Iterated Prisoners Dilemma Game

By

Raphael Baysa I Shucheng Ge

Abstract

In the 1980s, University of Michigan professor of Political Science Robert Axelrod created a tournament in which many scientists from many fields and specializations submitted strategies to solve an iterated Prisoners Dilemma Game. These strategies competed against other strategies as well as itself to see which strategy would beat out the rest. In the 2 tournaments he hosted, the winning strategy was “Tit-for-Tat”. This 4 lines of code strategy, on the first move cooperated then copied the opponents move from the previous round. With this information it has been concluded that this is an effective general strategy for games like this because it matches the complexity (greedy, cooperative, forgiving, etc.) of the opponent’s strategy. Thus, by looking at the conditions of the past tournament and research, trying to recreate it, and finding important factors to how the outcome came out to be, we can see how Tit-for-Tat came to be the winner of the tournament. From the new data we gathered from this project, we can see that the winning strategy was all contingent on the design of the tournament and how a “winner” was chosen.

Introduction

Prisoner’s Dilemma

Prisoner’s dilemma is a representative example of game theory’s non-zero-sum game, reflecting that the best choice for individuals is not the best choice for groups. In a group, individuals make rational choices often leading to collective irrationality. Although the Dilemma itself is only a model of game theory, it extends to price competition, environmental protection, etc. This situation occurs more times than not in many forms in the real world. The single game of prisoner’s dilemma and the iterated prisoners dilemma game can have different conclusions.

The general payoff matrix for a prisoners dilemma game is that if both participants cooperate they get a medium equal punishment. If one were to defect and the other cooperate, the person who cooperated is released while the person who defected gets a severe punishment. If both participants defected then that means they get an easy equal punishment. The problem with this, is that neither person knows the other persons move, which means that if they wanted to get an easy punishment(both defecting) then that means both of them would have to stay silent. but the enticing factor is that if one were to cooperate, and the other defect, then that means the cooperator could get out for free. Thus in the self interest, it is best to defect, but at the risk of the other player cooperating and you facing maximum time.

In the repetition of the prisoner's dilemma, the game is repeated. This means that each participant has the opportunity to "punish/compensate" the other opponent in the next round by non-cooperative behavior. At this time, the cooperation may appear as a balanced result. The motive for deception may then be overcome by the threat of punishment, which may lead to a better, cooperative outcome.

Ultimately, in practice, however, the prisoner's dilemma is very simple and thus not take into account many other human factors that are taken into account like affiliations, personal consequences of choices, and external factors that the nature of life brings. The results of these tests however, is fundamental to some theories of human cooperation and trust which makes it an integral part of studying game theory.

AxelRod's Tournament

In the 1980s, Robert Axelrod, professor of political science at the University of Michigan, invited scientists from all academic fields to create a strategy for an iterated prisoners Dilemma round-robin tournament. Each strategy was a set of rules which specified whether to cooperate or defect at a given turn in the game. Axelrod believed that the results of this tournament could help discover the best strategy for everyday human interactions that resembled the strategic structure of the Prisoner's Dilemma. The tournament itself focused on having the strategies maximize the number of points won across all interactions including the strategy going against itself and a strategy that randomly cooperates and defects.

The tournament itself was designed as a single round, round robin format. It was a simple and fair format that allowed strategies to face every other strategy. The winning objective was to obtain the maximum number of points across all the opponents. In the end Tit-for-Tat won the tournament. the strategy itself is the simplest of the 14 that was submitted. The strategy simply, cooperated on the first move, then on each move after that, they would copy the opponents last move. The interesting thing about the strategy though is that it can never actually ever win a game; in the sense that it can never achieve a positive point difference against any other program. This is due to the fact that in the first iteration, the program cooperates, which then any move after mimics the opponents move which means that their algorithms is as complicated as the opponents strategy, Thus, at most instances, Tit-for-Tat ties at a greater rate than any other strategy. This is what we will be looking at in our project.

Project Design

Since it is very obvious that recreating AxelRod's Tournament will give the same results, we decided to pivot and see how Tit-for-Tat works against random strategies in a round robin tournament and see if changing the tournament criterion could make Tit-for-Tat win and/or lose.

The structure of the tournament is a basic round robin tournament where each strategy would play 100 games against the other strategies. In each game, each strategy would have 50 turns each to decide whether to cooperate or defect. The end result is that each strategy would have an accumulated score based on the payoff matrix we have provided which is very similar to the original tournament game. From then whichever player had the lowest score (was punished the least) would be considered the winner of the game. From then on, we would accumulate their stats and graph the data that was presented.

The strategies we decided to implement are as follows:

Cooperative - This strategy will always cooperate no matter what

Defective - This strategy will always defect no matter what

Tit-for-tat - This strategy will cooperate on the first move then copy the last strategies move

Reversed Tit-for-tat - This strategy will defect on the first move then do the opposite of the last strategies move.

Random - generates a random number from 1-10000000 and if its odd cooperate, else defect

Half - This strategy will randomly generate a number from 1-100 and if its greater than 49 cooperate else defect. This is different from random because it will generate at the end an about even split of Cooperates and Defects. unlike Random which that isn't the case.

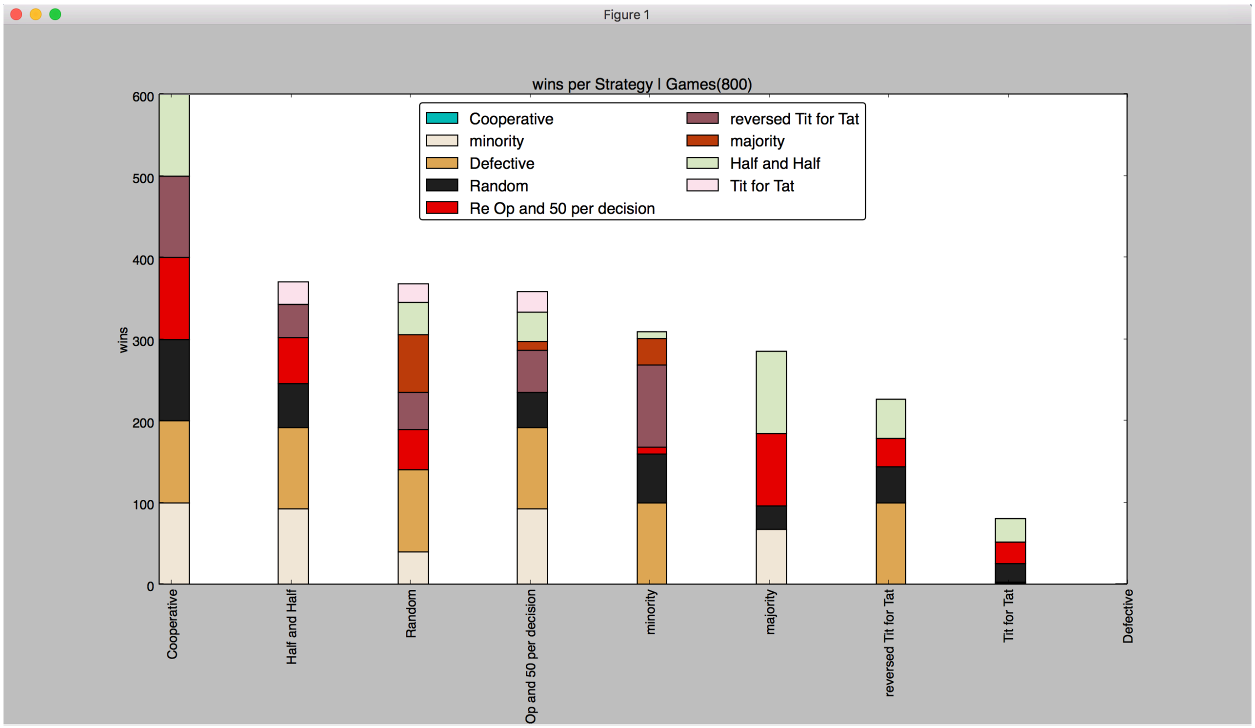
Re op and 50 per decision - This strategy will read the opponents moves and then has a 50% chance copying their move or to pick the opposite.

Majority - This strategy will read all the opponents moves and if the majority of their moves is Cooperate, then it will cooperate vice versa. If it’s a tie breaker then it will cooperate.

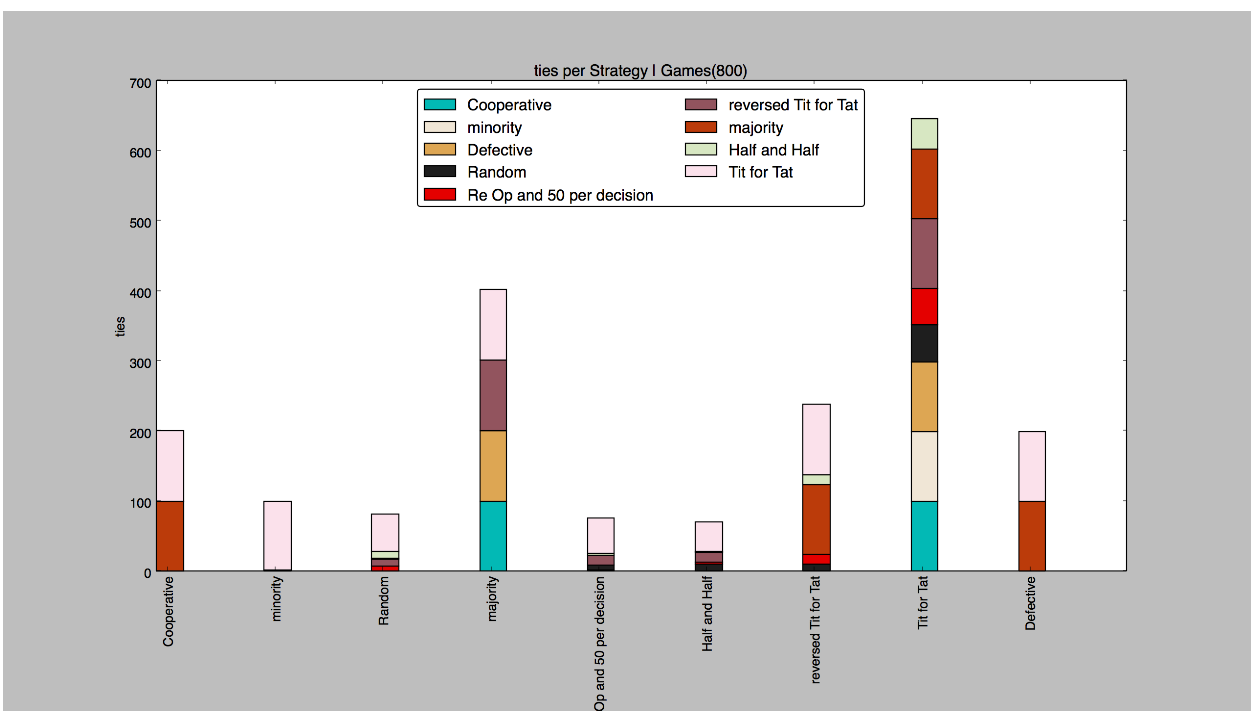
Minority - This strategy will read all the opponents moves and if the majority of their moves is Cooperate, then it will defect and vice versa. If it’s a tie breaker then it will also defect.

Strategy Reasoning: A lot of these strategies are random, but some are smart and read the opponents moves and cooperate/defect based on those facts. The strategies aren't as complicated as the ones submitted but represent a good range of strategies especially the random strategies which are supposedly the worst case for Tit-for-tat.

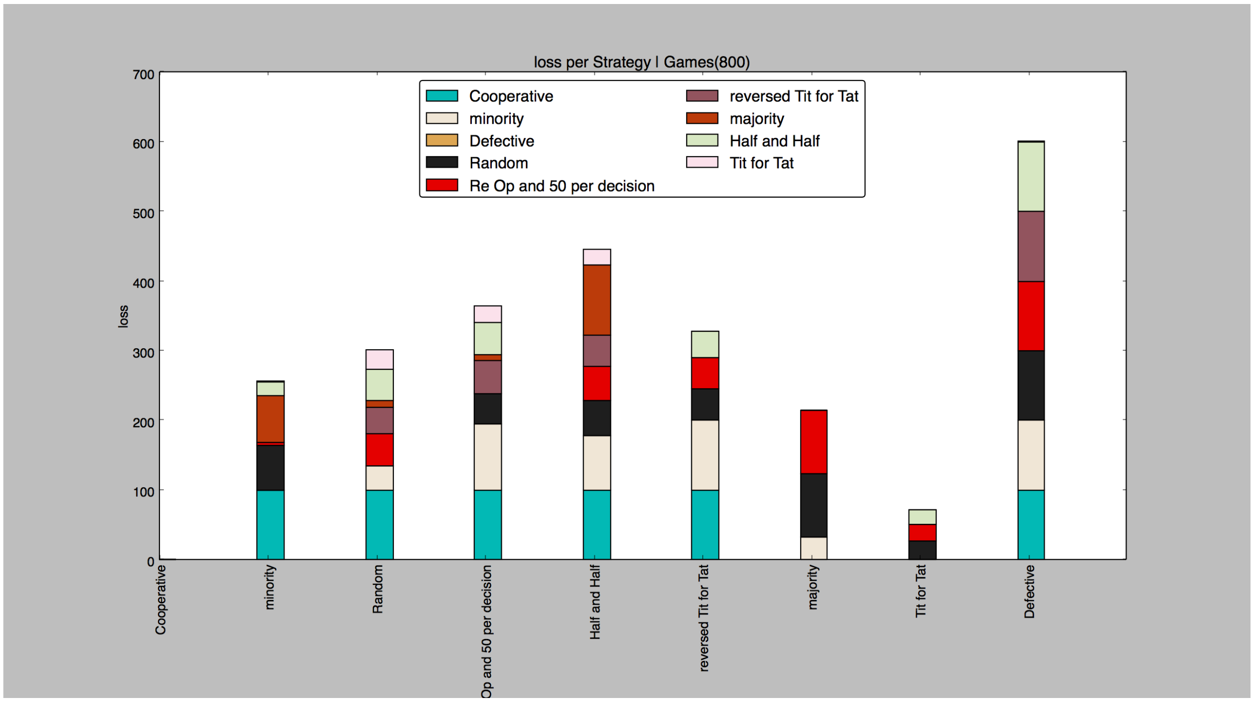
Results



Figure(a): A stacked bar graph showing the wins of each strategy against their opposing strategy



Figure(b): A stacked bar graph showing the number of ties of each strategy against their opposing strategy



Figure(c): A stacked bar graph showing the number of losses of each strategy against their opposing strategy

Analysis

From the results that we obtained, it seems that Tit-for-Tat is not a clear winner against these algorithms. If we were to look at figure A, we see that Tit-for-Tat is actually one of the lowest winning strategies. If the tournament was structured so that the winning strategy was the one that was able to accrue the most “wins” against the other strategies then clearly Tit-for-Tat would have lost by a clear margin. Cooperative strategy was able to win the most games because by always cooperating, on each turn the outcome would either be even, or the strategy would benefit if the other strategy defected. Intuitively the results makes sense as well. Whichever algorithm cooperated more likely over time, would win more games because of the statute of if you were to cooperate then you would have an even/benefit score from ur opponent.

It is interesting to note here that the reversed Tit-for-Tat also was in the lower percentile of wins but beat out the Tit-for-Tat by a greater margin, remember that reversed Tit-for-Tat does the exact opposite for tit-for-tat which is if the person cooperated last turn, then that means it would defect the next turn.

For the wins section, Tit-for-Tat did horrible and lost to every algorithm except the defecting strategy which makes sense since if the strategy is always defecting, then the tit-for-tat will always be defecting which means they would be tying a lot. On the first move, Tit-for-tat would cooperate while defecting would always defect no matter the turn which means that Tit-for-tat will always win because of its first turn.

Tit-for-Tat against random strategies is very interesting to look at because intuitively the Tit-for-Tat algorithm is as complex as the strategy it goes up against. This means that against random strategies, it will mimic it and should tie with all the other strategies. This can be clearly seen in Figure B which shows all the ties.

Now one is probably wondering how Tit-For-Tat could be the winning strategy of AxelRod's tournament given this data, but the simple tournament criteria we had designed was a bit different from the one in the tournament. If we had designed our tournament to ignore the amount of wins, but rather the amount of ties and lowest amount of losses like we saw in figure B and C, then by a landlslide Tit-For-Tat would be the clear winner. Our tournament did also contain the same round robin style that AxelRod had but our winning criteria was different. AxelRod's criteria was to get a maximum number of points/score through all the strategies played, while we isolated each instance of a strategy playing against another strategy and then declared a winner/loser from there. By doing AxelRod's method it is clear that Tit-For-Tat wins because by always copying the other algorithms, they can tie a lot more which means their score would always be equal to if not greater than their opponents at once. Thus if we summed all their games, we can see that Tit-For-Tat strategy would always have the greater score. But if we isolated each Win/Loss per player then we can see that Tit-For-Tat is nowhere near a winner. Thus, from this experiment as well as other research, we can see that Tournament Criteria is important in deciding a winning strategy. A round robin tournament is fair and allows all strategies to encounter each other giving a larger data point as opposed to a bracket style tournament where not every strategy gets a change to play another.

Conclusion

In conclusion, AxelRod's Champion "Tit-For-Tat" is only really a champion based on the criteria of AxelRod's tournament. Looking at Figure A from our results, we can see that Tit-For-Tat is at the bottom of the rankings. This is because we made each game against another strategy independent and counted the scores then instead of at the end. Based on looking at Figure B and C, the ties and losses graph, one can see that Tit-for-Tat ties a lot and losses very little. This means that for each game played no matter the strategy they tied with their opponent and very rarely did they lose. In the perspective of scores, that means they always an even score or a greater score than their opponent in the instance of a game and if we were to accumulate all those scores, then that means Tit-For-Tat would have the highest scores. Ultimately, this research does provide us an insight into games similar to the Prisoner's Dilemma. It shows us that ultimately, being able to deduce your opponents strategy before the end of the game and making the corresponding moves to maximize your "win condition" is an important step in making a strategy for situations like the prisoner's dilemma. There is no real winner, there is a strategy that can always beat the current strategy given the circumstances as well as the design of the tournament and game.

References/Resources

AxelRods research as well as added research - http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0134128#sec001

Prisoners Dilemma - https://en.wikipedia.org/Prisoner's_dilemma#The_iterated_prisoner.27s_dilemma

The Evolution of Strategies in the iterated prisoner's Dilemma -

https://books.google.com/books?hl=en&lr=&id=ddc9AAAAIAAJ&oi=fnd&pg=PA1&dq=iterated+prisoner's+dilemma&ots=0wjsOrCDY3&sig=_S1nHBXSB6STq_Mqe1G_BVtrfBk#v=onepage&q=iterated prisoner's dilemma&f=false

Stanford's Axelrod's Tournament synopsis - https://cs.stanford.edu/people/eroberts/courses/soco/projects/1998-99/game-theory/axelrod.html

Prisoner's Dilemma Analysis - http://www.pnas.org/content/109/26/10409.full