Lecture with Computer Exercises:
Modelling and Simulating Social Systems with MATLAB

Project Report

Axelrod's Tournament with Noise

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Zurich
Dec 2011

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We hereby agree to make our source code for this project freely available for download from the web pages of the SOMS chair. Furthermore, we assure that all source code is written by ourselves and is not violating any copyright restrictions.

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2 Individual contributions

2.1 Andermatt Samuel

- Further development of the game master
- Development and implemention of multiple players
- Data analysis and interpretation
- Contributions to the report
- Contributed experience in game theory

2.2 Bösser Jonathan

- Explore and explain GitHub [www.github.com]
- Development and implementation of multiple players
- Data analysis and interpretation
- Contributions to the report
- Literature study

2.3 Meier David

- Write the first version of the program
- Development and implementation of multiple players
- Responsible for the report
- Literature study

3 Introduction and Motivations

3.1 The Prisoner's Dilemma

The prisoner's dilemma is a model from game theory. 2 people are suspected to have done a crime together. Now they are examined separately in different rooms. In this situation, they can either whistle-blowing the other person to protect oneself or keep silent. Over all, it is of advantage, if both keep silent. But for the single person it is better to betray the other person. The risk of betraying is the following: if both accused people betray the other, the penalty for both is the highest. This problem is in game theory called "Prisoner's dilemma" [2].

3.2 The Axelrod Experiment

In the year 1981, Robert Axelrod invited for a competition to the iterated prisoner's dilemma. People from different fields like mathematics, politics, economy or psychology have been asked to develop a winning strategy for this competition. All the different strategies were playing against another to find the most successive strategy. Interestingly, the very simple strategy "Tit for Tat" (TFT) won the tournament. During the first round, TFT keeps silent (cooperation) and during the rest of the game, just does, what its counter player did the round before. This sort of experiment is very interesting, because the results can be applied in many different fields in real life. Just one out of many examples: 2 countries make an agreement on their amount of weapons. For the single country it is of advantage to haves more wmilitary strenth than the other nation. But as in the prisoner's dilema, if both nations rise their military strenth, for both it is just a loss money and an increase in danger. [3]

3.3 Introduction of Noise

A further development in the Axelrod Experiment is the introduction of noise. This means, cooperation is wrongly understood as defection and vise versa. The introduction of noise to the axelrod experiment ist nothing new, but very important, because in real world, noise and small distortions is always present. This can lead to serious complications. Just as an example: *"On September 1,1983 a South Korean airliner mistakenly flew over the Soviet Union (Hersh 1989). It was shot down by the Soviets, killing all 269 people aboard. The Americans and Soviets echoed their anger at each other in a short, but sharp escalation of cold war tensions."*[7]

4 Description of the Model and Players

4.1 Simple Players

4.1.1 Cooperative Player

The player 1 is a very simple player: He always cooperates. This "decision" does not depend on any circumstances like the decisions of its antagonist.

4.1.2 Defective Player

Also the player 2 is a very simple player: He always defects.

4.1.3 Random Player

Like all players from this subsection, the decision of the random player does not depend on the results of the previous tournaments. The decision is randomly distributed and no decision is preferred.

4.2 Players from Literature

All players in this subsection are taken from the first Axelrod's Tournament and implemented by us. Source: Lecture "Game Theory" [1]

4.2.1 Tit for Tat

The Player 4 during to the Axelrod Turnament the most successive player of all[1]. The decision is the decision of the counter player from the last tournament. In the first round, the decision is cooperation. If the counter player cooperated during the last round, this player will cooperate in the current round.

4.2.2 Friedmann

The Player "Friedmann" cooperates until its counter player defects once. After that, Friedmann now deflects for the rest of the game. This corresponds to "everlasting death".

4.2.3 Pavlov

Pavlov changes its decision every time when the counter player defects. But if the counter player cooperates, Pavlov gives the same decision as in the round before. The first decision is cooperation.

4.2.4 Tit for two Tat

The first decision is cooperation. If the counter player cooperates, Tit for 2Tat" cooperates as well. Tit for 2 Tat only defects, if the counter player defected the last 2 rounds.

4.2.5 Joss

This is basically the same player like the player "Tit for Tat". The only difference: 10% of the cooperative decisions are randomly defected. www.socio.ethz.ch/vlib/pesb/pesb9.pdf

4.2.6 Diekmann

The player "Diekmann" plays basically Tit for Tat. The difference is, that every 10th move, he playes cooperative twice. www.socio.ethz.ch/vlib/pesb/pesb9.pdf

4.2.7 D-Downing

4.2.8 C-Downing

4.3 Own Players

4.3.1 Tit for Average Tat

Based on the idea "Tit for Tat", we developed a player who averages the decisions of its opponent over the most recent Rounds. The first few rounds he plays Tit for Tat. Then he starts averaging over the most recent rounds and reacts to the opponents most frequent decision. After a fixed number of rounds, the player restarts from the very beginning. This can prevent beeing stuck in mutual defection.

4.3.2 Watcher

For this player, we investigated one possible concept for a learning algorithm. The idea is to learn by observing and copy the moves of the most succesful player. During the first few rounds, Watcher plays Tit for tat.

4.3.3 Reconciliation Tit for tat

TFT has a disadvantage. Once the players start a mutual defection it is stable. This makes TFT very susceptible to miscommunications and performs poorly against players like Joss. The approach here is to break this cycle by adding cooperative moves. The risk of adding cooperative moves is that the opponents exploit this strategy. This strategy tries to make these moves without becoming exploitable. In case the opponent defects, his recent performance gets calculated. It is also calculated, how good the opponent would have performed if both players were cooperating. In case the damage by the mutual defections is large enough that by defecting the reconciliation attempt he cannot gain enough to outperform cooperation. This way the strategy is not explotaible.

4.3.4 Tit for Tat with Reputation

This is a further Tit for Tat mutant. The basic strategy remains the same, but the opponents moves against other players are also observed. In case the opponent is mostly cooperative against others, then defection of the oponent is regarded as miscommunication and interpreted as cooperation.

4.3.5 Strategy Switcher

The strategy switcher is another example for a learning player. The player is equipped with a set of predefined strategies. In our case we chose the strategies TFT, TF2T, Pavlov, always cooperate and always defect. Initially he tries out all five strategies. After he tried out every strategy he calculates each strategies performance. In the subsequent turns he always plays the most successful strategy. After a given set of turns he will reevaluate the performance of the current strategy and compare it with the others. If one of its other strategies has a higher performance this strategy is chosen instead.

4.3.6 Evolutionary

This player tries to find the optimal sequence of moves by an evolutionary algorithm. The strategy of the player consists of a given set of moves. To determine the first set of moves he plays TFT in the first rounds. Once he has a sequence of moves he creates clones of this sequence and adds mutations to them. A mutation means that the decision in one move is altered. In the next step he plays each clone. After all clones are played he evaluates their performance. The clones are split into segments, for each segment the winnings are calculated. The performance includes the one move after the segment ended, otherwise the players would always reject in the last move. Then a new parent strategy is formed. Each segment is evaluated, if the first segment of a clone performed stronger then the parent strategy, the parents segment is replaced by the more successful segment. This parent is then played and cloned again. There is an assumption that with increasing simulation length the sequence becomes closer to the optimal sequence. At this point the mutations become a disadvantage. Therefore the mutability is lowered with time (but does not go to zero).

4.3.7 Limited Reconciliation Tit for tat

This strategy is similar to the Reconciliation Tit for tat. In this case however the number of reconciliation attempts is limited. Some players tend to reject all reconciliation attempts and while this does not exploit this player, it still limits its performance. This player will stop to try to reconcile after he was unsuccessful doing so for a given time. However, if the opponent has two consecutive cooperative rounds the counter for the reconciliation attempts is reseted.

4.3.8 Look Back D-Downing

4.3.9 Look Back C-Downing

	Cooperates in First Round	responsive	Memory	Exploitable	Can Exploit	Global view	Learning
Cooperative Player	×		0	×			
Defective Player			0		×		
Random Player	random		0		×		
Tit for Tat	×	×	1				
Friedmann	×	×	inf		×		
Pavlov	×	×	1				
Tit for two Tat	×	×	2	×			
Joss	90%	×	1		×		
Diekmann	×	×	1	×			
D-Downing		×	inf	×	×		(×)
C-Downing	×	×	inf	×	×		(×)
Tit for Average Tat	×	slow	5	×			
Watcher	×		6	×	×	×	×
Recon Tit for Tat	×	×	20				
TfT with Reputation	×	×	1	×		×	
Strategy Switcher	×	×	inf	×	×		×
Evolutionary	×	very slow	31	×	×		×
Lim. Recon. TFT	×	×	20				
Look back D-Downing		×	inf	×	×		(×)
Look back C-Downing	×	×	inf	×	×		(×)

5 Implementation

As described in the Introduction, the tournament is a repeated prisoners dilemma. the payoff matrix for this game is shown in figure ....

. To make the simulation more realistc, we added noise to it. Noise means that defection can be transmitted as cooperation and vice versa. The noise applied on cooperation and defection was varied independantly. The two noiselevels are set independantly to 0, 5, 10 and 15%. The noise only changed the information the players recieved, but not their payoff. For each combination of noise, we performed a tournament with 20000 rounds. In each round, every player plays agains all others and himself. To make the decisions, the player is provided with all the decisions made in the previsous rounds by all players. The playersdo not have information about the noise level.

The basic structure of a player is shown .... . And an example (TFT) of such a player would be:

In the following table 1 is shown the payoff matrix applied in our program.

Table 1: Reward Matrix

	Player B cooperates	Player B defects
Player A cooperates	A:3 B:3	A:0 B:5
Player A defects	A:5 B:0	A:1 B:1

- Spielablauf
- Informationen, die die Spieler sehen knnten
- Art des Noises
-

6 Results and Discussion

6.1 General Findings

- A noise that interprets cooperation as defection decreases cooperation drastically.
- A noise that interprets defections as cooperations increases cooperation, but the effect is weaker.

- Perfect information is not whats best for the system. If decisions are transmitted better than they are, the whole system gets more efficient.
- Friendly/cooperative players performance drastically decreases if the chance that cooperation is transmitted correct is less than 100%.
- Players that do not react immediately to defections look non-responsive.

6.2 Why most friendly players perform badly if cooperation is not reliably transmitted

Many of the friendly players perform well without noise, because they have an infinitely long sequence of mutual cooperations with other friendly players. Noise will trigger defections. This state requires then a way to come back into cooperation. Most cooperative players do not have a mechanism to reestablish cooperation if it has been destroyed, because they rely on a cooperation caused by the first turn decision being cooperative.

6.3 Why noise that covers up defections is beneficial for the system

Some players try out defective moves. For TFT mutants this can likely result in mutual defections. A noise that inserts cooperative moves results in the TFT player reacting cooperative again, driving the game in mutual cooperation again. Another thing is that hiding defections allows aggresive players to exploit players that would retaliate otherwise, and an aggresive player exploiting a weak one is better than if both players are defecting each other.

6.4 How do Axelrods recommendations for a successful strategy work under noise

Axelrod proposed a certain behavior to be successful. This behavior is: Be Nice, Retaliatory, Forgiving and Clear. Under noise the opponent will see defections from a player, even if he never defected. This diminishes the use of being nice. It is more successful to find out if he responds to defections and exploit the opponent if he is exploitable. In Axelrods tournament this was not the case, because this attempt might have long lasting effects. However noise somewhat covers up the past. The other recommendations still hold.

6.5 The Performance of each Player

Definition:

- Nose 1 = Chance, that a cooperation gets received as defection
- Nose 2 = Chance, that a defection gets received as cooperation

The performance plot shows the average reward of a cercain player, depending on the two noise levels. The simulation was run twice, therefor, each player has 2 performance graphs.

For most players there are tables that show how many of their moves are cooperative, dependant of the Noise levels under which the simulation was run. In this tables the entries in the first row have no Noise1 and the lower the row is the higher is Noise1. Noise2 is zero on the left side and gets higher for entries more on the right side. So the Noise 1 goes from 0 to 0.15 from top to bottom, and Noise2 goes from 0 to 0.15 from left to right.

6.5.1 Cooperative Player

The cooperative player's performance in both simulations is shown in the two figures below:

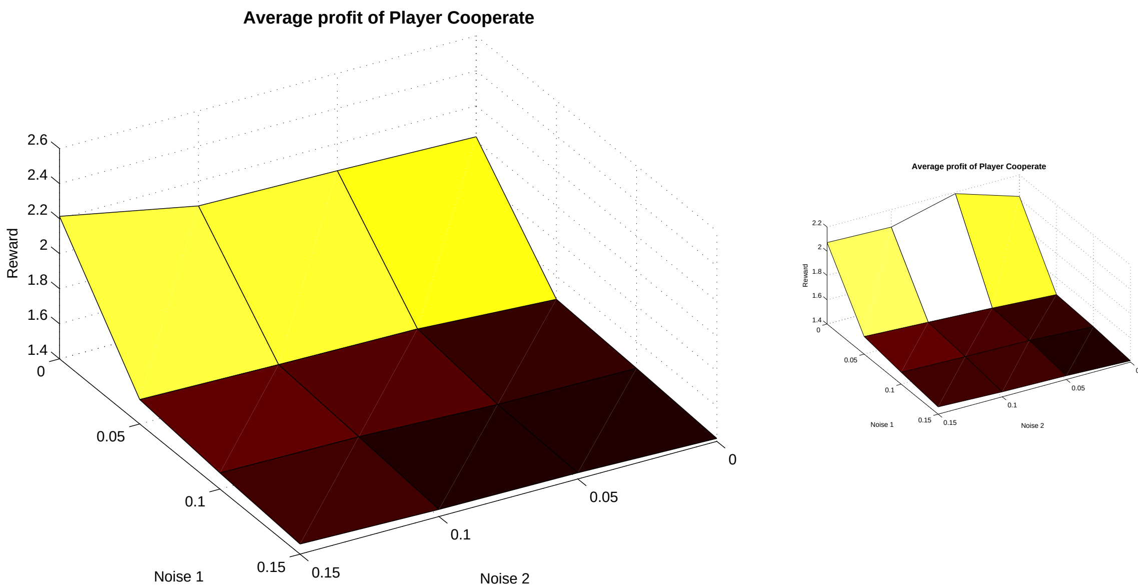


Figure 1: Reward plot of the Cooperative Player

In a situation of no noise, this player performs strong against mostly friendly players, but gets exploited by aggressive players. In this situation it performs better than always defect, but similar to random.

Because this player is cooperative and not reactive Noise2 doesn't matter. On the other hand performance drastically decreases with Noise1. The seemingly inserted rejections make other players explore defective moves. Because the defective moves are not retaliated the other players might then stick with these defective moves. Players that start exploiting this player are Friedmann, Pavlov, CDowning and LookBack CDowning.

In a situation with noise this strategy is still strong with TFT mutants, because a cooperative interaction gets restored in the fastest possible way.

Still with a drop of 0.7 to 0.8 in performance this player is one of the players that is the most susceptible to noise overall.

Traits of the player:

+ Can sustain cooperation with friendly players even in noise

- Exploitable

- Does not respond to the opponents move

6.5.2 Defective Player

The player's performance in both simulations is shown in the two figures below:

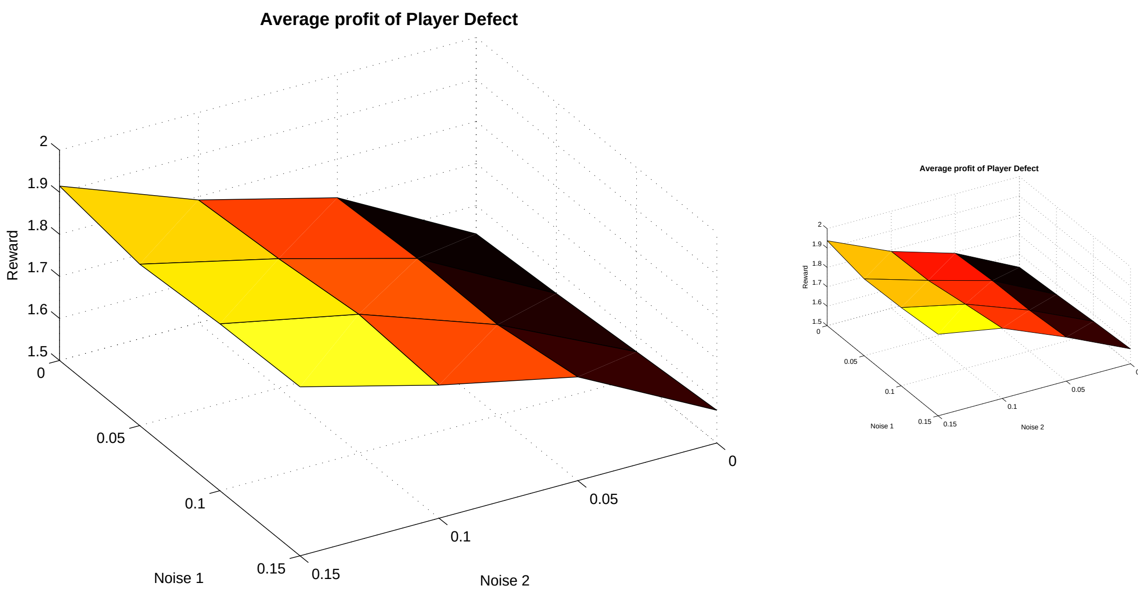


Figure 2: Reward plot of the Player Defect

The player is so unfriendly, that Noise2 help him. A move where he can exploit the opponent gives him 5 times the reward of mutual defections, therefore even a small number of exploiting moves helps him a lot. If we would run the simulation with a Noise close to 50% this player would become the most successful player. The performance increases in general against TFT mutants, but especially against players that try hard to avoid mutual defections, such as TF2T, reconciliation TFT, limited Reconciliation TFT. The strongest rise in performance comes against the player Evolutionary.

Traits of the player:

+ Can exploit players that do not respond

+ Performance increase with Noise

- Ends up in mutual defections with most players

6.5.3 Random Player

The player's performance in both simulations is shown in the two figures below:

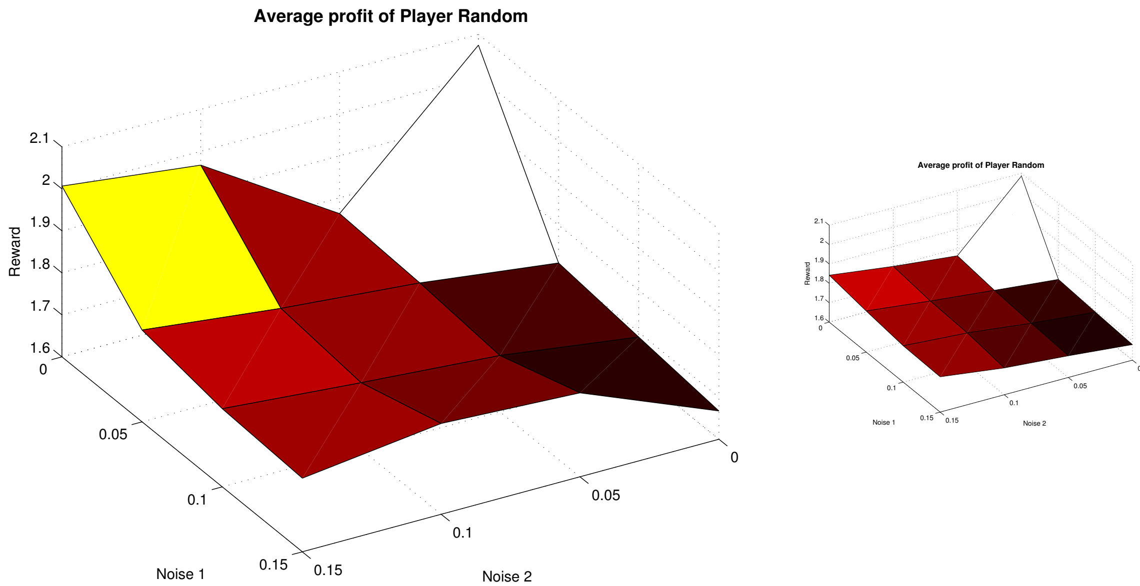


Figure 3: Reward plot of the Random Player

The player does not get influenced that much by noise. There is a strange peak at zero noise, we were unable to find out why. If the noise makes his moves appear a little more cooperate there is a slight increase in performance, most likely due to more cooperative reactions from TFT mutants.

6.5.4 Tit For Tat

The player's performance in both simulations is shown in the two figures below:

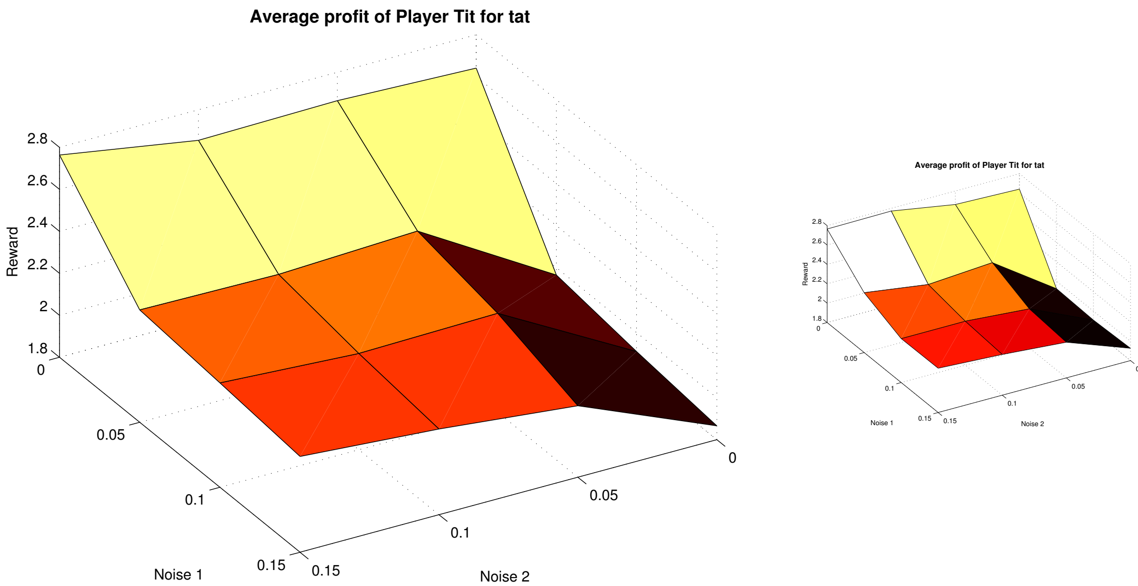


Figure 4: Reward plot of the Player Tit For Tat

Tit for Tat (TFT) is a rather strong player. He won Axelrod's tournaments that were without noise. For Noise1=0 he is one of the strongest of all players. These graphs above show that this player is extremely susceptible to noise1. The reason is that with no noise 1 he will always cooperate with other TFT mutants because the first move was cooperative. With noise the first move maters less. There are basically three states he can enter with himself.

State 1: Mutual cooperation. Performance 3

State 2: Alternating defection and cooperation. Performance 2.5

State 3: Mutual defection. Performance 1

A Noise1 signal changes the state from state 1 to state 2 or state 2 to state 3. Noise2 works in the other direction. The two noises are basically transition probabilities. For Noise1 greater than zero and Noise2 equal to zero the TFT ends up stuck in state three with itself. For equal noises in both directions TFT should be 50% of the time in state 2 and 25% in the states 1 and 3. This would imply the performance: $0.25 * 3 + 0.5 * 2.5 + 0.25 * 1 = 2.25$ The table below shows the performance of TFT against itself. Because the players in our simulation could only perform mirrored decisions state 2 was impossible and the actual performance was somewhat lower.

Table 2: Performance of TFT playing against TFT

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	3.0000	3.0000	3.0000	3.0000
Noise 1 = 0.05	1.0016	2.0127	2.3438	2..4745
Noise 1 = 0.10	1.0018	1.6184	1.9847	2.1967
Noise 1 = 0.15	1.0011	1.5170	1.7666	2.0086

Table 3: Cooperation of TFT depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8075	0.8247	0.8351	0.8917
Noise 1 = 0.05	0.3958	0.5967	0.6192	0.6516
Noise 1 = 0.10	0.3418	0.5127	0.5428	0.5866
Noise 1 = 0.15	0.2886	0.4240	0.4836	0.5297

Already at Noise1=0.05 the number of cooperative moves TFT performs drops from 40 to 80 percent. At higher Noise2 with no Noise1 the number of defections performed by TFT halves.

Traits of the player:

+ Responds fast

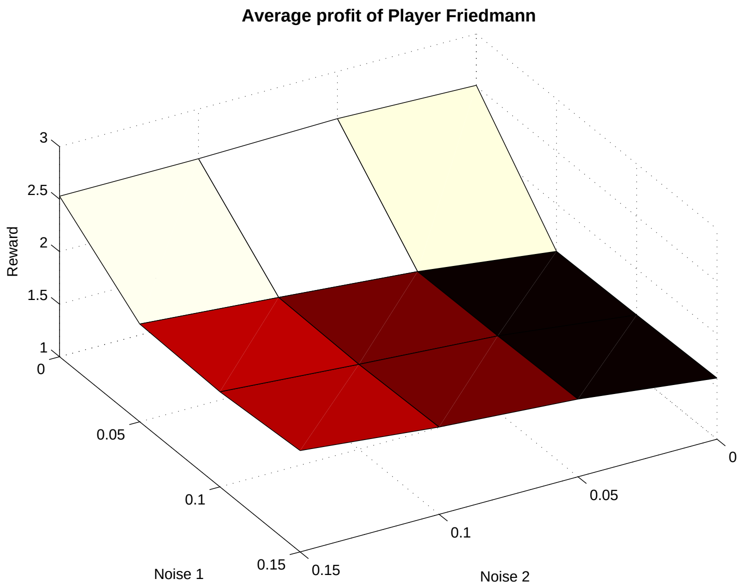
+ Not exploitable

+ Forgiving

- Only accepts an apology, but does not initiate it himself, so he can stuck in mutual defections!

6.5.5 Friedmann

The player's performance in both simulations is shown in the two figures below:



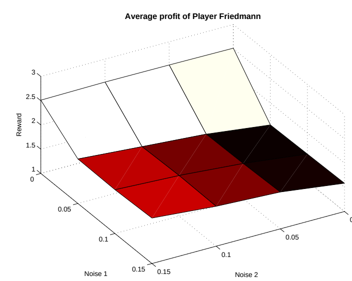


Figure 5: Reward plot of the Player Friedmann

In the case of perfect information this player can profit from mutual cooperation with many players. In this case he performs well. However for any Noise1 greater than zero the player will receive a rejection at some point and therefore act like the player "Defect" most of the time. Friedmann generally tries to retaliate so hard on a rejection that the other player will not even attempt one rejection. However Friedmann cannot capitalise on this deterrent effect, because the moment the opponent realises it is already too late and he cannot know it in advance.

Table 4: Cooperation of Friedmann dependant on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.6002	0.6000	0.6000	0.6000
Noise 1 = 0.05	0.0004	0.0001	0.0001	0.0001
Noise 1 = 0.10	0.0001	0.0001	0.0001	0.00016
Noise 1 = 0.15	0.0001	0.0001	0.0001	0.0001

As soon as Noise1 is greater than 0 the number of cooperative moves goes to zero. But already at zero noise Friedmann only has 60% cooperative moves, while TFT has 80%.

Traits of the player:

+ Stays in mutual cooperation with friendly players when Noise1 is zero

- Completely breaks down with Noise1 greater than zero

6.5.6 Pavlov

The player's performance in both simulations is shown in the two figures below:

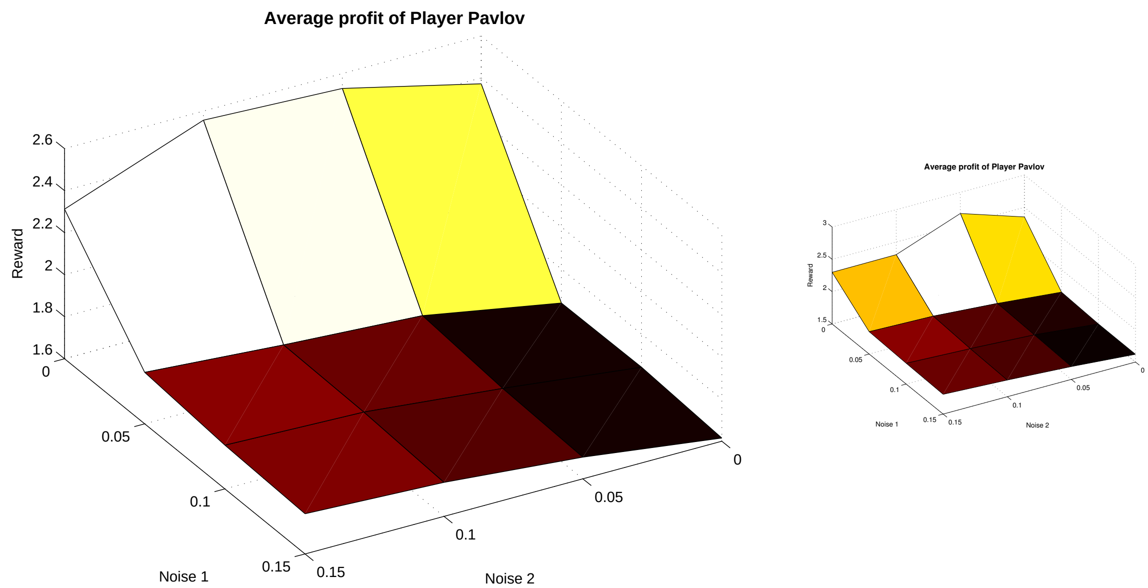


Figure 6: Reward plot of the Player pavlov

Pavlov performs rather well without Noise1. If Noise1 is greater then zero, some players realise that defections against Pavlov work as well as cooperations. Pure defect against Pavlov results in the rewards 5 1 5 1 5 1 for the opponent, while pure cooperation results in 3 3 3 3, given Pavlov is cooperative when the opponent started playing random. With zero noise the opponent gets an average reward of 3 for cooperation and defection but with noise the performance of cooperation decreases (because Pavlov retaliates). Players that largely start to defect against Pavlov are: Friedmann, Tit for average Tat, CDowning, LookBack CDowning and the Strategy switcher.

Table 5: Cooperation of Pavlov depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8239	0.8488	0.8541	0.8037
Noise 1 = 0.05	0.4885	0.5433	0.5697	0.5860
Noise 1 = 0.10	0.4939	0.5211	0.5338	0.5455
Noise 1 = 0.15	0.5063	0.5187	0.5251	0.5319

Without Noise 1 the number of Cooperative moves is around 80% while it is around 50% with Noise 1. It is interessting that with Noise2 but no Noise1 Pavlov is less cooperative than TFT.

Traits of the player:

+ Forgives fast

+ Initializes cooperation out of mutual defection

+ Not exploitable without noise

- Too many cooperative moves against defecting players

- Not retaliating (pure defect and pure cooperation perform equally well)

6.5.7 Tit For 2 Tat

The player's performance in both simulations is shown in the two figures below:

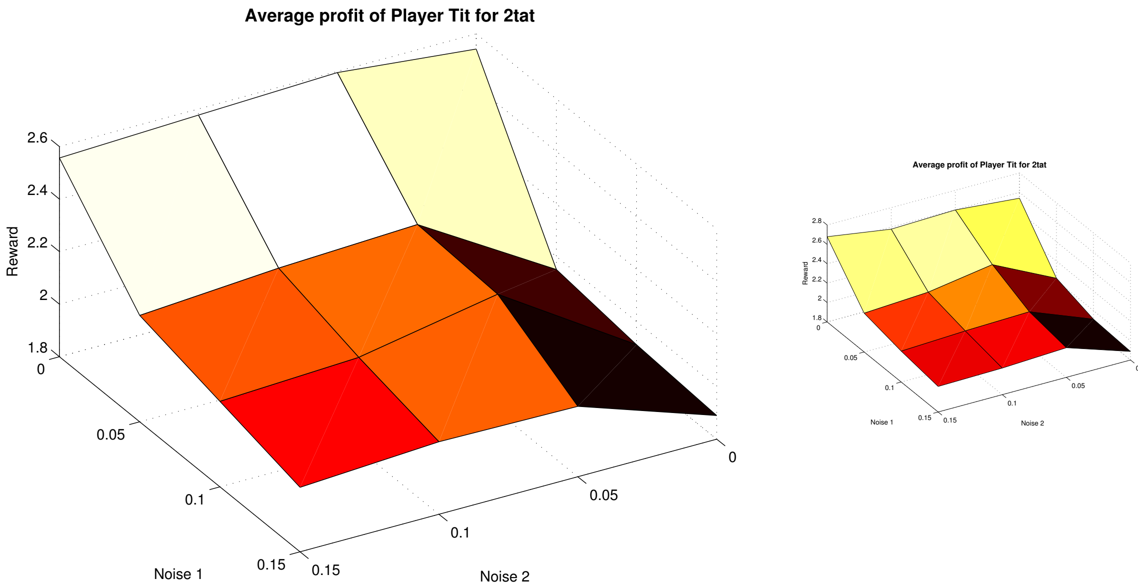


Figure 7: Reward plot of the Player Tit For 2 Tat

As a TFT mutant it has a similar performance. The difference is that this player is more forgiving. The bad thing is that this makes him exploitable. The better thing is that it is more robust to Noise1 as it does not react to single defections. The player still ends up in mutual defections with itself if Noise2 is zero and Noise1 greater than zero, but for both Noises greater than zero the player plays much stronger against itself. At zero noise the performance of TF2T is worse than the one of TFT, but with Noise1 their performances are similar. The effect that players like "Evolutionary" will exploit TF2T seems to balance out with the better resistance to noise.

Table 6: Cooperation of TF2T depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8271	0.8796	0.8880	0.8947
Noise 1 = 0.05	0.5366	0.7450	0.7712	0.7926
Noise 1 = 0.10	0.5132	0.7349	0.7375	0.7622
Noise 1 = 0.15	0.4864	0.6503	0.6977	0.72749

The cooperation stays much higher than for TFT especially if Noise2 also is not zero.

Traits different to TFT:

+ More Forgiving

- More Exploitable

6.5.8 Joss

The player's performance in both simulations is shown in the two figures below:

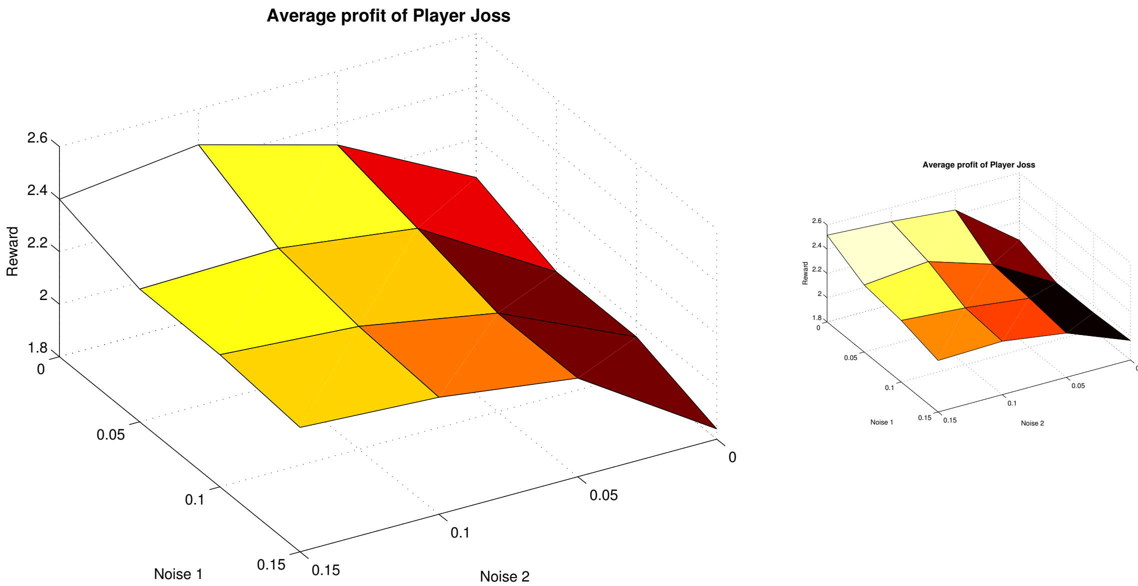


Figure 8: Reward plot of the Player Joss

While this is a TFT mutant, its performance dependence on noise looks totally different. The player generally performs poorly. At some noises this player is able to exploit TF2T (Noise2 greater than 0 and Noise1 0) however most of the time the retaliation of the defections outweighs their gain. TFT is very susceptible to Noise1 and Joss makes himself look like under Noise1 to his opponent. It is interesting that the performance of this player looks like the performance of "Defect" just shifted about 0.5 upwards.

Table 7: Cooperation of Joss depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.3983	0.5300	0.6102	0.6172
Noise 1 = 0.05	0.3983	0.5300	0.6102	0.6172
Noise 1 = 0.10	0.2968	0.4026	0.4625	0.5006
Noise 1 = 0.15	0.2404	0.3720	0.4225	0.4591

With higher Noise2 some cooperation can be achieved, but generally the player is mostly defecting.

Traits different to TFT:

- initates defections

6.5.9 Diekmann

The player's performance in both simulations is shown in the two figures below:

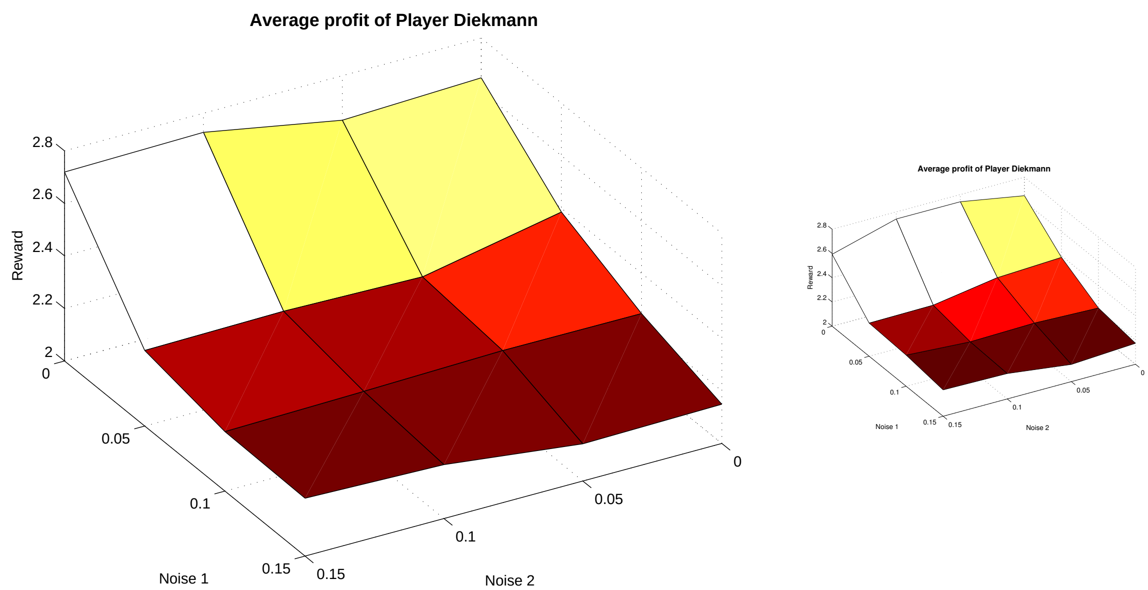


Figure 9: Reward plot of the Player Diekmann

This is a TFT mutant, that performs on the same level as TFT at no noise, and is therefore one of the strongest players if there is no noise. While his performance also drops with Noise1 the effect is much less severe. For Noise1=0.05 and Noise2=0, TFT drops about 0.9, while Diekmann only drops 0.5. This player actually initiates cooperation and gets not stuck in mutual defection with TFT mutants. The weakness of this player is that he is exploitable by defective moves every 10 moves. However on our simulation we haven't seen a player exploiting this weakness. Evolutionary could exploit it if the period in which the algorithm updates would be a multiple of the period in which Diekmann inserts cooperative moves.

Table 8: Cooperation of Diekmann depending on the noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8635	0.9034	0.9113	0.8741
Noise 1 = 0.05	0.7157	0.7263	0.7200	0.7359
Noise 1 = 0.10	0.6230	0.6500	0.6655	0.6946
Noise 1 = 0.15	0.5760	0.5895	0.6283	0.6496

The cooperation drops not nearly as much with the Noise as this is the case for TFT, he even is much more cooperative at no noise. At low noise2 values he is more cooperative than TF2T, but when both noises get high TF2T is more cooperative.

Traits different to TFT:

+ initates cooperation

- More Exploitable

6.5.10 Tit For Average Tat

The player's performance in both simulations is shown in the two figures below:

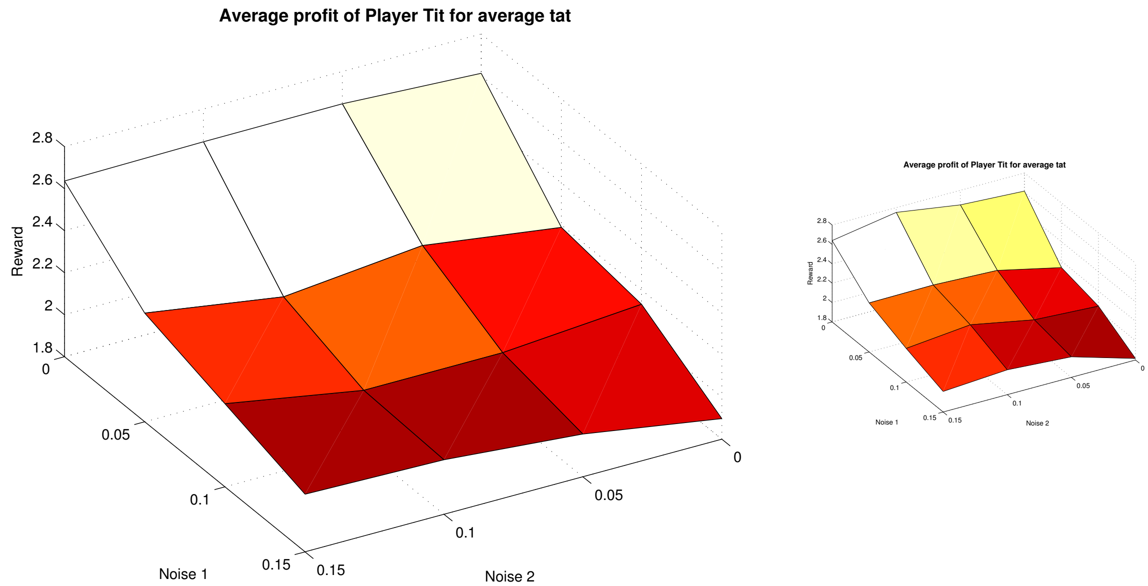


Figure 10: Reward plot of the Player Tit For Average Tat

This TFT mutant looks very similar to Diekmann and other friendlier TFT mutants. The fact that it reacts to the players average move during the last turns allows him to ignore some of the noise. The problem is that if mutual defection appears it is just as hard to get out of it as it was to get into it. Maybe this players performance would have decreased if the simulation was run even longer. In general this player performs about as well as Reconciliation TFT and a little bit worse than Diekmann. Theoretically this player is exploitable.

Table 9: Cooperation of Tit For Average Tat depending on the noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8056	0.8404	0.8456	0.8547
Noise 1 = 0.05	0.5316	0.6170	0.6140	0.6863
Noise 1 = 0.10	0.4712	0.4860	0.5100	0.5985
Noise 1 = 0.15	0.3419	0.4134	0.4660	0.5098

The cooperation drops surprisingly fast with Noise1, but still not as fast as for TFT. The number of cooperative moves is still more similar to TFT than Diekmann.

This is surprising, that the performances look so close, while the underlying moves are so different. Diekmanns very nice approach seems to be just as efficient as TFAT's more retaliating method.

Traits of the player:

+ ignores single moves

- Exploitable

6.5.11 Reconciliation Tit for Tat

The player's performance in both simulations is shown in the two figures below:

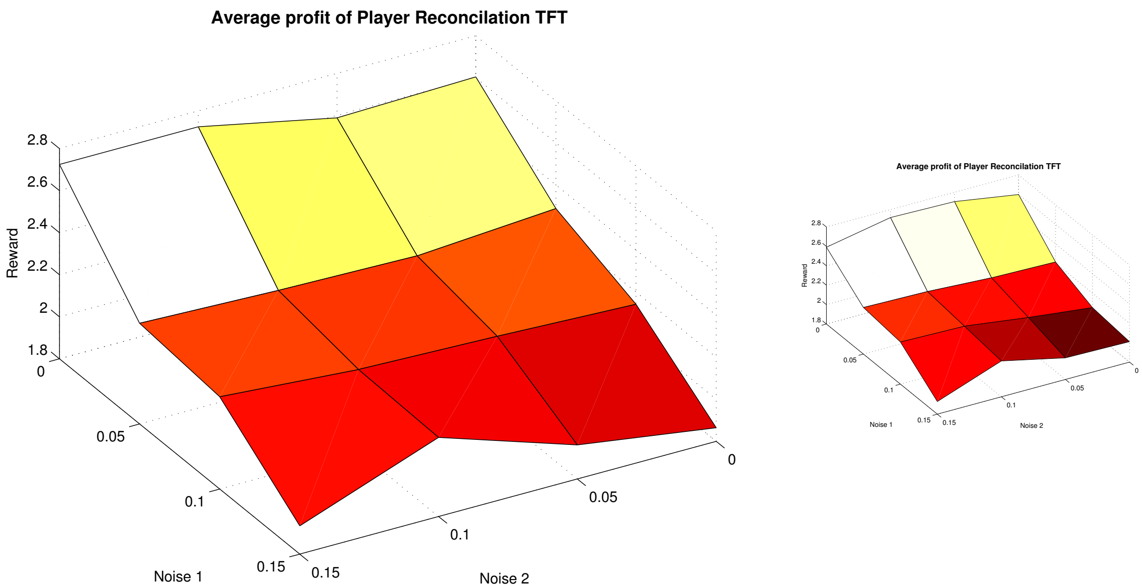


Figure 11: Reward plot of the Player Reconciliation Tit For Tat

Like other more forgiving TFT mutants he has similar performance to TFT without noise, and drops less with noise1. The disadvantage of this player is that while it is not exploitable it still performs worse against defective players, when its reconciliation attempts are shut down over and over again.

Table 10: Cooperation of Reconcilation Tit For Tat depending on the noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8728	0.8972	0.9033	0.8723
Noise 1 = 0.05	0.7169	0.7218	0.7397	0.7450
Noise 1 = 0.10	0.6861	0.7010	0.7175	0.7217
Noise 1 = 0.15	0.6930	0.6955	0.7161	0.67528

The number of cooperations is very high even with high noise1, at noise1=0.15 it's cooperation is higher than that of most TFT mutants. Generally the number of cooperative moves is more similar to Diekmann than to TFAT.

Traits different to TFT:

+ Initiates Cooperation

6.5.12 CDowning and DDowning

The two players' performance in both simulations is shown in the two figures below:

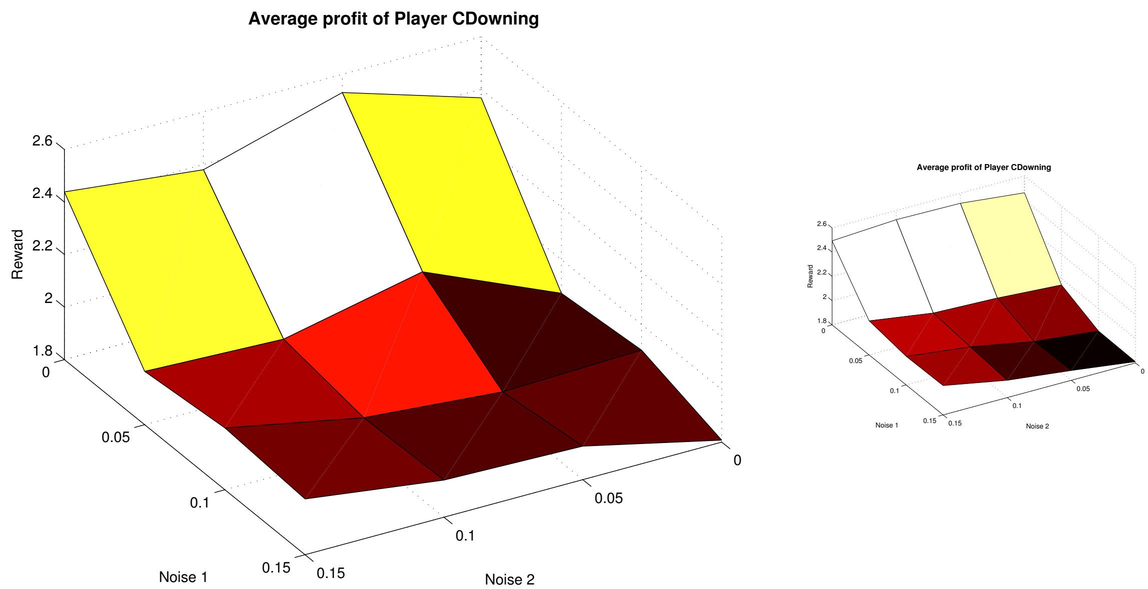


Figure 12: Reward plot of the Player CDowning

If Noise1 is zero, then CDownig performs stronger than DDowning. DDowning performs generally poorly with high Noise2 and no Noise1 there is a slight performance gain. At no noise DDowning outperforms CDowning against "Cooperate" and "Watcher", but is much worse against all TFT mutants and Friedmann. Noise2 improves the performance of DDowning against the TFT mutants a little. In the individual parings it seems that DDowning can end up in either mutual rejection or mutual cooperation. The decision where they end up seems to be random. For example at Noise2=0.15 mutual cooperation appears in TFT and TF2T, but not in Diekmann and Joss, while at Noise2=0.1 it is the other way around.

DDowning seems to reject almost all the time, while CDowning rejects most of the time if Noise1 is greater than 0. A problem of Downing is that it compares decisions that hapen at the same time, but at this time the opponent does not know Downings decision, so his decision can only be dependant on Downings past decisions.

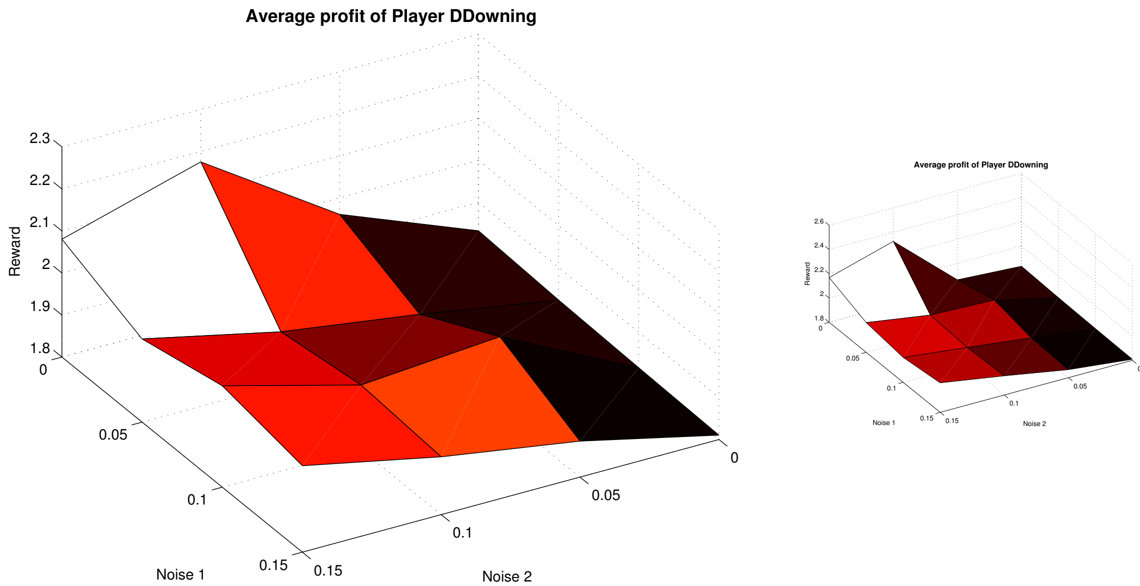


Figure 13: Reward plot of the Player DDowning

Table 11: Cooperations of CDowning depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.7507	0.6013	0.7660	0.6504
Noise 1 = 0.05	0.1210	0.1711	0.0829	0.0507
Noise 1 = 0.10	0.1169	0.0507	0.0508	0.0508
Noise 1 = 0.15	0.0507	0.0745	0.0504	0.0505

6.5.13 Tit For Tat with Reputation

The player's performance in both simulations is shown in the two figures below:

There were too many unfriendly players, that any player could have been friendly enough so that this player would have looked over a defection. The only player that would cooperate enough is "Cooperate". Against this player the number of cooperations was higher then the one of TFT, but because "Cooperate" is an exploitable player, this actually hurt this strategy. In an environement where most players are cooperating this player could theoretically be exploited.

The values in the upper table are very similar to the results of Tit For Tat

Table 12: Cooperations of CDowning depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.0500	0.1499	0.2997	0.3500
Noise 1 = 0.05	0.0500	0.0501	0.0517	0.0502
Noise 1 = 0.10	0.0500	0.1110	0.0503	0.0502
Noise 1 = 0.15	0.0501	0.0501	0.0501	0.0502

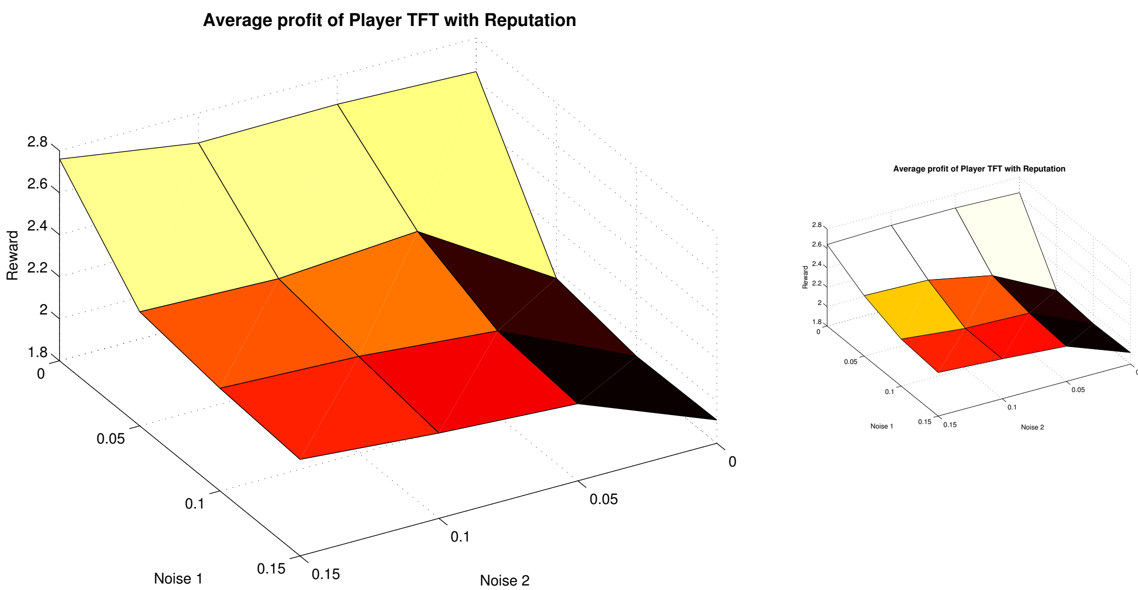


Figure 14: Reward plot of the Player Tit For Tat with Reputation

6.5.14 Strategy Switcher

The player's performance in both simulations is shown in the two figures below:

This player was by far the strongest player before the Downing players were added to the simulation. In the final simulation he is strong in fields, where the Noise is large as is performance is not impacted by noise. The disadvantage comes from trying out different strategies in the beginning. In the case of no noise this means that Friedmann will always defect. In the case of Downing mutants this seems to result in defections from the Downing players. Before these Downing players were added this player outperformed TFt by a huge margin, even at zero noise. The strength of this player comes from his ability to cooperate with TFT mutants and exploit exploitable players. This player might even be stronger if better strategies

Table 13: Cooperations of Tit For Tat with Reputation depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8059	0.8218	0.8375	0.8440
Noise 1 = 0.05	0.8059	0.8218	0.8375	0.84402
Noise 1 = 0.10	0.3476	0.4939	0.5341	0.5942
Noise 1 = 0.15	0.3202	0.4402	0.4906	0.5349

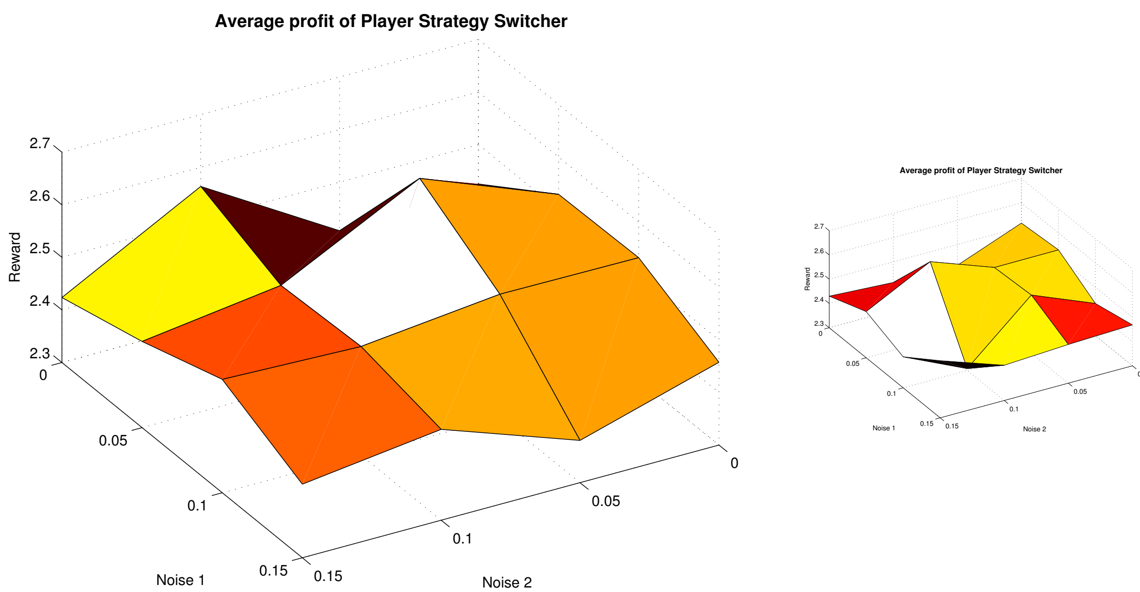


Figure 15: Reward plot of the Player Strategy Switcher

were given to his arsenal. Currently he had "Cooperate", "Defect", TFT, TF2T and Pavlov as choices. A more efficient choice might have been Limited Reconciliation TFT and "Defect". Currently it also contains exploitable strategies (TF2T), so the player could be exploited.

In long simulations the player can benefit from having the optimal strategy, while in short simulations he spends a large amount of the time trying out strategies that might not be very strong.

The number of cooperations is rather low, but also does not change very much with the noise. The number of cooperations is most likely low, because this player actively looks if an opponent is exploitable.

Traits of the player:

Table 14: Cooperations of Strategy Switcher depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.5164	0.5430	0.4803	0.4659
Noise 1 = 0.05	0.5164	0.5430	0.4803	0.4659
Noise 1 = 0.10	0.5098	0.5520	0.4497	0.4888
Noise 1 = 0.15	0.5097	0.5318	0.4675	0.4467

+ Can exploit others

+ Noise doesn't impact performance

+ Very adaptive

+ Strong in long simulations

- Exploitable himself

- Exploring defective moves can backfire (Friedmann)

- Is hard to read initially, this might trigger defections

- Weak in short simulations

6.5.15 Lookback CDowning and Lookback DDowning

The two players' performance in both simulations is shown in the two figures below:

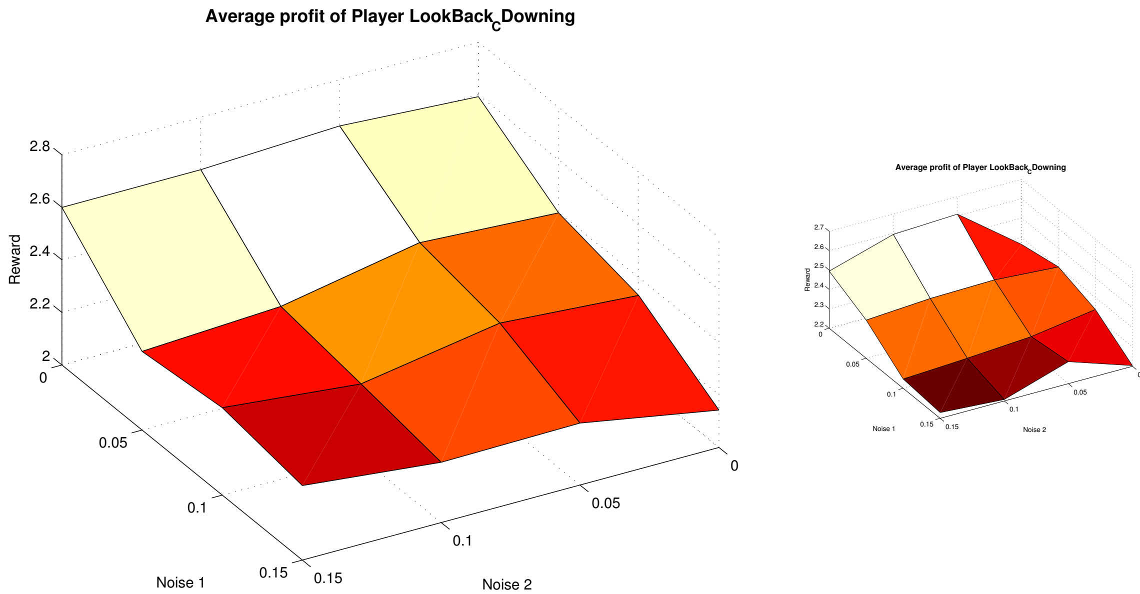


Figure 16: Reward plot of the Player Lookback CDowning

Generally both Lookback Downings are stronger than the not Lookback Downings. If Noise1 is zero, the CDowning mutant has again a higher performance. Comparing the second last move with the last move of the opponent seems to be the better way to correlate your actions with your opponent's actions. DDowning seems to be very resilient to Noise.

At zero noise CDowning performs well with most players, except "Evolutionary", Strategy Switcher, and some Downing mutants. With noise the performance against Friedmann and some Downing mutants that went well before drops. The overall performance however stays higher than TFT. The Look-back Downing behaves similar like Lookback CDowning behaves with noise.

The number of Cooperations is in general much higher then for the Variants that do not look-back. For Noise1 greater than zero about 40% cooperative moves remain, while CDowning and DDowning fall down to 5-10% cooperative moves. The average rewards for these players are also 0.2-0.5 higher then their not look-back counterparts.

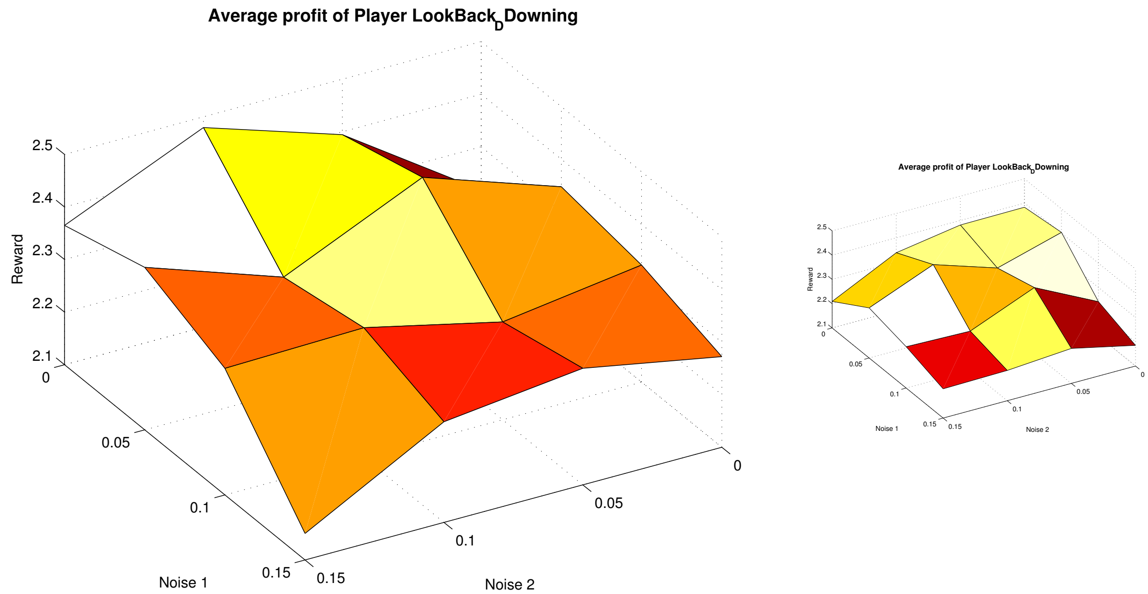


Figure 17: Reward plot of the Player Lookback DDowning

Table 15: Cooperations of the Lookback CDowning depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.7507	0.6511	0.6509	0.7010
Noise 1 = 0.05	0.4385	0.4405	0.4376	0.4329
Noise 1 = 0.10	0.4297	0.3865	0.3787	0.3696
Noise 1 = 0.15	0.3814	0.4120	0.3682	0.3271

6.5.16 Watcher

The player's performance in both simulations is shown in the two figures below:

This player generally does not perform very strong. It does not respond and can therefore be exploited. It also does not take the local situation into account. It will betray Friedmann even in no Noise, because in short term this is successful. After that the player copies strategies that were cooperative the whole time, while Friedmann is defecting. There is point of higher performance, where Noise2 is 0.15 and Noise 1 is zero. For some reason it performs strong against the Lookback-Downing algorithms.

Generally the number of cooperations is rather low, but there are no drastic jumps.

Table 16: Cooperations of the Lookback DDowning depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.4037	0.4563	0.4071	0.4762
Noise 1 = 0.05	0.4386	0.3912	0.4303	0.3848
Noise 1 = 0.10	0.3864	0.4025	0.3784	0.3827
Noise 1 = 0.15	0.3868	0.3262	0.3840	0.3769

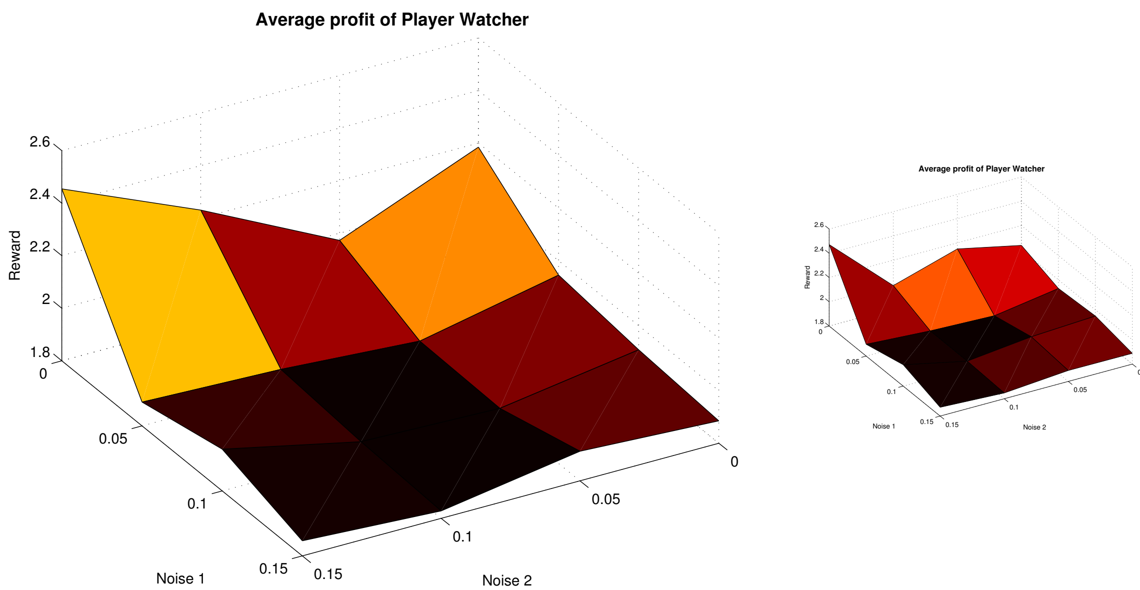


Figure 18: Reward plot of the Player Watcher

6.5.17 Evolutionary

The player's performance in both simulations is shown in the two figures below:

This player performs rather poorly at all noises. Less Noise is better for him, because more reliable information allows the player to adjust. Noise generally promotes bad strategies, while they are sorted out when there is little noise. The problem is that this players does add rejections and therefore triggers others rejections. The player himself has a very slow reaction time. Changing his strategy by mutations takes hundreds of turns. This is a stimescale the opponents cannot see. To the opponents this player does not look responsive. The player himself can only see the opponents reaction if it is within the segment legnth that the player tries to optimize. The interesting thing is that this player is able to exploit TF2T, he will add

Table 17: Cooperations of the Watcher depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.5399	0.4704	0.4298	0.4020
Noise 1 = 0.05	0.4569	0.3854	0.3544	0.3552
Noise 1 = 0.10	0.4297	0.3691	0.3522	0.3576
Noise 1 = 0.15	0.4125	0.3510	0.3428	0.3504

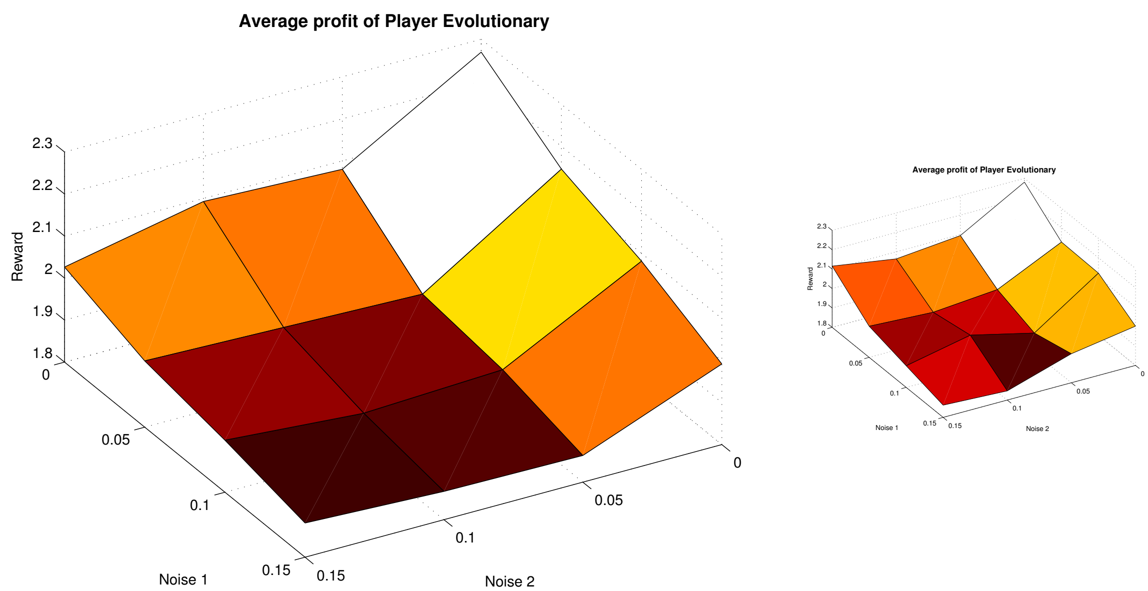


Figure 19: Reward plot of the Player Evolutionary

defections with mostly one sometimes two cooperative steps between them. It has a performance of 3.65 against TF2T at zero noise.

The decisions seem to be mostly an even mix of defections and cooperations, with a slight preference of defections.

Table 18: Cooperations of the Evolutionary depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.4330	0.4941	0.5151	0.4878
Noise 1 = 0.05	0.3859	0.4745	0.4860	0.4855
Noise 1 = 0.10	0.3987	0.4750	0.4919	0.4914
Noise 1 = 0.15	0.3755	0.4793	0.4733	0.4896

6.5.18 Limited Reconciliation Tit For tat

The player's performance in both simulations is shown in the two figures below:

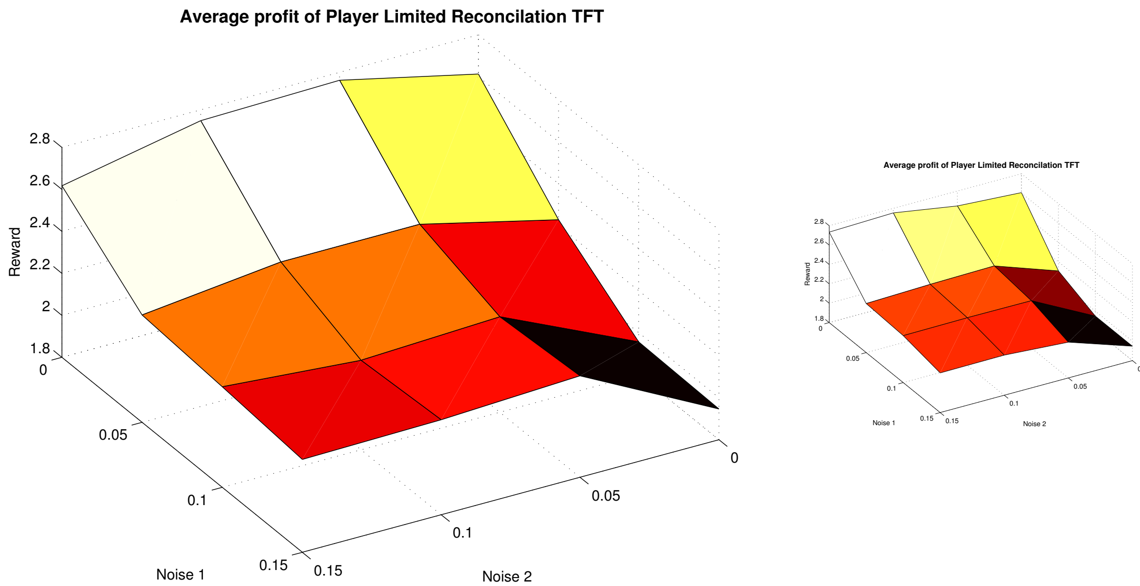


Figure 20: Reward plot of the Player Limited Reconcilation Tit For tat

At noise1 equal to zero the performance is similar to TFT. It does not perform as well as Reconciliation TFT against Joss, therefore it might be wiser to make the time between the reconciliation attempts larger every time, instead of limiting it to 3. Compared to TFT its performance does not break down that much with noise1, this is a property it shares with Diekmann, TFAT and Reconciliation TFT. The fact that the number of reconciliation attempts is limited makes the player stronger against defecting players like Friedmann (under noise1) and "Defect".

It is not as cooperative as the friendliest TFT mutants Diekmann and RTFT, but more friendly than standard TFT and TFAT.

Table 19: Cooperations of the Evolutionary depending on the Noise

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	0.8064	0.8386	0.8942	0.8976
Noise 1 = 0.05	0.5084	0.6577	0.6834	0.7043
Noise 1 = 0.10	0.4254	0.6300	0.6568	0.6822
Noise 1 = 0.15	0.4208	0.5956	0.6383	0.6648

The table below shows the performance of LTFT minus the performance of TFT averaged over all matchups and both simulations:

Table 20: Comparison of the two players Limited Tit Fot Tat and Tit For Tat

	Noise 2 = 0	Noise 2 = 0.05	Noise 2 = 0.1	Noise 2 = 0.15
Noise 1 = 0	-0.0317	0.0414	0.0375	-0.0892
Noise 1 = 0.05	0.2235	-0.0006	0.0310	-0.0679
Noise 1 = 0.10	0.0438	0.0340	0.0019	0.0066
Noise 1 = 0.15	0.0514	0.0720	0.0189	-0.0312

At higher values for Noise1, LTFT outperforms TFT, while at high Noise2 values the reconciliation attempts are not needed, because the noise itself achieves that.

7 Summary and Outlook

The aim of this simulation was to investigate two things. The first was the impact of noise on the tournament. It turned out that Noise that lets Defections appear as cooperations is beneficial for most players. The opposite, when cooperative moves are perceived as defections, has a much larger impact. The performance of most friendly players drastically drops. It is especially harsh for players that relied on the effect of the first move being cooperative and have no mechanism to restore cooperation once it is lost.

The second investigated topic was how learning players would perform. Of the three learning mechanisms, copying others, Evolution and Strategy switching, Strategy switching performed the strongest. The strategy was also stronger than most not learning strategies. The other two approaches failed, because they were not responsive.

Outlook: The performance of the players was heavily impacted by the nature of the other players participating in the simulation. It would be interesting to run the simulation with more players. Another possible investigation could be to find out if the average performance increases with a noise that covers up defections forever, or if there is a turning point after which the performance decreases again.

8 References

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A Submitted Researchplan

A.1 General Introduction

Tournament like simulation of the prisoner's dilemma with repeated inter- actions. Random errors are introduced in the information about the player's recent behavior. We want to observe the different outcome of the traditional players if noise is introduced. Further we want to try to implement new players with learning strategies.
We believe that this makes the simulation more realistic.
Extension of Axelrod's Tournaments.

A.2 Fundamental Questions

Can a dispute based on miscommunication be overcome?
Can treason be hidden behind pretended miscommunication?
Does miscommunication discourage cooperation?
How much miscommunication can cooperation survive?
Do learning strategies have an advantage over the other ones?
How do the traditional players act and how does the final result change, if noise is introduced?
Independent variables: length of simulation, reliability of communication, rewards
Dependent variables: correlation between cooperation and success, frequency of co-operation, successful strategies

A.3 Expected Results

Miscommunication works against cooperating strategies.
Programs that reconcile are more successful.
The reward of the learning players is less influenced by the noise.

A.4 References

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- How to Cope with Noise in the Iterated Prisoner's Dilemma, J. WU and R. AXELROD, JOURNAL OF CONFLIC RTESOLUTION, Vol. 39 No. 1, March1995 183-189

- Five Rules for the Evolution of Cooperation, M. A. NOWAK, Science 314, 1560 (2006)

A.4.1 Research Methods

Agent-Based Model

A.5 Other

The type(s) of the learning strategies we will decide later, after reading some of the literature.