Tag-Based Cooperation in N-Player Dilemmas
(Extended Abstract)

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ABSTRACT
This paper studies the emergence of cooperation in the N-Player Prisoner's Dilemma (NPD) using a tag-mediated interaction model. Tags have been widely used to bias agent pairwise interactions which facilitates the emergence of cooperation. This paper shows some of the key parameters that influence the emergence of cooperation in an evolutionary setting. The aim of this paper is to demonstrate the most vital factors that are commonly ignored in many existing NPD studies.

Categories and Subject Descriptors
I.2.11 [**Distribute Artificial Intelligence**]: Multi-Agent Systems

General Terms
Experimentation

Keywords
Cooperation, Tag-Mediated Interactions

1. INTRODUCTION
When a common resource is shared among a number of individuals, each individual benefits most by using as much of the resource as possible. While this is the individually rational choice, it is collectively irrational and a non pareto-optimal result. NPD's involve many individuals interacting as a group. NPD's have been shown to result in widespread defection unless agent interactions are structured. This is most commonly achieved through using spatial constraints such as spatial grids [3]. This paper examines a series of simulations involving a tag environment. Tags are visible markings or social cues which serve to bias agent interactions based on their similarity [1]. Further to studying tags, this paper also examines the key payoffs used in the NPD. This paper uses a traditional tag-mediated interaction model as proposed by Riolo, due to its clarity and generality [4]. By proposing a tag mediated interaction model for n-player games, we hope to bridge the gap between the research already conducted involving tags in two player games [4], and the need for more detailed research involving tags and the NPD.

Cite as: Tag-Based Cooperation in N-Player Dilemmas (Extended Abstract), E. Howley and J. Duggan, *Proc. of 10th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2011)*, Tumer, Yolum, Sonenberg and Stone (eds.), May, 2–6, 2011, Taipei, Taiwan, pp. 1211-1212.

2. MODEL DESIGN
The NPD stipulates that individual rationality favors defection. In our base case when all individuals defect they each receive 0.25, while if all cooperate they each receive 5. If U_d represents the utility to a defector, while U_c is the utility to cooperator for a given value of x then in the traditional NPD game we can state the following: $U_d(x) > U_c(x)$

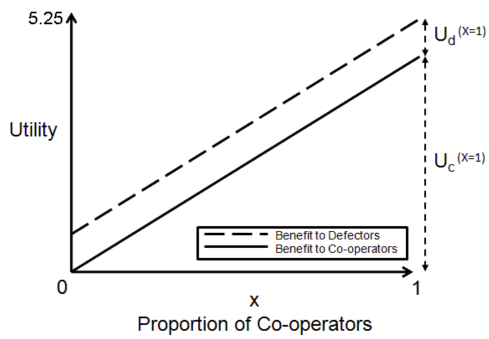

Figure 1: The N-Player Prisoner's Dilemma

Figure 1 shows the utility values $U_c^{x=1}$ and $U_d^{x=1}$ which in this paper are set to 5 and 0.25 respectively. Therefore, we can state that $U_c^{max} = U_c^{x=1}$ and $U_d^{max} = U_c^{x=1} + U_d^{x=1}$ for the maximum payoffs. Therefore $U_c^{max} = 5$ and $U_d^{max} = 5.25$

In this research, a population of 100 individuals evolves using a genetic algorithm. Each agent is represented using a agent structure $\{G_C, G_T\}$ where the G_C gene represents an agent's probability of cooperating, and G_T represents its tag value. Each of these values are in the range [0.0, 1.0]. Similar to previous tag-mediated models, the tag values are used to determine peer interactions [1, 4]. In our model each agent A is given the opportunity to make game offers to all other agents in the population. The intention is that this agent A will host a game and the probability other agents B will participate is determined using the relative tag difference; $d_{A,B} = 1 - |A_{GT} - B_{GT}|$. The genetic algorithm determines the fittest individuals through their average payoffs. Roulette wheels based on these fitnesses are then used to select parent pairs to generate new offspring. A probability of 0.9 is applied in favor of selecting two genes from the the fittest parent, and a 0.1 probability of choosing one gene from each parent. Similar to the implementation used by Riolo, each gene is exposed to a two percent chance of mutation. This mutation operator determines a displacement using a Gaussian distribution with a mean of zero.

3. RESULTS

The impact of partitioning the agent population, or limiting interactions has previously been shown to significantly effect cooperation [2]. This experiment examines the impact of alternative ratios of agents in a fixed size tag environment. We will refer to this as examining the 'tag space'. The simulation data is from 200 experiments and 10000 generations.

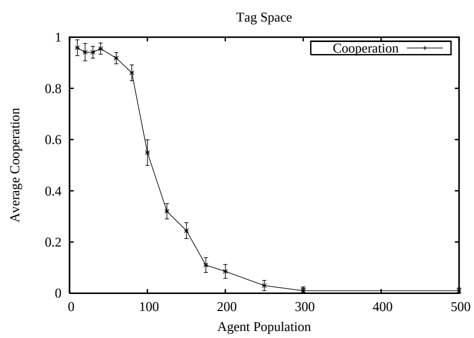

Figure 2: Tag Space - Average Cooperation

The data shown in Figure 2 shows the average levels of cooperation achieved for alternative population sizes in a tag space limited to the range of [0.0, 1.0]. The results use the final generation of each experimental run to calculate the average. The results show the dramatic effects of the population size on the levels of cooperation. High levels of cooperation occur in relatively small populations but these fall dramatically once the population sizes become larger. In larger populations the probability of avoiding exploitation is reduced as increased peer interactions increase the chance of meeting an exploiter. This is a key factor in the success of failure of tag environments to facilitate the emergence of cooperation. Once small clusters of cooperators can emerge due to a low probability of meeting exploiters then the tag environment will be a success. Larger populations that result in a crowded tag space undermine this principle and therefore result in low levels of cooperation.

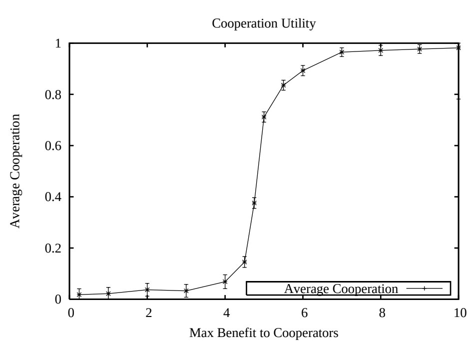

Figure 3: U_c - Average Cooperation

In second experiment examines the effects of the $U_c^{x=1}$ value. This value reflects the maximum utility that a cooperative individual can receive. The additional benefit to defectors ($U_d^{x=1}$) remains fixed at 0.25. Figure 3 shows alternative values of $U_c^{x=1}$ in the range [0.0,10.0]. Since the defector reward ($U_d^{x=1}$) is fixed at 0.25 the $U_c^{x=1}$ value has a direct impact on the utilities received by defectors. These exploiters receive the U_c value and in addition to the defector reward. The results shown in Figure 3 demonstrate the impact of this ratio between the reward to cooperators and defectors in the game environment.

The final experiment examines benefit to defectors parameter ($U_d^{x=1}$). While previously fixed at 0.25, this value is now varied in order to examine its influence on the emergence of cooperation in the tag environment while the value of $U_c^{x=1}$ remains fixed at 5.0.

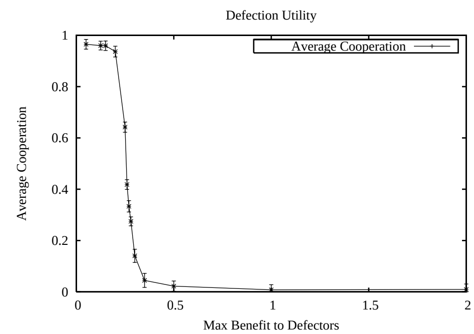

Figure 4: U_d - Average Cooperation

Figure 4 shows the levels of cooperation recorded for various values of $U_d^{x=1}$. The benefit to defectors has a significant influence on the emergence of cooperation in the population. The parameter has a major impact on the ability of cooperative individuals to survive in the population and as the value of $U_d^{x=1}$ directly impacts on the advantage to exploiters in the population. The data shows this parameter can dramatically influence the emergence of cooperation in the NPD.

This paper has shown the key factors that result in the emergence of cooperation in the NPD in a tag-mediated environment. While significant research has examined these individual questions, this paper has shown in a very clear and concise manner the key criteria that are necessary for cooperation to emerge. The authors would like to gratefully acknowledge the continued support of Science Foundation Ireland.

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