$

$$P_i^g(u) = \sum_k \alpha_i^k(u) A \alpha_j^k(u)^T \quad (1 \le k \le 30) \qquad (2)$$

After the all agents experienced Sequential PDG, the decision of each group will be made separately. "Decision" in this case is to select the representative strategy of the group. In this process, every strategy will be updated as the following way.

1. The strategies of the group are graded according to its score (ranking).
2. One strategy in the group is selected according to the irrational decision (noted below) and becomes the representative strategy. This strategy is chosen "by the group" (not by the agents).
3. Two parts of the representative strategy is copied to the same position of the other 7 strategies in turn. The length of fraction randomly changes from 1 to 15 in every copying process.
4. After finishing above, each character of created new strategies is reversed according to the probability (1/1000).

Above steps are executed independently in both groups. Representative strategy itself does not change except the mutation (Step 4). This mechanism of selecting representative and updating strategy is named as the "evolutionary process". Through the process, every strategy is updated and ready for the following match. Above procedure, that is, Sequential PDG between groups and the following evolutionary process is defined as one generation, and to investigate fluctuation in long period, one game simulation lasts until generation reaches to 5,000. All results described later are the average of 30 times simulation.

2.3 Introducing Irrational Decision

In the context of PDG, it is usually thought that cooperative relationship would not develop if there were no additional elements. The supplement often mentioned before is the "Tag" [3, 4, 5] or the "Spatial Structure" [6, 7, 8, 9]. The former is the way to distinguish agents by giving each of them identification. An agent can check the tag of another agent and know whether he is cooperative or not. The latter is introduced to define neighborhood connection around agents. In the condition, agents interact only with those who are directly connected.

In this research, as a new candidate to generate cooperative relationship, we introduce the "Irrationality" that means 'irrational decision of the group (that will be abbreviated as irrational decision)'. The reason why we propose this is derived from the fact that above previous methods can not express altruistic behavior of human society.

In the irrational decision, the greatest score strategy in the group is not selected as representative. Therefore the representative strategy will be one of the strategies except the highest. It is selected randomly from the strategy of score grade 2 to 8 in the group (Irrational selection). The strategy with the lowest score may be chosen as representative, but this event does not occur in every evolutionary process. The selection of the lowest strategy may be regarded as human mistake in decision making.

3 Results

To tell the truth, in a one sense it could be predictable before executing simulation that unconditionally irrational decision has an effect on emergence and maintenance of mutual cooperation. If you want to keep a good (cooperative) relationship to the other, you should not be prepossessed with the temptation of recent future [1,2]. Fully irrational decision faithfully follows this rule by sacrificing payoff of the group.

Therefore, we probed the traits of this cooperative relationship by introducing probabilistic rational decision. When every group sometimes makes rational decision, how is the cooperative relationship affected? Next we give the answer for this question.

The influence of occasional rationality is exhibited in Figure 1a and 1b. From the result you can see how the rate of rationality affects mutual cooperation. Note that the rate of rationality means the probability how rationally the decision of each group is made in every evolutionary process (generation). Therefore if the rate of rationality is 0.3, it indicates that the rational decision will be made with that probability (and also the possibility of the irrational decision should be 0.7). This probability is independent between two groups.

As shown in the result, increase of rationality accelerates the growth of mutual defection and induces the decline of mutual cooperation. However, the acuteness for the rate of rationality is different between mutual defection and cooperation. The frequency of mutual cooperation decreases more rapidly than the linear line does, whereas the growth of mutual defection is comparatively slow.

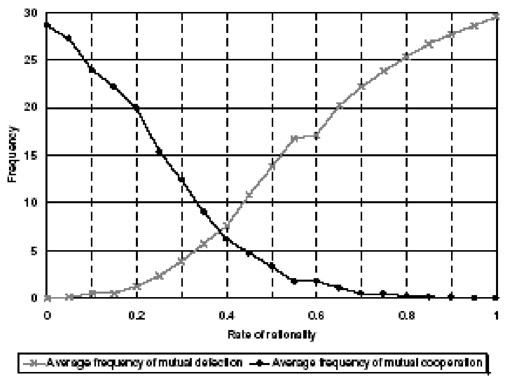

Figure 1a: Effect of rationality on average frequency of mutual defection and cooperation in last generation. The rate of rationality designates that how often the rational decision is made in every group during the simulation.

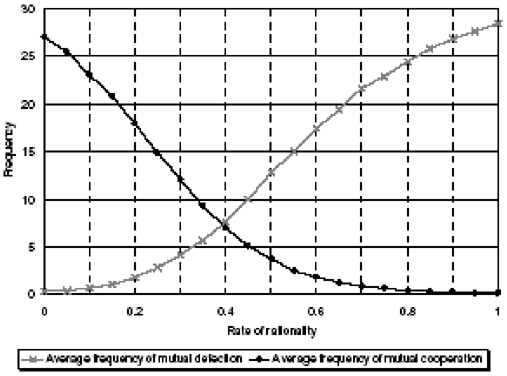

Figure 1b: Effect of rationality on average frequency of mutual defection and cooperation about all generation.

4 Conclusion

We have introduced a new model for researching a conflict of interest within two groups. The character of the model is summarized in three points: First, strategy has no memory. Second, the structure of strategy is the sequential array of fixed length. Third, through the evolutionary process, it is consistently overwritten by representative strategy. In the works of IPDG, which partly resembles Sequential PDG, strategy is often defined as a reaction for a previous move of opponent. From that point of view, someone may criticize our work because the strategy of our model has no reactive action explicitly. However, if you know well about the study of PDG and IPDG, you can recognize it is not the rare case that agent doesn't use its remembrance (such as [6, 10] or the case of no iteration and memory is [4]). Sequential PDG is like not so much standard IPDG as one shot PDG because agents have no chance to adjust their strategies if once Sequential PDG starts between them. However, due to the length of the strategy, there are quite many various patterns of strategy (2^{30}) in comparison with PDG (only 2 patterns). That mechanism supports the operation like genetic algorithm in evolutionary process. In addition, because the elimination of memory makes it more difficult to build cooperative relationship with each other, it is quite significant that cooperative relationship emerges within that condition. That's the reason we designed Sequential PDG as noted before.

The effect of occasional rationality (Figure 1a, 1b) offers a suggestive idea that mutual cooperation is strongly influenced by a little rational behavior. If you want to maintain cooperative relationship with the other, you should not desire to get more payoffs. Only a few times of defection will cause the serious collapse of cooperation.

This research is still at a preliminary stage and so has many ways of extension. We have already started to apply the model to the spatial game, using networks of various topologies. Some interesting properties have been obtained from this further research. It will be shown in the near future.

References

[1] Axelrod R (1984), *The Evolution of Cooperation*. Basic Books, New York.

[2] Maynard Smith J (1982), *Evolution and the Theory of Games*. Cambridge University Press, Cambridge.

[3] Riolo R L (1997), The effects and evolution of tag-mediated selection of partners in populations playing the iterated prisoner's dilemma. *Proc. of the 7th Int. Conf. on Genetic Algorithms (ICGA97)*, San Francisco: Morgan Kaufmann, pp.378-385.

[4] Hales D (2001), Tags produce cooperation in the prisoner's dilemma. *Simulating Society V workshop: "The frontiers of social science simulation"*, Kazimierz Dolny, Poland.

[5] Riolo R L, Cohen M D C, Axelrod R (2001), Evolution of cooperation without reciprocity. *Nature* 414, pp.441-443.

[6] Nowak M A, May R M (1992), Evolutionary games and spatial chaos. *Nature* 359, pp.826-829.

[7] Cao Z, Hwa R C (1999), Phase transition in evolutionary games. *Int. Jour. of Mod. Phys. A* 14, pp.1551-1560.

[8] Ahmed E, Hegazi A S, Elgazzar A S (2002), On spatial asymmetric games. *Advances in Complex Systems* 5, pp.433-443.

[9] Kim B J et al. (2002), Dynamic instabilities induced by asymmetric influence: prisoner's dilemma game on small-world networks. *Phys. Rev. E* 66, 021907.

[10] Fort H (2003), Cooperation with random interaction and without memory or "tags". *Jour. of Art. Societies and Social Simulation* 6, http://jasss.soc.surrey.ac.uk/6/2/4.html.