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Strategies for the Iterated Prisoner's Dilemma in a Natural Environment

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Abstract. Natural behaviour in cooperation and competition is often studied in games such as the Iterated Prisoner's Dilemma (IPD). We consider ten common IPD strategies in a spatial environment with biologically-inspired evolutionary conditions. Agents who accumulate sufficient payoffs ('energy') through IPD games with their neighbours are able to reproduce. Agents can also adapt by adopting the strategies of their neighbours. Simulation results show that cooperative strategies are more likely to survive and reproduce in harsh environments. Moreover, evolution is in the advantage of cooperative strategies, because many unsuccessful defectors evolve into cooperators. This work gives light to how strategies for IPD perform in a biologically-realistic environment.

1 Simulation of Spatial IPD

In the Iterated Prisoner's Dilemma (IPD) game, two players must decide to cooperate or defect in each of many rounds. In contrast to the one-short Prisoner's Dilemma game, in IPD cooperating will pay off better on the long term [1]. From his famous tournament of aspatial IPD, Axelrod concluded that successful strategies have the properties of being nice, forgiving and simple. Here, 'nice' is defined as cooperation on the first move and 'forgiving' as reciprocity even after being betrayed. Studies of spatial IPD followed, as summarized in Table 1. Our work studies a more general setting than before, with evolution, reproduction and aging, and considers a greater range of strategies, described in the survey [2].

2 Simulation Results and Analysis

We formulated three hypothesis: (1) Successful strategies are nice and forgiving; (2) Harsh environments favour cooperators; and (3) Evolution favours cooperators. Experiments were conducted in NetLogo on a 100x100 square lattice. The initial population was randomly distributed equally across the 10 strategies. Neighbouring agents, according to a Moore neighbourhood, play IPD each round. Success of strategies was measured by the final agent count after 500 iterations.

Across a set of experiments varying evolution threshold (when should an agent adopt the strategy of its strongest neighbour?), cost of living (energy depleted by

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Table 1. Models of spatial IPD

Model	Strategies considered	Evolve?	Mutate?	Reprod.?	Aging?
[4]	ALLC, ALLD	x	.	.	.
[5]	3-bit binary strings	x	.	.	.
[3]	n-bit binary strings	x	x	.	.
[7]	ALLC, ALLD, RAND, TFT, GRIM	.	.	.	.
[6]	ALLC, ALLD	.	.	x	.
This work	ALLC, ALLD, RAND, gTFT, sTFT, TFTT, TTFT, GRIM, Pavlov	x	.	x	x

the environment each round), minimum energy level to reproduce, and agents' age limit, we found that the same order of strategies arose. The six nice strategies outperformed the four non-nice strategies: GRIM, TTFT, TFT and TFTT stayed quite close to each other, followed by ALLC and PavlovC; RAND, PavlovD, ALLD and STFT always ended up in the final four places. The order of the first four strategies is the exact order from sternest to most forgiving. Hence we conclude that nice (start with cooperation) but stern (non-forgiving) strategies are most successful. This conclusion both confirms and contradicts Hypothesis 1 and Axelrod's finding when applied to a more realistic setting.

Hypothesis 2 was tested with the the cost of living and the ability to reproduce, which is affected by the energy and age limitations. Our results show that harsh environments give advantage to cooperators: high cost of living, high bar for reproduction and low age limits result in the success of cooperative strategies and the failure of defective strategies, given that the cooperative strategies are nice. Similarly, we find support for Hypothesis 3. Evolution gives cooperative strategies a boost and inhibits defective strategies: after approximately 200 generations defective strategies start adopting nice, cooperative strategies.

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