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Self-adaptive win-stay-lose-shift reference selection mechanism promotes cooperation on a square lattice

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ABSTRACT

The preferential reference selection is a new research direction in the evolutionary game theory which provides a paradigmatic framework to study the evolution of cooperation. This paper presents a new reference selection model called self-adaptive win-stay-lose-shift (WSLS) mechanism for strategy updating. Within the proposed reference selection mechanism, the reference model is determined by a self-adaptive way that each individual retains its reference if the receiving payoff does not decline, otherwise switches the reference by randomly selecting a new one from its remaining neighbors. Two social dilemma models, the prisoner's dilemma game (PDG) and public good game (PGG), are utilized to simulate the interactions among individuals and verify the effectiveness of the presented mechanism on square lattices. The simulation results demonstrate that this simple mechanism can evidently increase the cooperation level, which reveals a new means to promote the emergence of cooperation.

1. Introduction

Cooperation is widely existent in nature and human society. Understanding the intrinsic mechanism of cooperation is a growing issue of interest in many research fields from biology [1] to behavioral sciences [2,3], etc. [4–12]. For decades, evolutionary game theory has become a paradigmatic framework to study the evolution of cooperation within population dynamics [13–18]. Within this framework, the prisoner's dilemma, snowdrift game, and public goods game are several common metaphors for understanding the emergence of cooperation between competitive individuals.

Among previous studies, various importance factors of promoting cooperation have been deeply investigated. Many typical mechanisms attract massive and continuing interest, which include population topology [19,20], mobility of players [21,22], heterogeneous activity [23–25], social diversity [26–28], role assignation [29–31], to name but a few [32–39]. Besides, an information fusion technology, Dempster–Shafer theory [40–44], has been imported into the research of evolutionary games recently to design the mechanism of promoting cooperation [45]. Among them, network reciprocity, also known

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as spatial reciprocity, has been inspired the most research enthusiasm [46–51]. Evolutionary game has paid much attention on the change of each individual strategy. During the evolutionary process, strategic updating rule has played an important role. Typical rules include replicator dynamics [52], Fermi dynamics [53], moran process [54], etc. In the most of prevailing strategic updating rules, to update the strategy of a player x, a neighbor y is drawn randomly among the linked neighbors of x. The strategy associated with the chosen neighbor y replaces that of x with a probability p which depends on the payoff difference between x and y. In other words, the reference model is randomly selected for strategy updating. However, the real situation may be not consistent with that in social facts. An obvious evidence is the Matthew effect which shows the phenomenon that “the rich get richer and the poor get poorer” [55].

Recently, many researchers have paid great attention on the reference selection pattern. Wu et al. [56] introduced a dynamic preferential rule for the neighbor selection, which boosted the cooperation level visibly. Gao et al. [57] proposed a simple model that individuals can recommend the ones they imitated in the past to their neighbors for strategy updating. The simulation results showed that the cooperation was substantially enhanced when such recommended role mechanism was applied. In [58], in terms of the observation that some individuals are more influential so that their’s behaviors are more likely to be imitated, it was found that social influence-based reference selection pattern can promote cooperation in the public goods game. Wang et al. [59] studied the public goods game under an age-related preferential selection mechanism. In [60], the authors studied the prisoner’s dilemma game and snowdrift game with a preferential mechanism where the selection of imitation object needs referring to its popularity. Wang and Perc [61] have found that increasing the probability of selecting the fittest player within reach could promote cooperation. In addition, other reference selection mechanisms [62,63] have also been investigated among previous studies.

In [64], the authors proposed an aspiration-based reference selection for strategy updating in which an individual switches its reference model if its current payoff is lower than the aspiration level, otherwise the reference model is maintained. Specifically, in the aspiration-based reference selection, the aspiration level P_{ia} for an arbitrary individual i is determined by $P_{ia} = k_i A$, where k_i is the number of neighbors of i, and A is a parameter to adjust P_{ia} which is the same for each individual. Considering a square lattice as the interaction network, obviously, the aspiration level is definitely the same for any individuals regardless of the time change. However, the realistic situations often do not go this way. For example, a rational person often expects to obtain more profits in an advantageous circumstance, while focuses on maintaining the current benefit in adversity. In other words, the aspiration level of each individual is associated with its local and temporary circumstance, so the aspiration level should be time-changing. Based on this idea, this paper aims to investigate the reference selection mechanism by considering the difference and time-variance of aspiration levels. In this paper we present a self-adaptive win-stay-lose-shift (WSLS) reference selection mechanism for strategy updating. Within the proposed reference selection mechanism, the reference model is determined by a self-adaptive way that each individual retains its reference if the receiving payoff does not decline, otherwise switches the reference by randomly selecting a new one from its remaining neighbors. By means of Monte Carlo simulations, we demonstrate that the self-adaptive WSLS reference selection mechanism can promote cooperation significantly on square lattices.

The rest of this paper is organized as follows. Section 2 shows the basic model. In Section 3, the simulation results are given and discussed. Section 4 concludes this paper.

2. The model

2.1. Prisoner’s dilemma and public good game

Many social dilemma are expressed in the way of games, for example the literature [65] clarified the relationship between dilemmas and specially studied the dilemma contained in a two-player symmetric game. In this paper, we study the prisoner’s dilemma game (PDG) and public good game (PGG) on a square lattice with periodic boundary conditions. As the typical representatives of 2×2 games and multi-player games, the PDG and PGG have different features on network reciprocity. In [66], the author shows us that the PGG encourages cooperation through establishing assortative networks, while the 2×2 PDG favors dissortativity to enhance cooperation. In the network, an individual, represented as a node, plays games with its linking neighbors. The neighbors of each individual are its von Neumann neighborhood. In the PDG, there are two kinds of players who can choose either cooperation (C) or defection (D), simultaneously. In accordance with common practice [67], the temptation of defect $T = b$ determines the payoff received by a defector when he meets a cooperator, the reward for mutual cooperation is $R = 1$, the punishment for mutual defection is defined by $P = 0$, and the sucker’s payoff $S = 0$ is the payoff received by a cooperator if playing against a defector, where $1 < b < 2$.

The PGG is so-called multi-person version of the PDG. In the PGG, individuals independently and simultaneously determines whether investing money to a common pool or not. In the square lattice, a PGG consists of five players who are an arbitrary individual and its associated von Neumann neighbors, and each individual takes part in five PGGs. Continuing to use the notations given in [58], we assume that each cooperator contributes $c = 1$ to the common pool, but defectors devote nothing. The collected contribution is multiplied by a factor r and then redistributed to the N players equally, where N is the number of players in a PGG ($N = 5$). So, each player i can receive a payoff of $P_i^g = r\sum_{j=1}^{N} s_j c/N - s_i c$ from a PGG, where $s_j = 1$ if individual j is a cooperator, otherwise $s_j = 0$. Due to each individual participates in $G = 5$ PGG, therefore, the accumulated payoff of individual i is $P_i = \sum_{g=1}^{G} P_i^g$. Following the literature [58], we normalize the enhancement factor as $\eta = r/G$.