Applying modern data analysis techniques to tournament results of the Iterated Prisoner's Dilemma.

1 Introduction

According to Charles Darwins theory of evolution [2], natural selection is ruled by the survival of the fittest. However, in spite of all the 'selfish genes' it is observed that in interactions both social and biological cooperation emerges. Individuals that cooperate more than other can even outperform their population. Thus the following question arises: why cooperation emerges; More over, how cooperative an individual must be to perform well in their respective environment.

In the field of Game Theory the game of the Prisoner's Dilemma (PD) has been used to explain the emerge of cooperative behaviour. The PD is a 2 player game where both players have two strategies. They can either cooperate (C) or defect (D) with one another. Their decisions are made simultaneously and independently.

The normal form representation of the game is given by matrix 1.

$$\begin{bmatrix} (R,R) & (S,T) \\ (T,S) & (P,P) \end{bmatrix} \tag{1}$$

where the payoffs (R, P, S, T) are constrained by equations (2) and (3).

$$T > R > P > S, \tag{2}$$

$$2R > T + S. \tag{3}$$

Constraint 2 ensures that D dominates the first action C and constraint 3 ensures that a social dilemma arises. That is because the sum of the utilities to both players is best when they both cooperate.

Though not many insights can be gained from one shot game, complex behaviour that allow further investigation arise in the repeated form; in the Iterated Prisoner's Dilemma (IPD).

In the 1980s, a political scientist called Robert Axelrod carried out a computer tournament. Scholars from various disciplines were invited to submit strategies in computer code and they would compete in a round robin tournament where the strategy with the highest average score would be the winner. Axelrods tournament has been used to explain how cooperation can be evolutionarily advantageous.

Strategies are a set of rules used to describe to a player how to play the IPD game. The research of computer tournaments includes studying the interactions of such strategies and the exploration of a strategy that dominates them all.

2 Collecting data

For performing a large number of computer tournaments the open source package Axelrod Library [1] is used. The package was introduced in 2015, it is written in the programming language Python and it allow us to perform a number of different tournaments with different strategies. The payoff values used in Axelrod are $(3, 1, 0, 5)$ and the following type of tournaments have been performed.

There are several tournament types introduced in the literature that have not been discussed.

1. **Standard tournament**. A round robin tournament where the number of turns for each match can vary between 200 and 1. The tournament is repeated between 10 and 100 times.
2. **Noisy tournament**. Similar to a standard tournament. A noisy tournament in a round robin tournament where noise is introduced. Noise is the probability that a players action is flipped. The probability of noise is ranging between 0 and 1.
3. **Probabilistic ending tournament**. Similar to a standard tournament however in a probabilistic ending tournament the number of turns is not specified. There is a probability (ranges between 0 and 1) that the match will end in the next round. Probabilistic ending tournament will be referred to as probend hereupon.
4. **Noisy and Probabilistic ending tournament**. A combination of noisy and probabilistic ending tournaments.

The process for generating the data set is described by Algorithm 1. Every 20 iterations of a random seed a new sample is chosen. For each sample, for 20 repetitions random numbers of turns, repetitions of the tournament, the probability of noise in the tournament and the probability of the game ending in after each interaction are sampled.

For that set of parameters, four types of tournaments (as discussed above) are conducted. A standard one, a noisy one, a probend one and lastly a probend with noise.

Once a tournaments is performed we export a summary of the performance of each strategy in the tournament. In the following sections we discuss how we manipulate the result set exported by Axelrod and hold a data analysis.

3 Data preparation

Each tournaments exports a summary of the results. These are separated by tournament type. The structure of a single row of the results set is shown in Table 1. Name is the name of the strategy. Stochastic, Memory depth and Use of arguments are characteristics of the given strategy. The performance of the strategy is reflected by columns Rate, Median score, Rank and Wins.

The environment and the type of tournaments are captured by columns Noise, Probend, Repetitions, Size and Turns. Note that when turns are non given the tournament is a probabilistic ending one, and vise versa.

Algorithm 1 Generating data

```
for seed in 10000 do
    if seed mod 20 = 0 then
        size ← random size
        players ← random players
    else
        turns ← random turns
        repetitions ← random repetitions
        noise ← random noise probability
        end ← random end probability
        standard results ← tournament(turns, players, repetitions)
        noise results ← tournament(turns, players, repetitions, noise)
        probend results ← tournament(players, repetitions, end)
        probend noise results ← tournament(players, repetitions, noise, end)
    end if
    return standard, noise, probend, probend noise results
end for
```

Name	Stochastic	Memory depth	Use of game	Use of length	CC rate	CD rate	Cooperation rating	DC rate	DD rate	Median score	Rank	Wins	Noise	Probend	Repetitions	Seed	Size	Turns
Adaptive	False	inf	True	False	0.195	0.214	0.409	0.279	0.310	2.430	14	77.0	0.391	NaN	25.0	0.0	101.0	148.0

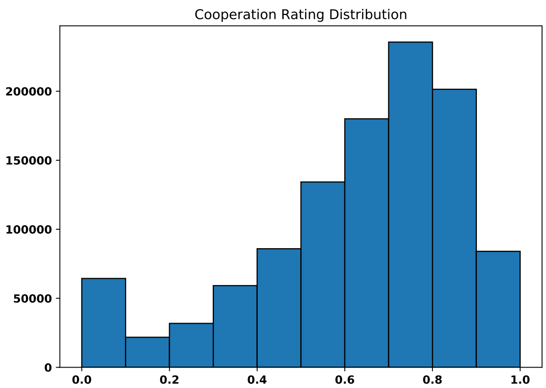
Table 1: Result Set

Similarly, when Noise argument in non given the tournament is known to be standard. Finally, when both Noise and Probend are non zero then the tournament is an probabilistic and noisy tournament.

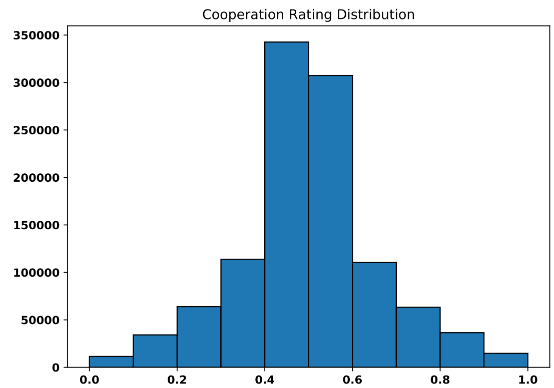
Each types is explored separately. Figure 1 shows the distributions of the cooperation rating for each type. As suggested probabilistic ending tournaments are the most cooperative tournaments. Standard tournaments appear to be most cooperative as well and any tournament which includes noise the cooperation rating appears to follow a normalised distribution.

In this work each tournament type is studied individually. An individual data set containing the following information is constructed for each type.

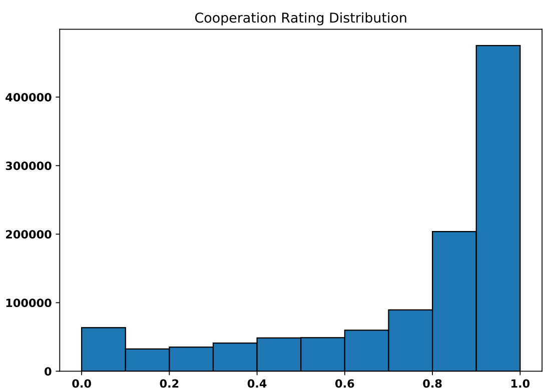
- tournament index i
- tournament size N_i
- maximum cooperation rating C_r^*
- minimum cooperation rating $\tilde{C}_r$
- mean cooperation rating $\bar{C}_r$
- median cooperation rating $\breve{C}_r$
- standard deviation of the cooperating ratio σ
- C ratio of the winner C_W
- C ratio of the looser C_L
- C to CC rate of the winner
- C to CD rate of the winner
- C to DC rate of the winner
- C to DD rate of the winner
- normalised rank of maximum cooperator $\bar{r_C}$
- normalised rank of minimum cooperator $\bar{r_D}$



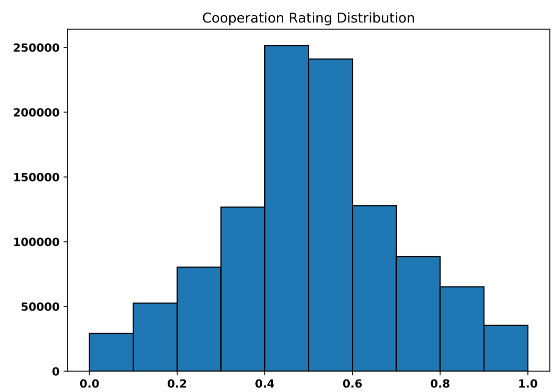
(a) Standard tournament type.



(b) Noise tournament type.



(c) Probend tournament type.



(d) Noise Probend tournament type.

Figure 1: Cooperation rating distribution.

4 Analysis

References

[1] The Axelrod project developers . Axelrod: ¡release title¿, April 2016.

[2] David R Oldroyd. Charles darwin's theory of evolution: a review of our present understanding. *Biology and Philosophy*, 1(2):133–168, 1986.