Analysis of Generalised Tit-For-Tat Strategies in Evolutionary Spatial N-player Prisoner Dilemmas

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ABSTRACT

This work explores the evolution of a population of generalised *tit-for-tat* (TFT) strategies playing an N-player prisoner's dilemma on a regular lattice. We show that the generalised TFT can be robust to invasion by defectors in most cases. However, interestingly, the TFT strategies which are highly tolerant perform worse than totally cooperative strategies. Furthermore, although, the TFT strategies cannot guarantee the promotion of cooperation, the less tolerant TFT strategies obtain a stable and higher level of cooperation against defectors and populations containing both defectors and cooperators.

Categories and Subject Descriptors

I.2.11 [**ARTIFICIAL INTELLIGENCE**]: Distributed Artificial Intelligence—*Multiagent systems*; J.4 [**Computer Applications**]: SOCIAL AND BEHAVIORAL SCIENCES

General Terms

Theory, Experimentations

Keywords

Evolutionary games, N-player prisoner's dilemma, spatial topology, cooperation

1. INTRODUCTION AND RELATED WORK

Much work in the iterated prisoner's dilemma focused on the performance of TFT-like strategies which were shown to be relatively robust and successful in a range of environments. These strategies are characterised by a willingness to reward cooperative behaviour with reciprocated cooperative behaviour and a willingness to punish non-cooperative behaviour. These strategies can induce cooperation among similar cooperative strategies and can avoid being overly-exploited by non-cooperative strategies.

The iterated game has been researched extensively following Axelrod's work in the iterated prisoner's dilemma [2]. In his book, Axelrod also introduced the TFT strategy which always cooperates on the first move, and then copies the opponent's move for subsequent turns. Axelrod showed the robustness of the TFT strategy, and claimed that although TFT may not outperform any of its individual opponents, it may perform well by inducing cooperation among cooperators [2]. Axelrod also showed that the TFT strategy dominated the population in the tournament selection of the evolutionary style games [2, 1]. The majority of work in the iterated prisoner's dilemma research has concentrated on the 2 player game although there is also considerable interest in the N-player game [3].

In this paper, we explore the emergence of cooperation in spatially organised populations of strategies participating in an N-player prisoner's dilemma. We explore a range of strategies including cooperative, non-cooperative and a family of generalised TFT strategies. The strategies interact with each other based on the spatial constraints placed on the strategies, attain payoffs based, and the population is updated periodically by allowing strategies adopt a strategy of a neighbouring strategy if that strategy has obtained a greater payoff. We consider different starting conditions including random configurations and pre-defined patterns to explore the spread of cooperation or defection.

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2. N PLAYER PRISONER DILEMMAS

In this research, we use a set of N-player TFT strategies. Suppose that a TFT player is playing against N opponents in an iterative N-player game. In each iteration, the player looks at all of his opponents' moves in the previous turn, and then decides the next move based on the number of cooperative opponents.

DEFINITION 1. *The N-player TFT strategy (called TFTn) defects in the next iteration when it has less than n* ($0 < n \leq N$) *cooperative opponents in the previous iteration; it cooperates in all other cases. In this paper, we call n the level of tolerance. When n is small, we say the level of tolerance is higher, as it can tolerate more defecting opponents.*

On the lattice graph with Moore neighbourhood (with 8 immediate neighbours), there are 8 different N-player TFTn strategies, ranging from TFT1 to TFT8. The pure-C strategy can be viewed as TFT0, as it always starts with a cooperation and does not need cooperative neighbours to continue cooperating. It is also worth noting the pure-D strategy (always defect) is not equivalent to TFT9 as it always start with a defect, whereas TFT9 will cooperate on the first move before defecting for the remainder of the game.

3. EXPERIMENTS AND RESULTS

The experiments have been setup on an 81×81 lattice graph. With adaptable parameters for the game's pay-off matrix, we compared the experimental results of the non-iterated game, and the iterated game with N-player TFTn strategies, on both random initialized graphs and graphs with pre-designed initialization. The payoff matrix we used in the experiments is: $\begin{bmatrix}1.0 & 0\\ \beta & 0.0\end{bmatrix}$. The experiments have been ran both for $\beta = 1.51$ and $\beta = 1.61$

When $\beta = 1.51$, in populations with pure C player (Figure 1). The level of cooperation varied with varying levels of tolerance (as expected). However, it was surprising in the manner in which it varied. The cooperation rate of the final state can be increased over the level obtained with TFT4 by either increasing or decreasing the level of tolerance. So, in the extreme situation (such as TFT1 or TFT8), the cooperation rate of the final state is found to be much higher.

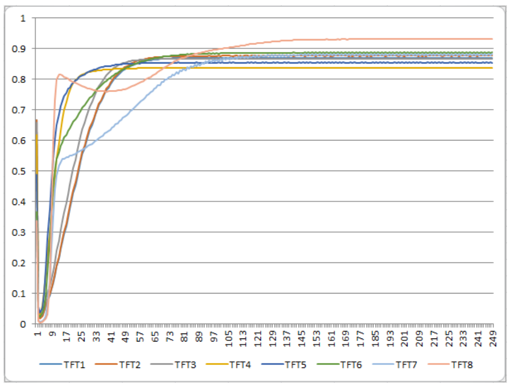

Figure 1: The TFTN strategy player playing with Pure C/D strategy players start with random initialization $\beta = 1.51$

Figure 2 is the plot of TFT1-TFT8 strategies playing against a set containing pure C and pure D strategies in a randomly initialized population while $\beta = 1.61$.

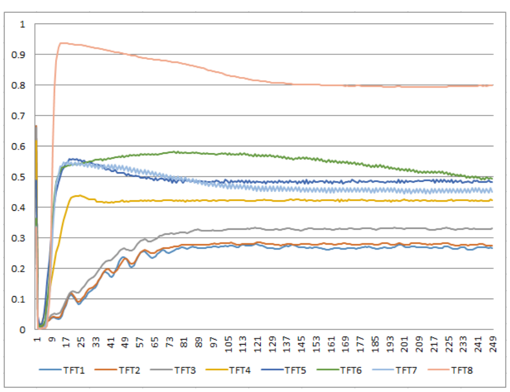

Figure 2: The TFTN strategy player playing with Pure C/D strategy players start with random initialization $\beta = 1.61$

Figure 3 shows the game under preset initialization (Hawok and May preset [4]).

In the experiment results shown in all the plots above, the lower the level of tolerance, the harder it is for the defector to invade the TFT players.

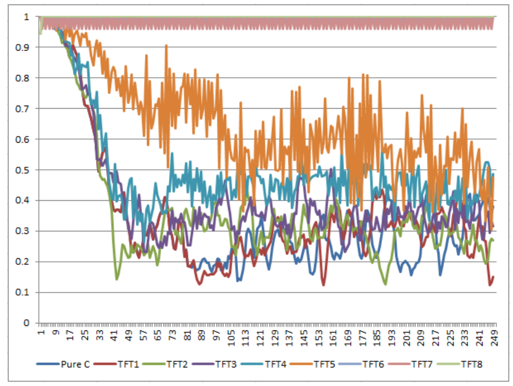

Figure 3: One defector's invasion in a group of TFT0(pure C) to TFT8 players $\beta = 1.61$

4. CONCLUSION

By exploring populations of TFTn strategies playing an iterated N-player game, we found that although in comparison with pure C strategies, TFTn strategies have a better chance to invade the pure D strategy in the evolution, it does not, however, guarantee that bringing TFT players into a society including both pure C and pure D players will increase the cooperation rate. Actually, it may even decrease the cooperation rate with certain settings (Random initialization, $b = 1.51$).

We also found that, sometimes, for the N-player TFT, either increasing or decreasing the level of tolerance are both better at promoting cooperation than the intermediate value (such as the random initialization, $b = 1.51$), but this situation will no longer happen when the value of the temptation pay off (b) is raised to 1.61. Over all, the strategy with the lowest level of tolerance, which is the TFT8 strategy, has the best performance against the defectors. For most experiments including the TFT8 strategy, the cooperation rate at the final state is close to 90%. Higher level of tolerance will decrease the cooperation rate at the final state, which is not as we initially expected.

5. ACKNOWLEDGMENTS

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