Cooperation in Prisoners Dilemma Form Games

Abstract

A common subject of study in game theory is the prisoner's dilemma. The dilemma stems from the fact that when players act in their own interests, the best strategy is to defect. However, this outcome is not Pareto optimal, and is actually worse for both players. To maximize utility for both players, it would be desirable to find a solution that allows for cooperation between the players. This paper examines the emergence of cooperation in a repeated prisoner's dilemma game, in attempts to find environments that lend themselves to cooperative strategies.

Introduction

In an evolutionary iterated prisoner's dilemma, players repeatedly play the prisoner's dilemma game against the other players. Players may adjust their strategies over the course of the game. In this experiment, several parameters may be modified and monitored, to observe the emergence of cooperative behavior. These parameters include the agents knowledge of the effectiveness of their own or others strategies, the agents connections with the other agents, or an agent's utility function, especially its social utility.

Each of these parameters can be analyzed to examine prisoner's dilemma style situations in the real world. It can apply to the localization vs globalization debate, politics, the interactions of tightly knit groups, or social network interactions. By experimenting with these parameters, we can determine why cooperation emerges in some of these situations but not others.

Background Information

Typically, in evolutionary iterated prisoner's dilemma games, a tit-for-tat strategy will dominate after many generations of play. Tit-for-tat is a minimally cooperative strategy compared to an always-defect strategy. Of interest is situations that support the spread of more cooperative strategies such as tit-for-tat (Deshmukh and Srinivasa). In their experiment, Deshmukh and Srinivasa identify different ways to model the localization vs globalization debate with the prisoner's dilemma. In particular, they termed *entrenchment of acquaintance* and *entrenchment of knowledge*.

Entrenchment of acquaintance is the situation where an agent interacts mostly with a small, consistent group of other agents. For example, members of a small town where everybody is acquainted with everyone else in the town, or a small, tightly knit organization with their own unique and possibly extreme ideas. While agents that are entrenched in their acquaintances often foster cooperation between agents in their community, it often discourages cooperation amongst members outside of their entrenched community.

Entrenchment of knowledge is the propensity of an agent to find information from its own community, as opposed to outside sources. This means agents find strategic knowledge mostly from their social acquaintances, as opposed to books or the internet. According to Deshmukh and Srinivasa, disentrenchment, especially disentrenchment of knowledge, encourages the spread of cooperative strategies.

Another situation that effects cooperation is the expectation of cooperation in a community (Shibusawa, Otsuka and Sugawara). In this case, agents know that cooperative strategies will bring more shared utility in the long run, and thus will try to encourage cooperation. In their study, they gave each agent a parameter that measured their probability of cooperation, which would fluctuate after each game played. By modifying this parameter, it's effect on the rate of cooperation in a system could be measured.

Project Description

Deshmukh and Srinivasa's study modeled an evolutionary iterated prisoner's dilemma game, and observed that tit-for-tat strategy dominated an always-defect strategy over time. Thus, they observed how entrenchment would effect the rate at which tit-for-tat would spread in an environment. Every time an agent switches from an always-defect strategy to a tit-for-tat strategy, cooperation will spread. Every time an agent switches from a tit-for-tat strategy to an always-defect strategy, then the population is becoming more disillusioned with the idea of cooperation.

I propose to simulate an evolutionary iterated prisoner's dilemma game similar to the experiment run by Deshmukh and Srinivasa. I will also include parameters from other experiments, such as the study run by Shibusawa, Otsuka and Sugawara. I will also use the expectation of cooperation strategy to model the probability of cooperation in each strategy in the game. By running trials with different parameters, I can model the effects of each parameter on the system, and determine the environment that fosters cooperation the best, in attempts to apply the results to real-world scenarios and environments.

My simulation uses Python to model an evolutionary iterated prisoner's dilemma game. Each agent has trust, meaning they use a more cooperative tit-for-tat strategy, or does not trust, meaning they use an always defect strategy. Each agent also knows the payoff of its strategy, or how well it is doing in the iterated prisoners dilemma game. This will be used for the evolutionary portion of the game. In addition, each agent tracks its own "contentness", which is a measure of how often the agent changes strategies throughout the games.

To run the simulation, agents are collected into societies. The number of agents per society can be modified by changing the input parameters to the simulation. When a society is formed, connections between agents are randomly formed. This is used to model the entrenchment effect within the society. Several functions are provided in order to run several variations on the prisoners dilemma game, as well as to measure and report information about the society and its agents.

The evolution of the agent's strategies works as follows. For each iteration of the prisoner's dilemma game, agents will participate in several prisoner's dilemma games with other agents in the society. Depending on the version of the game, agents will play against every other agent in the society, or just agents they are connected to. After each round of prisoner's dilemma games, agents will adjust their strategies based on a variety of factors. Each agent will compare their total payoff during the previous round of prisoner's dilemma games, and compare it to the payoffs of other agents they are connected to. If the agent sees that another agent is performing better with a different strategy, then the agent will adjust. Every time an agent switches from always defect to a tit-for-tat strategy, that outcome is measured, and the individual and overall “contentness” of the society is increased. Conversely, every time an agent switches from tit-for-tat to always defect, the individual and overall levels of discontent in the society are increased.

After each round of prisoner’s dilemma games, information about the society is collected and displayed. By controlling the input parameters, the trust and contentness levels in the society can be observed. The number of games played, number of agents per society, starting trust levels, connection chance, and type of iterated prisoner’s dilemma game can be modified. The simulation can also run multiple societies and once, and display the distribution of data across the simulations of multiple societies.

Results

Running the simulation of a connected evolutionary iterated prisoner’s dilemma, with a starting ratio of 80% always defect and 20% tit-for tat, with 6 games played per round, 500 agents per society, and 10 generations, the resulting trust and contentness ratios were found. These ratios were tested for variable levels of entrenchment in the society, and each test was repeated 100 times before the resulting data was collected and averaged.

Connection Probability	**Mean Contentness Ratio**	**Median Contentess Ratio**	**Mean Trust Level**	**Median Trust Level**
0.5%	1.549	1.520	0.562	0.610
1.0%	2.221	2.331	0.766	0.992
1.5%	2.406	2.623	0.787	1.000
2.0%	2.550	2.801	0.771	1.000
2.5%	2.441	2.640	0.700	1.000
3.0%	2.755	2.970	0.683	1.000

Running the simulation as above, with a constant 1.0% connection probability, but with a variable starting trust ratio results in the following.

Starting Trust Ratio	**Mean Contentness Ratio**	**Median Contentess Ratio**	**Mean Trust Level**	**Median Trust Level**
5%	0.685	0.526	0.023	0.000
10%	1.301	0.747	0.192	0.012
15%	2.079	2.038	0.547	0.892
20%	2.221	2.331	0.766	0.992
25%	2.394	2.364	0.947	0.994

30%	2.469	2.443	0.993	0.996
35%	2.545	2.486	0.994	0.996
40%	2.758	2.808	0.995	0.996

Conclusion

Based on the results, there are multiple factors that determine happiness and trust in a society. If a large enough portion of agents in a given society adopt a trusting, tit-for-tat strategy to begin with, then the society will shift to high-trust and high-contentness. A similar effect can be seen if agents are well connected, representing friends, family, co-workers etc. Even though the starting trust levels are normal, if connection levels are low then contentness and trust in a society plummet. As connection levels rise, contentess levels rise, although trust levels will stagnate.

In either case, the tipping point for increased trust and contentess in a society occurs when it is probable for trusting agents to be connected. For each round of prisoner's dilemma games, if a trusting agent is paired with distrustful agents, then the distrustful, always defect agents will gain a slight edge. However, if there are at least 2 trusting agents that are connected, then they will both benefit by playing each other in the game. This benefit is enough to offset the minor losses incurred against distrustful agents.

The data supports this – for example refer to table 2. Given a society of 500 members and a connection probability of 1%, each agent is, on average, connected to 5 other agents. So, for a trusting agent to be paired with another trusting agent, there needs to be about a 20% starting trust ratio. At around the 15%-20% point, the contentness and trust levels in societies increase rapidly, as expected.

Another factor that may influence trust levels is the number of games played. Running 5-7 games is standard for these models. But if agents play more games, then the trusting agents will lose comparatively less when matched against distrustful players.

In conclusion, my simulation results align with those found by Deshmukh and Srinivasa. In addition to increasing starting trust levels in a society, decreasing of entrenchment via forming more connections between agents will also result in high levels of contentness in a society. Contentess levels often increase at a higher rate then trust levels, when compared to directly increasing starting trust levels in a society. This occurs due to particular sub-groups of distrustful agents that reduce the mean trust levels in a society. However, the majority of agents in such a society are content and trusting.

References

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