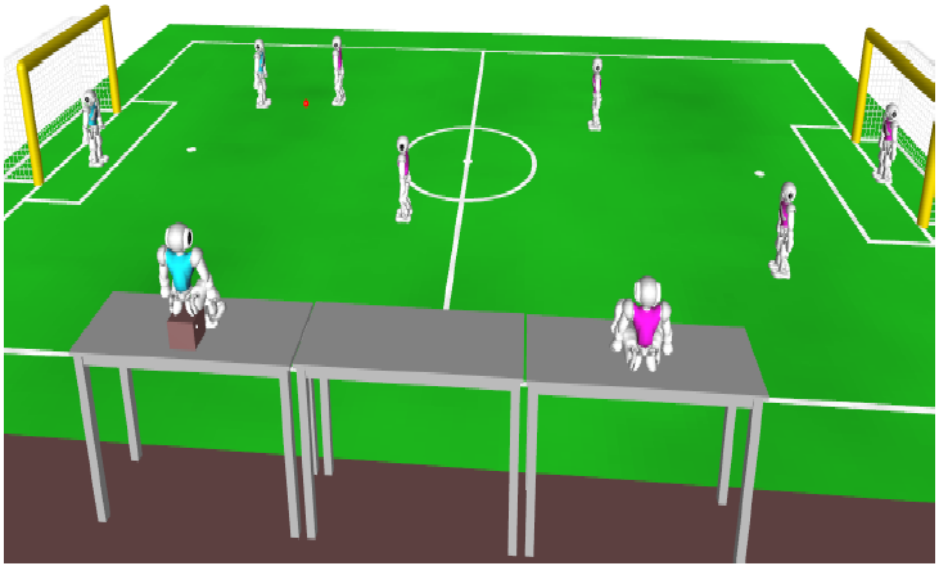
A coaching robot in the Standard Platform League



Bachelor thesis by Fabian Voorter

A coaching robot in the Standard Platform League

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Abstract

The strategy of the Dutch Nao Team in the Standard Platform League is static. If strategies are dynamically changed during the match, then the overall performance of the team could be increased. The implementation of strategies should take into account the meaningful conclusions from previous researches for the positioning of defenders and strikers. After these strategies are implemented, they will be simulated against each other and the position of the ball will be continually tracked. With the results of this simulation, a coach is able to effectively decide a strategy suited to fit the current phase of the match. This way, the coach is able to increase the overall performance of the Dutch Nao Team considerably. This increase is measured by the average position of the ball on the field.

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Contents

1 Introduction

"*People have expectations of me but I'm not a magician.*"
- Ruud Gullit (Dutch coach)

The coach, standing at the sideline and giving strategic positioning advice to the field players, is a vital part of a normal soccer team. This coach uses its judgement to change the role of the field players by, for example, changing a defender to a striker, based on the developments of the game. Currently, a coach is not yet allowed in the SPL (Standard Platform League), but in July of this year, coaches will be allowed to participate in the world championship in Brazil for the first time. The purpose of this coach is to observe the game from an external position and to give strategic advice to its team. This coach is a NAO robot just like the players in the rest of the team.

The SPL is one of several leagues within the RoboCup, an international competition with autonomous robotic soccer matches, where the matches played in the SPL consist of teams competing with NAO robots. Teams of five NAO robots play against each other on a $9 \times 6m^2$ field. These NAO robots can communicate with each other and receive decisions of the referee, through WLAN.

The coach receives game statistics from the GC (GameController) about the ongoing match, this GC is a human-controlled interface apart from the field. The GC maintains game statistics about the match, such as: the amount of players in the field for both teams, the score, when a player returns to the field and the time that is left on the clock. The messages from the coach are relayed to the field players by the GC. These messages have a maximum size of 40 kilobyte and have delay of 8-12 seconds before they reach the field players. This reflects the intent that the coaching robot should make long-term strategic decisions instead of directly controlling the players. It is intended to display the coach's messages to the audience via the GC display. Therefore, these messages have to be translated to a human-readable format.

The coaching robot is not placed on the field but at the sideline, next to the GC interface. The coaching robot may either sit on the table or in a seat. For safety reasons, it is not allowed to move (except for its head and arms) or to enter a pose different from ordinary seating. Seats will not be provided by the organisers, but teams may bring their own seats or small platforms that have a maximum height of the seating surface of fifteen centimetre. Except for a backrest that is no higher than the sitting robot, no additional elements are allowed to be attached to the seats. The positions of the seats

are not specified in detail and might differ from field to field. However, at each field there will be marked coaching zones (one at each side of the GC computer) in which the coaching robots can be placed.

Coaches in soccer have access to many different strategies, however, the coach presented in this thesis will have the following three strategies at its disposal: offensive, defensive and neutral. To show that these are effective, these strategies will be simulated against the old Dutch Nao Team strategy. The main research question in this thesis is: could a SPL team play more effective when it switches from strategy during the match with the assist from a coach?

2 Related research

"*Without the ball, you cannot win.*"

- Johan Cruijff (Dutch coach)

Research on creating the most effective strategy in soccer has started since the foundation of the FIFA (the Fédération Internationale de Football Association) in 1904 [8]. The foundation of the FIFA has ensured that the same rules of soccer are applied everywhere.

Various game statistics, for example the number of goals, are essential factors for the coach to decide to switch between strategies during the game [1]. These game statistics also enable the coach to classify the behaviour of the opponent. If the strategy of the opponent is known, then the coach is able to adjust the strategy of its own team to counter that of the opponent [2]. The coach is required to know different strategic positions that are used by the teams in general. These strategic positions can be classified into three primary strategies: offensive, defensive and neutral. A defensive strategy consists of four defenders, an offensive strategy consists of four strikers and a neutral strategy consists of two defenders and two strikers.

The purpose of the defenders is to intercept the ball, and Kyrylov and Razykov show that the probability to acquire the ball is increased with better positioning [9]. In addition, Kyrylov and Razykov find that the optimisation of the formation of the defenders is influenced by the formation of the strikers of the opposing team. The purpose of the strikers is to score. Here, Kyrylov and Razykov argue that the following two prerequisites determine the success of the strikers:

1. Players must preserve formation and open spaces.

2. Attackers must be open for a direct pass and maintain a clear path to the opponent's goal.

In order for the three primary strategies to be implemented, all of the field players should be able to perform one of the three roles: goalie, defender and striker. The implementation of these roles has already been done by the B-Human team [4], but this has not been made public. The goalie, defender and striker have now also been implemented by the Dutch Nao Team, but this implementation holds true to the framework provided by the B-Human team. This implementation grants the coach the ability to dynamically change these roles, allowing the coach to alter the strategy of the field players in general [11]. A number of studies have shown arguments for choosing a certain strategy for a certain situation, however none of these studies have shown the influences of a coach in the SPL. The experiment in this thesis will show the practical challenges of a coach in the SPL.

3 Research Method

"*You have got to shoot, otherwise you can't score.*"

- Johan Cruijff (Dutch coach)

A suggested implementation for each of the three primary strategies, as stated in the previous section, are described in this thesis. Each strategy will decide its efficiency according to the other two strategies. In addition, the proposed offensive strategy show to be more effective than the strategy last used by the Dutch Nao Team.

3.1 Framework

As stated in the previous section, the software framework that is used by the Dutch Nao Team is designed by the German B-Human team [4]. The framework is able to control the NAO and commands to the NAO are hence processed through this framework. The framework consists of a simulator which is able to simulate a complete SPL match. The experiment described in this thesis uses the 2013 version of the B-Human framework. This simulation also has a GC that can be controlled by the console in the simulation. The commands used to operate the GC are:

1. gc ready : The field players go to their position in the field.
2. gc set : The field players are set to their positions.
3. gc playing : The match is starting.

Figure 1 shows the outline of the simulator in the framework. It shows the overall behaviour of robot1 and specifies the various states that robot1 could be in. These states are primarily: The state of the GC (This example: Playing), the role of the NAO (This example: Goalie) and the action that the NAO is performing (This example : WalkToGoal). Traditionally, the time duration of the states are shown at the far right of the behaviour, however in figure 1 this duration is not visible. The command console is presented in figure 1 at the bottom left. At the left side, the scene graph is shown in which each robot could be selected and the field seen in figure 2 could be shown.

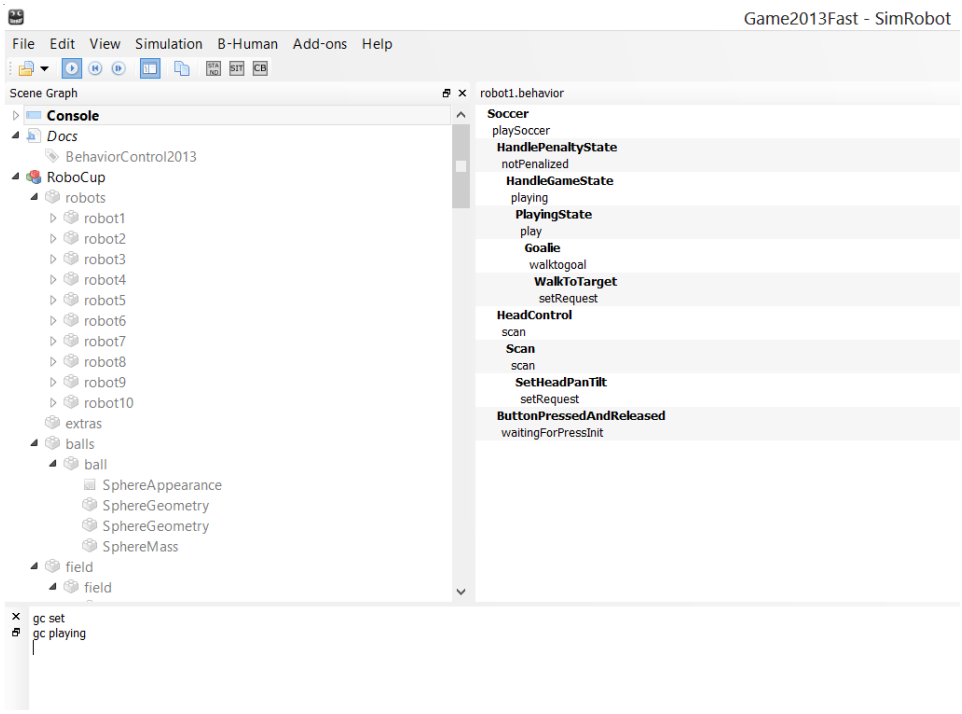

Figure 1: Outline of the Simulator

3.2 Strategies

The coach presented in this thesis will have the following three strategies at its disposal: offensive, defensive and neutral. Within these three strategies the individual field players can each perform one of three roles. Like said in the previous section, these roles are: striker, defender and goalie.

3.2.1 Roles

1. The striker : walks to the ball and kicks the ball in the direction towards the goal of the opponent.

2. The defender : stands at a given position on its own half if the field, if the ball is in a certain radius around it, then it kicks the ball away.

3. The goalie: stands in the penalty area of our teams goal, if the ball is in its radius, then it kicks the ball away.

These individual positions of the field players are adjusted within each strategy, otherwise the players will collide with other team members. However, the purpose of each role within a strategy remains the same. Each strategy consists of only one goalie, thus the remaining four field players are divided into the roles: striker and defender.

3.2.2 Offensive

The offensive strategy presented in this thesis fulfils the two prerequisites presented by Kyrylov and Razykov in 2008 [10]. The offensive strategy consists of four strikers each with a different distance from the ball. The strikers are always facing the ball.

1. The first striker walks to the position of the ball and kicks or passes it.

2. The second striker stands 1000 millimetres on the right side of the ball and is open for passes. If the ball is in a radius of 500 millimetre, then the striker walks to the ball and kicks or passes it. If 1000 millimetres to the right from the ball is behind the sideline then the striker will be standing 1000 millimetres to the left from the ball.

3. The third striker stands 1000 millimetres behind the ball. Thus, it will always stand behind the first striker and is able to launch counterattacks. If the ball is in a radius of 500 millimetres, then the striker walks to the ball and kicks or passes it. If 1000 millimetres behind the ball is in the penalty zone of our team, then the striker walks towards the ball and kicks or passes it.

4. The fourth striker is a mix between a striker and defender. The striker is always positioned at the centre line of the field and stands 1000 millimetres left of the centre of the goal. If the ball is in a radius of

500 millimetres, then the striker walks to the ball and kicks or passes it.

Each striker is positioned differently with respect to the ball, therefore the strategy consists of formation and open spaces. Because there are open spaces between the strikers, each striker is able to receive a pass.

3.2.3 Defensive

The optimising positions for defenders is influenced by the positions of the strikers of the enemy team, as concluded by Kyrylov and Razykov in 2007 [9]. However, the field players of the Dutch Nao Team do not yet have a correct algorithm for recognising enemy field players. Therefore, positioning the defenders while studying the positions of the strikers of the opponent is not possible yet.

All four defenders stand at the same X position which is 1500 millimetres from the ground line of the their own goal.

1. The first defender stands on a Y position 500 millimetres left of the centre of the goal. If the ball is in a radius of 500 millimetre then the defender walks to the ball and kicks or passes it.

2. The second defender stands on a Y position 500 millimetres right of the centre of the goal. If the ball is in a radius of 500 millimetre then the defender walks to the ball and kicks or passes it.

3. The third defender stands on a Y position 1000 millimetres right of the centre of the goal. If the ball is in a radius of 500 millimetre then the defender walks to the ball and kicks or passes it.

4. The fourth defender stands on a Y position 1000 millimetre left of the centre of the goal. If the ball is in a radius of 500 millimetre then the defender walks to the ball and kicks or passess it.

3.2.4 Neutral

The neutral strategy consists of both offensive and defensive players. The first two strikers of the offensive strategy play in the neutral strategy. The first two strikers do have the most influence on the meaningful points for strikers mentioned by the research of Kyrylov and Razykov in 2008 [10]. Therefore, the first two strikers are the most reliable of all four strikers to score. In addition, the first two defenders of the defensive strategy play in a

neutral strategy, these defenders are the closest two to the goal and therefore chosen in the neutral strategy.

3.2.5 Strategies in Simulation

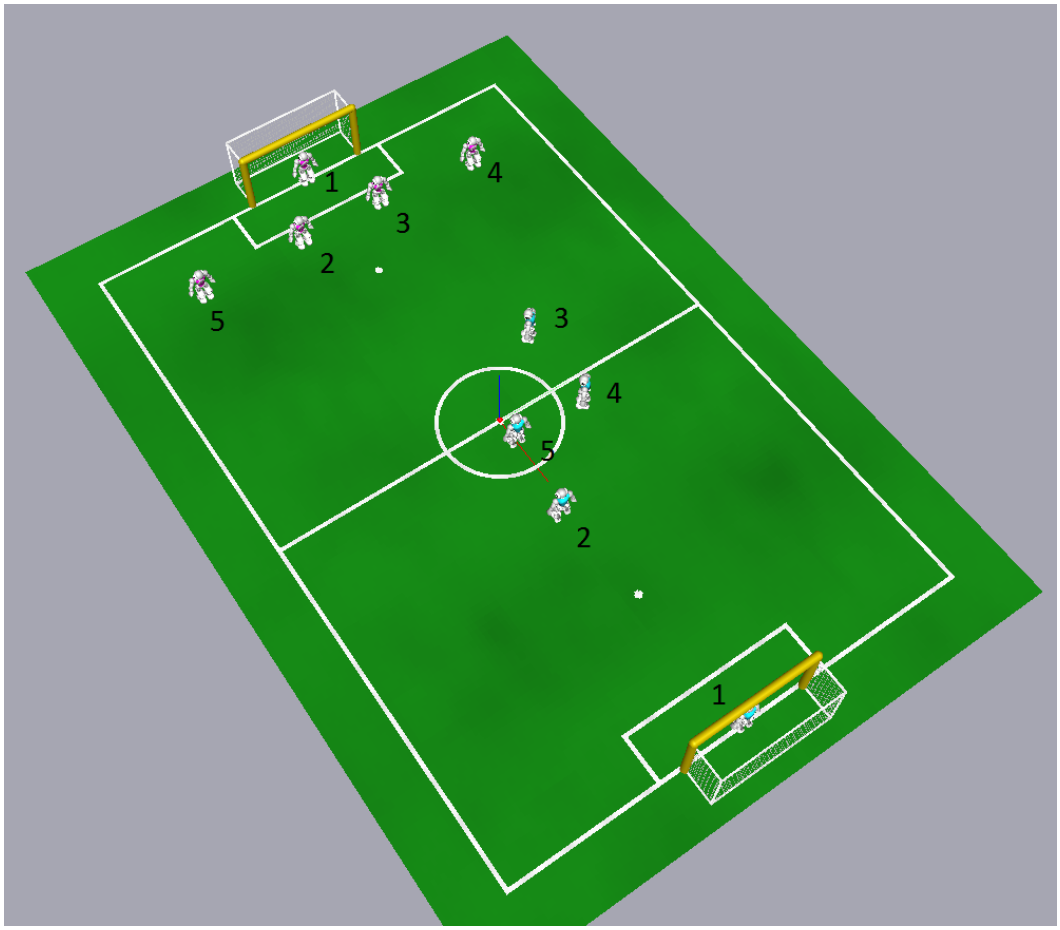

Figure 2: Offensive vs Defensive in the simulator

Figure 2 shows a picture of the simulation when team with colour Blue plays offensive and team with colour Red plays defensive. Within the simulation the NAOs in the field get an unique number in their team, this number is written next to the NAOs. As shown in the figure the NAO with number one always is the goalie. The first defender is assigned to NAO number two, the second defender to NAO number three etc. When playing offensive it is

the other way around, thus the first striker is assigned to NAO number five, the second striker to NAO number four etc.

3.3 Opponents strategy

Research done by Kuhlmann in 2006 [2] has shown that modelling the behaviour of an opponent is meaningful when the coach decides a strategy for its own team. Therefore, the coach is more effective when it can classify the strategy of the opponent. The coach decides with score, which will be delivered by the GC, which of the described strategies above is played by the opponent. The coach knows which strategy is effective against another strategy and it knows the strategy of its own team. Therefore, the coach knows with the score from the GC if the strategy of the opponent is effective or not against the strategy of its own team. The word effective in this sentence means that the score will be higher.

The finite-state machine of the coach is shown in figure 3. The results from the experiment within this thesis show what strategy is effective against another strategy.

Figure 3: Finite-state machine of the coach

3.4 The experiment

Primarily, the experiment consists of two parts: the strategy face-off and the reality check. Initially, in the strategy face-off each strategy described in this thesis will be simulated five times with a duration of 50 seconds against another proposed strategy. The X position of the ball is tracked each second within these matches. In the second part of the experiment the strategies show that they are more effective then the strategy last used by the Dutch Nao Team. Each of three strategies will be simulated five times with a duration of 50 seconds against the old Dutch strategy. The last game of the Dutch Nao Team was in Iran in April 2014.

4 Results

"To win you have to score one more goal than your opponent."
- Johan Cruijff (Dutch coach)

4.1 Strategy face-off

The figures 5-9 contain the simulation of five matches, however each graphic differ in the strategy that is used for both teams in the simulation. Each match appears in a various coloured bar in the graphics and the bars are stacked upon each other. Thus, the distance of the bars, which represent the matches, is cumulative. There are two different teams in the simulator, these teams are called the Blue team and Red team due to their colour in the simulation. At the start of each match the Blue team always kicks off. The strategy used by the Blue team always appears on the left side, thus it is Blue versus Red. The Y-axis in the graphics shows the X position of the ball. The different sizes of the field are shown in figure 4. The negative Y value in the graphics means that the ball is at the half of team Red, the zero line of the Y-axis is the half line of the field and a positive Y value means that the ball is at the half of team Blue. Positive Y-values indicate that the Blue team is losing. The X-axis shows the time, each match has a duration of 50 seconds and the players could be penalised for pushing another player, leaving the field and being inactive.

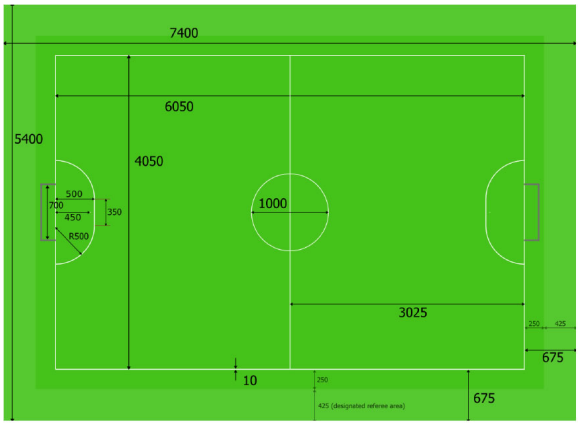

Figure 4: Size of the field

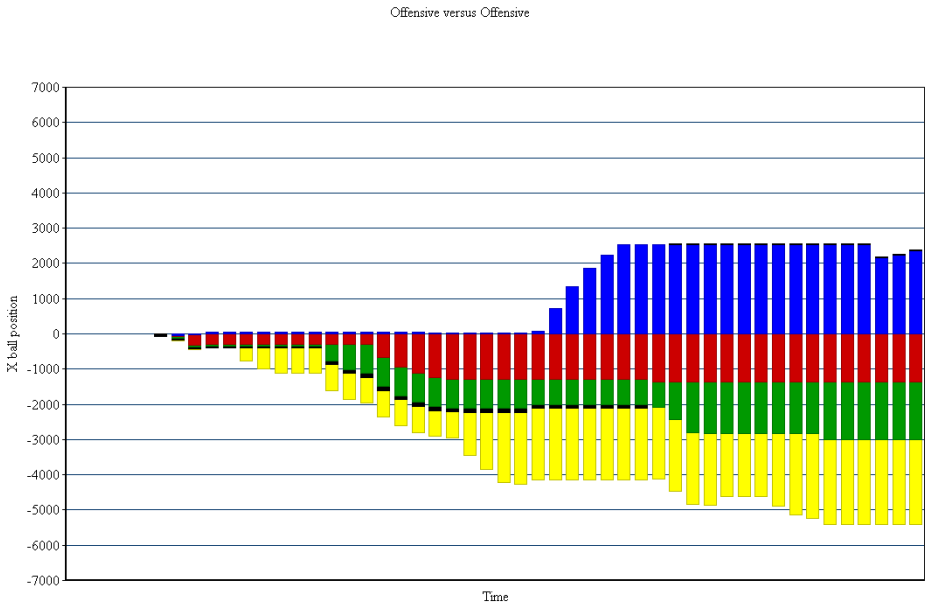

Figure 5: Offensive versus Offensive (cumulative)

Figure 5 shows the offensive strategy against the offensive strategy. There was not any player in the field penalised, also neither team Blue nor team Red had scored a goal. The negative values for the red, green and yellow game show that after the kickoff by blue the ball was the whole time of the match possessed by the Blue team. The match that is presented by the blue bar is an outlier, because the flatness of the graphic shows that the ball only was kicked once towards the goal at approximately 30 seconds by team Red. Obviously, by just kicking the ball towards the goal does not mean that any strategy is used. Therefore, the match showed by the blue bar does not show if the offensive strategy is effective against another strategy. As appeared in figure 5 playing offensive, when playing against an offensive opponent and while having kickoff, is effective.

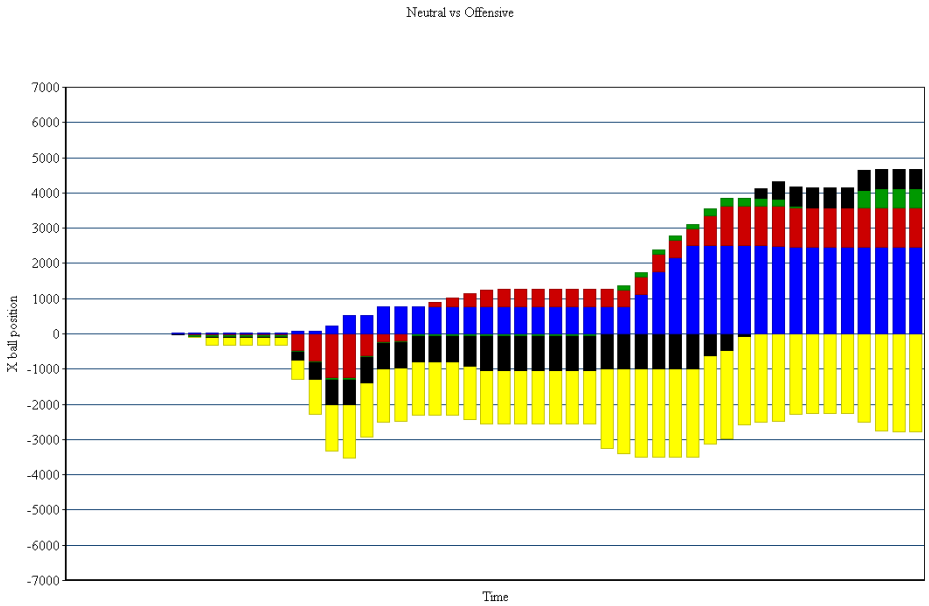

Figure 6: Neutral versus Offensive (cumulative)

Figure 6 shows the neutral strategy against the offensive strategy. There was not any player in the field penalised, also neither team Blue nor team Red had scored a goal. After the kickoff by the Blue team the ball was quickly confiscated by the Red team, however the Red team was not able to infiltrate the defense of the Blue team. There are two matches which are presented by the yellow and blue bar, which show that the defense of both teams is not waterproof and the ball appears in the penalty area. Figures 5 and 6 show that playing neutral against an offensive opponent while kicking off is less effective, than playing offensive in the same situation.

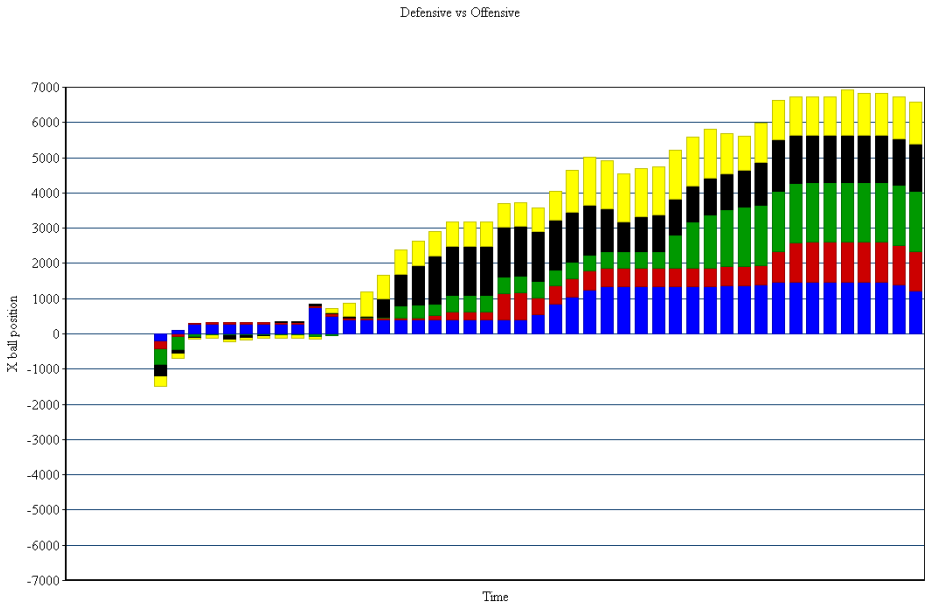

Figure 7: Defensive versus Offensive (cumulative)

Figure 7 shows the defensive strategy against the offensive strategy. There was not any player in the field penalised, also neither team Blue nor team Red had scored a goal. After the kickoff by the Blue team the ball was quickly confiscated by the Red team. The ball, after it was confiscated by the Red team, is at the half of the Blue team during the whole remainder of the playtime. However, the ball was obstructed at approximately 1500 millimetres from the goal of the Blue team due to the defenders of the Blue team. Defensive positioning has shown to be effective, because at approximately 1500 millimetres from the goal is the X position of the defense line.

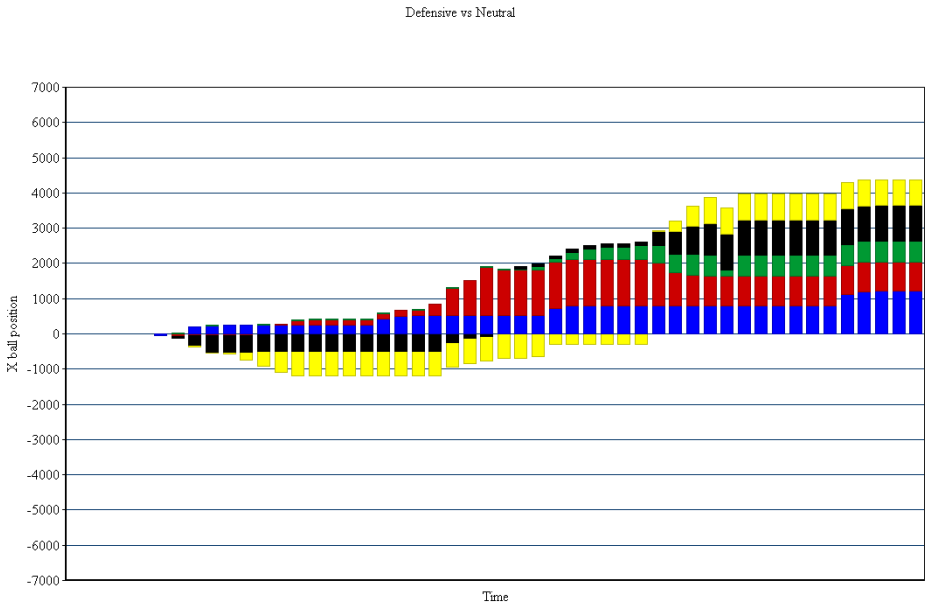

Figure 8: Defensive versus neutral (cumulative)

Figure 8 shows the defensive strategy against the neutral strategy. There was not any player in the field penalised, also neither team Blue nor team Red had scored a goal. After the kickoff by the Blue team the ball was quickly confiscated by the Red team. The ball, after it was confiscated by the Red team, is at the half of the Blue team during the whole remainder of the 50 seconds of playtime. However, the ball was in these matches slower confiscated by Red team then in the defensive versus offensive matches seen in figure 7. Because, the ball is slower confiscated, each striker in an offensive strategy will be effective in an attack.

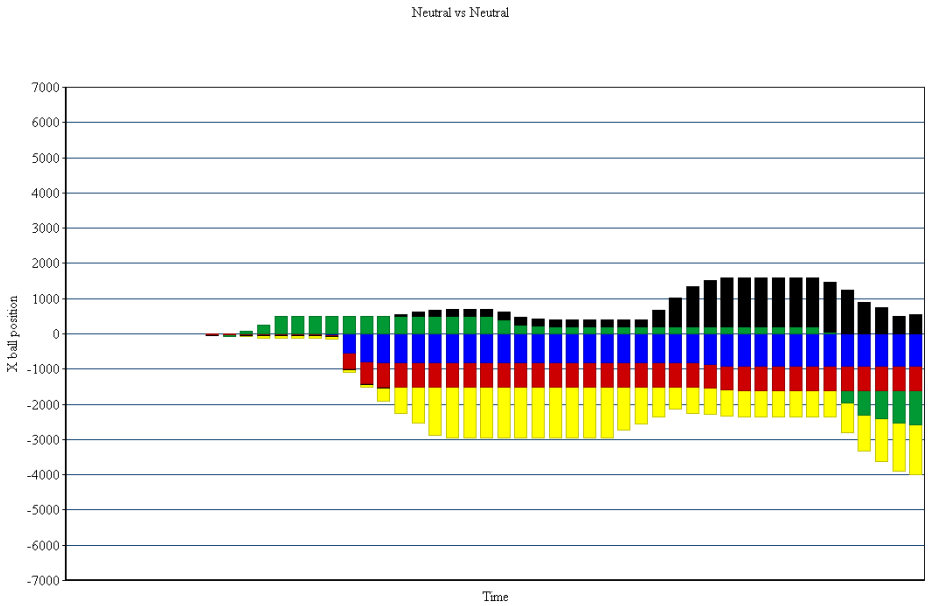

Figure 9: neutral versus neutral (cumulative)

Figure 9 shows the neutral strategy against the neutral strategy. There was not any player in the field penalised, also neither team Blue nor team Red had scored a goal. Figure 9 show a perfect balance between defending en playing offensive. The ball is both on the half of the Red team and the Blue team. However, the ball had never crossed the defense line during the matches. Therefore, the two members of the defensive which are pick for the neutral strategy are the most meaningful two within a defensive strategy. Because Blue had the kickoff most of the time the ball is on the half of team Red.

These graphics only show five of the eight face-off matches which are simulated, the remaining three give no new insights, therefore the results of the remaining three will not be shown and discussed.

4.2 Reality check

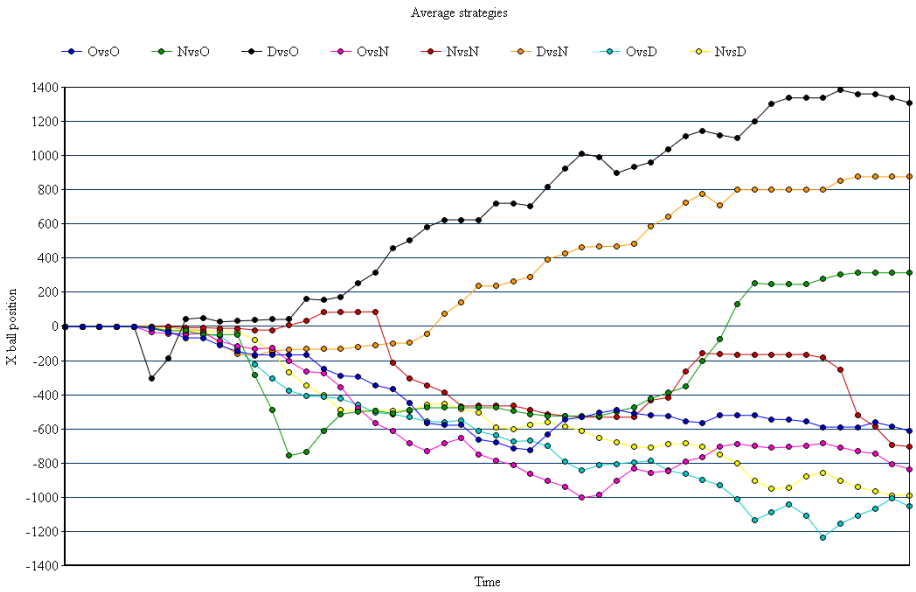

Figure 10: Average of all the strategy face-off matches

Figure 10 shows that the averages of the strategies are logically organised. When the team plays defensive the ball will always end at their own half. Thus, scoring while playing defensive is a long shot. Defensive versus defensive has not been showed in the average, because the ball will be kicked towards the player of another team, which will kick it back. After that the ball will be located in the middle of the field and the defenders are not close enough to reach it. Figure 10 shows which strategy is effective against another strategy with respect to the three strategies described in this paper. However, the question is if the strategies implemented in this thesis are effective in the SPL. The last game of the Dutch Nao Team was in Iran in April 2014. The team then existed of four strikers which all did perform the same behaviour as striker one described in this thesis. This behaviour is obviously classified as offensive due to the amount of strikers.

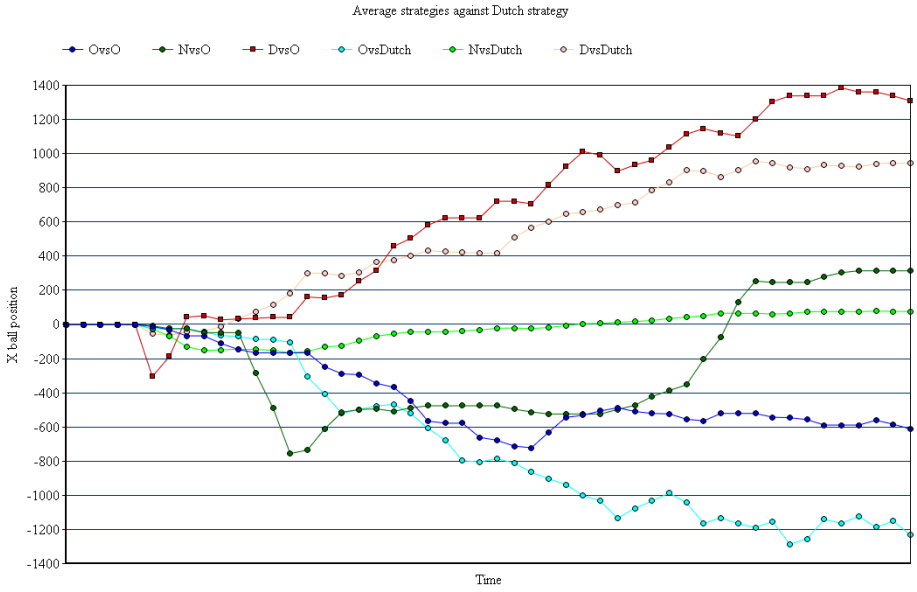

Figure 11: The average of the strategies against the old Dutch strategy

Figure 11 shows that when playing offensive the Dutch team is easier avoidable than playing against the offensive strategy. Playing neutral against the old Dutch causes not much action, all the player of the Dutch team align behind the ball and are trying to kick it away. However, the Dutch team was not able to avoid the two offensive players in the neutral strategy. Thus, the ball approximately stays in the centre of the field the whole match. A defensive strategy versus the Dutch team is not explicit different then the defensive strategy against the offensive strategy. As shown in this graphic the old Dutch strategy is less effective then the offensive strategy described in this thesis. However, maybe the old Dutch strategy is more effective when kicking off.

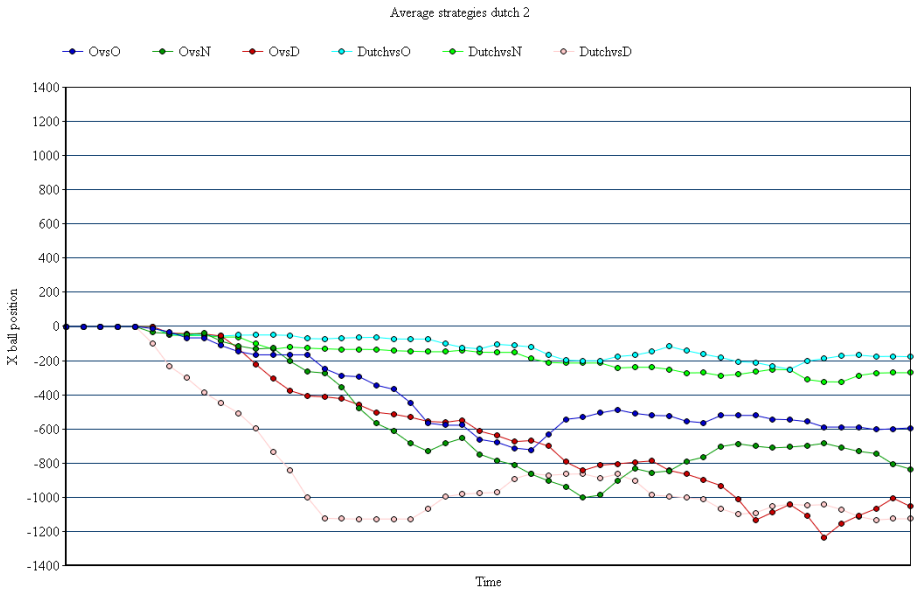

Figure 12: The average of the old Dutch strategy against the strategies

In figure 12 the average of the X position of the ball is shown when the Dutch does have kickoff. The figure shows that the Dutch team has a difficult time to launch an attack against the neutral and offensive strategy. There is no real strategy in the Dutch team this is also when playing against a defensive strategy. The steepness of the graphic shows that the ball will just be kicked towards the goal without correctly building an attack.

5 Evaluation

"*Behind every kick of the ball there has to be a thought.*"

- Dennis Bergkamp (Dutch player)

Figure 10 shows that playing offensive is only not effective when the opponent also plays offensive and the opponent kicks off. However, in the figures 5 and 6 show that playing offensive is risky, because the opponent could outplay the strikers of our team and after that there is not one defender to block a counterattack. The coach will therefore only play offensive when the team is losing. If the score is the same then the coach will decide for a neutral strategy. When the team is winning it will take on a defensive strategy.

Figure 10 shows that switching between different strategies could be effective. As the coach only reacts to goals, be it on his side or that of the opponent, the team will by default start with a neutral strategy. Therefore, when facing an offensive opponent, the probability that the opponent will score first is high. However, after this first goal the team will switch to play offensive as well, which will probably result in a goal for the team, according to figure 10. This means that switching within the match is indeed important, which is also proven by MacAlpine in 2013 [11]. However, MacAlpine did not show which strategy is effective against another strategy. Also, the offensive strategy implemented in this thesis prove to be more effective than the strategy of the Dutch Nao Team. To show this increase in efficiency, the average position of the ball in the old Dutch strategy is subtracted from the average position of the proposed strategies, which is divided by the average position of the old Dutch strategy.

$$\frac{AverageStrategies - AverageDutch}{AverageDutch} \times 100\% =$$

$$\frac{(OvsO - OvsDutch) + (NvsO - NvsDutch) + etc.}{OvsDutch + NvsDutch + etc.} =$$

$$\frac{304 - 146 + 117 - 104 + 372 + 251}{689 + 89 + 585 + 743 + 183 + 134} \times 100\% = 32,85\%$$

The Dutch Nao Team, when implementing the strategies proposed in this thesis, plays 32,85 percent more effective according to ball position than it did with their old strategy. In addition, the team's last offensive strategy with four strikers did not take the primary offensive prerequisites proposed by Kyrylov and Razykov [10] into account.

6 Discussion

"*Every disadvantage has its advantage.*"

- Johan Cruijff (Dutch coach)

Generally, one would derive the performance of a team by the amount of goals it had scored in a fixed set of matches. However, in the world championship in Istanbul in 2011, the Dutch Nao Team scored only once in a total of six matches. The only time they scored was because an opposing player had kicked the ball in his own goal [4]. Therefore, in this experiment the average ball position was taken to show the effectiveness of the implemented strategies instead.

The results clearly show the differences between playing with respectively four, two and zero strikers. However, the efficiency of the amount of defenders cannot be derived from the data. In the figures 7 and 8 the ball does not cross the 1500 millimetre line, which is exactly where the defenders are standing. Unfortunately, this is the only statistic available to derive anything about the efficiency of the defenders, which is not enough to draw any solid conclusions.

The connection between the real NAO and the GC of 2014 programmed by the B-Human, is not yet established by the Dutch Nao Team. The NAO receives the message from the GC, because it shows the corresponding colour code with its LEDs and the GC then shows the corresponding message via its display. However, the NAO does not change its behaviour like it should according to the messages. The connection between coach and its field players will be established after the championship by the Dutch Nao Team. The Dutch Nao Team will concentrate on the technical challenges at the SPL world championship.

7 Conclusion

"*Losing is not in my vocabulary.*"

- Ruud van Nistelrooy (Dutch player)

As shown in this thesis the coach is indeed as important in the SPL as it is in soccer. As seen in the evaluation within this thesis, the dynamic strategies of the coach will perform better than the static strategy of the Dutch Nao Team. Both the Blue and the Red team were not able to score during the match, but, the X position of the ball turned out to be a good estimation for scoring. In addition, the X position of the ball shows the maximum kick intensity, thus the distance the ball will cover in one kick. This is approximately 1200 millimetres, thus scoring when the ball is more than 1200 millimetres from the goal is a long shot.

The offensive strategy described in this thesis is 32,85 percent more effective than the old strategy of the Dutch Nao Team. Therefore, upgrading the team to the aforementioned offensive strategy has a positive influence on the overall performance of the team. In addition, with the X ball position in mind, the coach could classify the strategy of the opponent in less time and can therefore switch before the opponent scores.

Not only the strategies implemented in this thesis will increase the overall performance, but also, as shown in the evaluation, switching between strategies during the match does so. The strategies coined in this thesis are a good baseline for the coach and are working effectively in the SPL, however future research can increase this efficiency.

8 Future Work

"*You only stop learning when you quit.*"

- Ruud Gullit (Dutch coach)

8.1 Individual performance

Previous research done by Kyrylov and Razykov in 2007 [9] has shown that it is more likely that the defenders will intercept the ball when knowing the positions of the strikers of the opposing team. More roles could also be implemented, such as for example, a midfielder. In addition, the individual performance of the NAO could be updated, for example, the NAOs in the field were not able to dribble with the ball and passing to another player was not very accurate. Therefore, when the individual performance of the NAO is updated, the strategies become more valuable for the team.

8.2 Strategies

The amount of strategies could also be increased, for example one striker, three defenders and one keeper. If there are more roles implemented, the amount of different strategies could also be increased. The experiment in this thesis only shows the strategies during the kickoff, but not the effectiveness of switching strategies during play. Further research could strive to show the efficiency of switching during play.

8.3 NAO

The coach is effective in the simulation within the framework, however, in reality the coach should be a NAO. In the SPL the coach should not listen to the GC but rather decide a strategy according to its own vision. With this vision, the NAO could perceive the position of the ball and the game statistics by himself. Figure 13 is a model which shows the approximate view of the coach, however the NAO has a much smaller point of view.

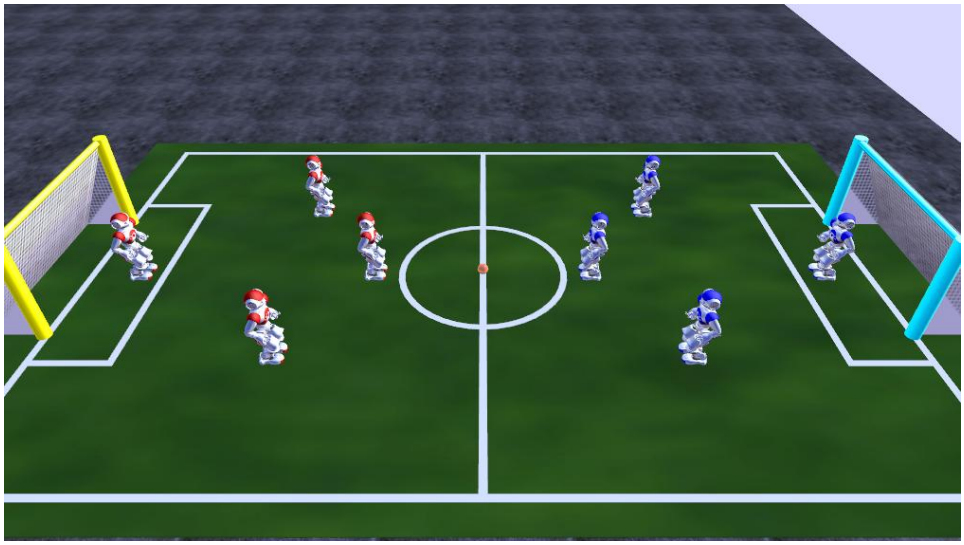

Figure 13: View of the coach

8.4 Learning strategy

The feedback algorithm of the coach could also be updated. The coach is now changing its strategy according to the score, however changing the strategy quicker could have a more positive influence for the field players. By looking at the position of the ball, the opponents strategy could be quicker classified and, therefore, the coach could be more effective.

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