Chaos, Solitons and Fractals 77 (2015) 39–46

Contents lists available at ScienceDirect

Chaos, Solitons and Fractals

Nonlinear Science, and Nonequilibrium and Complex Phenomena

journal homepage: www.elsevier.com/locate/chaos

Individual choice and reputation distribution of cooperative behaviors among heterogeneous groups

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ARTICLE INFO

Article history:
Received 11 March 2015
Accepted 17 April 2015
Available online 16 May 2015

ABSTRACT

Cooperation is vital for our society, but the temptation of cheating on cooperative partners undermines cooperation. The mechanism of reputation is raised to countervail this temptation and therefore promote cooperation. Reputation microcosmically records individual choices, while cooperation macrocosmically refers to the group or averaged cooperation level. Reputation should be preferred in order to investigate how individual choices evolve. In this work, we study the distribution of reputation to figure out how individuals make choices within cooperation and defection. We decompose reputation into its mean and standard deviation and inspect effects of their factors respectively. To achieve this goal, we construct a model where agents of three groups or classes play the prisoners' dilemma game with neighbors on a square lattice. It indicates in outcomes that the distribution of reputation is distinct from that of cooperation and both the mean and standard deviation of reputation follow clear patterns. Some factors have negative quadratic effects on reputation's mean or standard deviation, and some have merely linear effects.

1. Introduction

Human society is based on cooperation among strangers, which explains why cooperation is vital for our society [1–3]. However, people are commonly seduced to defect other than cooperate by the temptation of cheating on cooperative partners, in that selfless contributors receive less while selfish defectors are greatly rewarded [3]. Defectors take advantages of kind-hearted cooperators to acquire higher payoffs, while cooperators are trapped and suffer a great deal. Therefore, temptation becomes the main mechanism that undermines cooperation [3–5].

Researchers in related fields including spatial game theory [4–6] have proposed many solutions or counter-temptation mechanisms [3,7–9] to overcome temptation and promote cooperation. Spatial prisoners' dilemma games [5,6,9,10] and public goods games [7,11–33] are widely applied to achieve this goal. They have raised serials of anti-temptation mechanisms or solutions, such as influence [28], recommendation [25], tolerance [32], expectation [10,34], punishment [21,29,32,35], reciprocity [35–39], networks [40–46], structured population [47–50], multiplex network [51–53] and volunteering [54–57], etc. It suggests that they all enhance cooperation under specific circumstances.

Among them, reputation is an important solution that efficiently countervails temptation [3,5,7,8,12,24]. Reputation records agents' history of cooperation or defection, so that each individuals or agents are able to identify, cooperate with, or imitate the neighbor with highest reputation [2,3,5]. It indicates in experiments of reputation-based spatial game theory that reputation does countervail temptation and enhances cooperation effectively [2–4,6,8,9]. However, three issues remain unsolved: First, most of existing studies deem cooperation as the explained variable, while keeping reputation as one of the explaining variables [2,3,5,8], and therefore

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http://dx.doi.org/10.1016/j.chaos.2015.04.012
0960-0779/

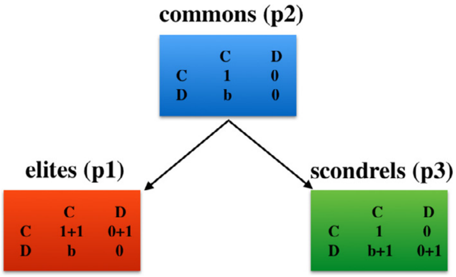

Fig. 1. Common's neighborhood. The whole society on a square lattice consists of three classes: common in blue has the standard payoff matrix; elite in red gets higher payoff when cooperating; scoundrel in green obtains higher payoff when defecting. For each common, the neighbors or local environment possibly includes elites, commons, and scoundrels. (For interpretation of the references to colour in the text, the reader is referred to the web version of this article.)

ignoring its evolution on traits of distribution. As the outcome of individual choice, it should be deemed as an independent or explained variable as well; second, reputation merely indicates the non-negative summation of individual choice [3,5,24,58], which is not enough in that defection should be a negative term otherwise; third, spatial games with reputation are usually played within a homogenous groups [6,59], while in the real world diversity [6,17,24,27] and heterogeneity [31,59] are pervasive.

Under the paradigm of spatial lattice-based games [5,6,14,15,17], this work provides one possible solution to these problems and expands related research on reputation: the first problem is fixed by deeming reputation as the outcome variable of individual choices, distribution of reputation including mean and standard deviation would be investigated as well; expanding the definition of reputation solves the second one, so that the fluctuation reputation indicating dynamic choices would be seen; heterogeneous sub-groups are introduced to settle the problem of homogeneity.

2. Model

2.1. Spatial heterogeneous groups

Contrary to merely one homogenous population in existing studies, we introduce three groups, commons, elites and scoundrels, consisting of the whole society on a square lattice [4–6,13–15,17,20–22,24]. Elites and scoundrels are derived from the commons that play games with the standard payoff matrix [3–6] in blue in Fig. 1. Elites in red get higher payoffs when they cooperate; the first row is one unit higher than commons. Likewise, scoundrels represented in green get higher payoffs when they defect. It can be interpreted that elites feel ashamed of defection while scoundrels are born to defect. Three groups of agents are randomly distributed on a square lattice.

Agents play the game indicated in Fig. 1 on a square lattice where each one has eight neighbors. The number of agents is 10,000, i.e. 100 $*$ 100. The initial cooperation rate is 0.5, and b ranges from 1.1 to 2.0 with an increment of 0.1. Parameters $p1$, $p2$, and $p3$ represent proportions of elites, commons, and scoundrels respectively. The group of elites as well as scoundrels is the minority, and the majority is the group of commons. Hence, $p1$ and $p3$ are no more than 0.3 and therefore they takes on values from the set {0, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3}. We focus on the majority or commons to investigate how individuals make choices and which factors influence this process.

2.2. Strategy updating

For each agent, strategy updating is probabilistic and determined by the transition probability or Fermi function in Eq. (1), where $P_{S_c\to S_a}$ denotes the probability for the agent to transit from a current strategy S_c to an alternative action S_a. For instance, $P_{C\to D}$ denotes the possibility for one who cooperate this time defects next. Likewise, $P_{D\to C}$ denotes the probability for one who defects cooperates next time [3–6,32]. If the current payoff is larger than the alternative one, the agent tends to adopt the alternative strategy, and vice versa. Parameter β represents the intensity of selection ($\beta\to 0$ leads to random drift while $\beta\to\infty$ deterministic imitation) [3,5]. It is assumed that $\beta\equiv 1$ for each simulation.

$$P_{S_c\to S_a}=\frac{1}{1+\exp\left[(u_a-u_c)\,\beta\right]} \tag{1}$$

2.3. Reputation recording individual choices

The rate of cooperation for a society or ρ_c [2,3,5] is a collective or macro perspective, other than a micro perspective. They utilize individual choices process to explain a macro-level phenomenon in existing research [2,5,14,24]. It cannot be denied that ρ_c is good indicator, but it is not the best choice. Reputation does a better job to measure outcomes of individual choices in that it is a micro-level variable and records the whole history of individual choice. Hence, instead of keeping ρ_c as the main explained variable, we prefer individuals' reputation $R_i(t)$. Eq. (2) is widely used to calculate reputation of individual, and they commonly assume that $\Delta_i R(t)$ equals 1 as individual cooperates and 0 as he or she defects [3,5]. The terms of $R_i(t)$ and $R_i(t-1)$ represent individual's reputation at time t and t–1 [3,5,6].

$$\begin{aligned}&R_i(t)=R_i(t-1)+\Delta_i R(t)\\&\begin{cases}\Delta_i R(t)=1 & \text{if } a_{it}=C\\ \Delta_i R(t)=-1 & \text{if } a_{it}=D\end{cases}\end{aligned} \tag{2}$$

Existing settings lead to a problem that the slope of reputation is non-negative, which is unreasonable. It should be that reputation declines as the agent defects and increases as the agent cooperates. Therefore, we assume that $\Delta_i R(t)=-1$ as the individual defect in Eq. (2). If t is continuous, reputation has the calculus form in Eq. (3).

$$\begin{aligned}&R_i(t)=\int_{t=0}^{T}\Delta_i R(t)\\&\begin{cases}\Delta_i R(t)=1 & \text{if } a_{it}=C\\ \Delta_i R(t)=-1 & \text{if } a_{it}=D\end{cases}\end{aligned} \tag{3}$$

Therefore, the derivative of reputation at t equals exactly the individual action at time t, which is shown in Eq. (4). Although individual reputation $R_i(t)$ and group cooperation rate ρ_c might be positively correlated, we apply reputation as the main explained variable. Besides, we investigate the distribution traits of $R_i(t)$. Distribution traits include mean