FC PORTUGAL 2003 SHOOT EVALUATION BASED ON GOALIE MOVEMENT PREDICTION

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Abstract: This paper describes an evaluation method for shots on goal based on goalie movement prediction that was used by FC Portugal simulated robotic soccer team in RoboCup 2003. The paper discusses and explains the theoretical background and implementation of such evaluator and presents results showing the usefulness of this approach.

Keywords: Multi-Agent Systems, Opponent Modeling; RoboCup; Simulation

1. INTRODUCTION

RoboCup is an international initiative that aims to motivate the research on multi agent systems and intelligent robotics (Kitano *et al* 1995). Every year RoboCup organises scientific meetings and world robotic competitions in the fields of robotic soccer and robotic search and rescuing. Some competitions use simulated environments while others use real robots.

In the soccer simulation league 11 autonomous agents of one team play against 11 opponent agents using the soccerserver simulator framework. This simulator models several real-world characteristics like noise, limited angle of vision, low-bandwidth communication, limited stamina, etc.

In a (simulated) soccer game, a team that does not score will most definitely be a losing team. Even though if in every other game situations the team's behavior is excellent, if it cannot score, then it can never win a game.

By analysing the logs of the final rounds of the last RoboCup World Cup (Padova 2003), it becomes clear that the games of the RoboCup Simulation League have been increasing in team play complexity (especially between the best world teams), which means more spectacular games, but also tougher games, with less goal opportunities against stronger defenses. The player's individual skill has also grown considerably with players dribbling very well the ball and passing it with precision.

In this scenario, goal opportunities cannot be lost: if the player can score, then he must score! There are no second opportunities, and an unsuccessful shoot means loosing the ball control and moving from an attacking situation into a defensive situation.

This paper discusses an alternative to an already existing shoot evaluation mechanism in FC Portugal robotic soccer team. This proposal does not guarantee that every shoot made by a player will be successful. It simply claims that if a player can score, then it will not miss, but if a player cannot score and there is no other good move for him, then he will choose the shooting angle that gives the best scoring chance.
Throughout this article we assume the reader has good knowledge about the RoboCup initiative (Kitano 1995) and soccer server (SServer 2003) and basic knowledge of artificial intelligence and real soccer.

The FC Portugal players are already capable of (Reis, Lau and Oliveira 2001, Reis and Lau 2001, Reis and Lau 2002):

- Flexible team strategy composed by tactics, formations (used inside tactics) and player types to be used in different game situations;
- Extensive use of the concept of player type defined at three different behaviours levels (strategic, ball possession and ball recovery);
- Distinction between strategic and active situations;
- Situation based strategic positioning mechanism;
- Dynamic positioning and role (player type) exchange mechanism based on utility functions;
- Intelligent communication based on teammate modelling and on a communicated world state;
- Intelligent perception through a strategic looking mechanism based on utility functions;
- Integration of soccer knowledge on the positioning mechanism, ball possession decisions and ball recovery decisions;

- Very strong kick based on online optimisation;
- An intelligent goal keeping strategy for 2D soccer;
- Marking techniques based on teammate modelling and
- An agent architecture, multi-level world state and high level decision module capable of supporting this approach.

With this work, the FC Portugal player will also be capable of correctly evaluating a good scoring chance accordingly to a new model: the goalie movement prediction model.

This paper has five sections, being the first this introduction, where the problem of correctly evaluating a possible shot is introduced. Section two discusses some related work in the area. Section three describes the new shoot evaluation approach, the several steps and models behind the algorithm. The presentation and discussion of results takes place in section four, and finally, section five presents some conclusions.

2. RELATED WORK

In the field of shoot evaluation it must be referred the optimal scoring model (Kok, Boer and Vlassis 2001) developed for UvA-Trilearn team. In their work, the shoot evaluation problem is divided into two sub problems:

- Determine the probability that the ball will enter the goal when shot to a specific point in the goal from a given position; and
- Determine the probability of passing the goalkeeper in a given situation.

Both of these sub-problems are solved based on mathematical models of non-white noise that was parameterised with values obtained by experimental methods. After computing these two values, the real probability of scoring is given as a product of them both.

The optimal scoring model used requires the position of both the shooting player and of the goalkeeper, as well as the shooting position.

The use of ideal models of opponents as a tool for the decision process has also been experimented in (Stone, Riley and Veloso, 2000). They tried to model opponent ideal behaviour in order to preview opponent actions and better select own actions. This technique has been applied to the goal-scoring objective.

3. THE FC PORTUGAL SHOOT EVALUATION APPROACH

3.1 Background

In order to successfully predict a future situation, several parameters must be analysed and computed. The first task is to determine objectively which parameters are really needed to predict the best goalie movement possible given the current situation.
At the shooting time, the player must have some information about the opponent goalie (position, velocity and direction). He also has information about the ball's current position and velocity.

Based only on this information, the player must be able to predict all of the goalie's movement in case of a shoot at a given position in the current cycle. This prediction has to be the more realistic possible, so the player must bear in mind that the goalie will only know the shooting target position in the next cycle (at best).

Accordingly with the information available, the goalie's movement prediction must be analyzed in two steps:

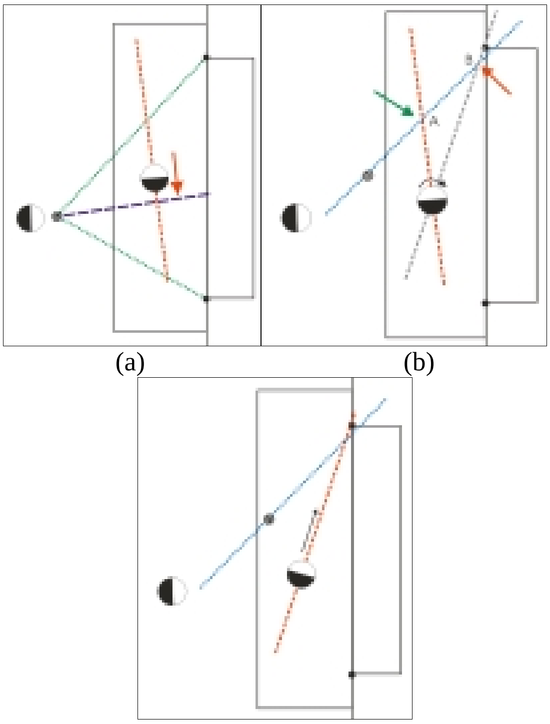
I. What will the goalie do at the shooting cycle and
II. What will the goalie do after he knows to where the ball is going.

This prediction based mechanism is only interested in evaluating the probability of the goalie catching the ball. FC Portugal uses more evaluation parameters to correctly evaluate a shot on goal. However, a correct evaluation of this probability makes this parameter the most important, with a very considerable weight of the total action score. An illustrative scheme of the goalie's movement prediction can be seen in Figure 1.

3.2 High Level Algorithm

The main algorithm is iterative, where each iteration represents a cycle prediction movement of both goalie and ball. At the end of an iteration, the information about both goalie and ball is updated, in order to prepare the next cycle. In the beginning of each iteration, the probability of the goalie catching the ball is calculated, based on the distance of the goalie to the ball. Because of all the different errors existing in a simulation game, the distance calculated is multiplied by the confidence that the player has on the goalie position. This distance is used to compute the cycle probability of the goalie catching the ball. This is obtained using equation 1. This equation gives the cycle's goalie catching probability factor: *probability_decay* is the speed at which the probability must decrease according to the distance of the goalie to the ball (*dist_ball_goalie*) and *max_prob* is the initial probability value. The value obtained is added to the value given by the remaining algorithm iterations. The prediction stops if at least one of the following conditions is verified:

- The ball's speed is lower than a given threshold;
- The probability calculated is 1.0;
- The ball crosses the goal line (inside or outside the goal).



(a) (b)

(c)

Figure 1 - Goalie movement prediction. (a) Before Shoot; (b) First cycle after shoot; (c) Goalie running.

$$cycle\_probability = probability\_decay \cdot dist\_ball\_goalie + \max\_prob \quad (1)$$

The internal loop algorithm is, as discussed in section 3.1, divided into two steps. The high level algorithm of each of the defined steps is discussed in the next sub-sections.

3.2.1 Step one

The first step of the prediction algorithm refers to the goalie action at the shooting time (cycle 0). At cycle 0, the goalie does not know to where the ball will be shot, if it will be shot at all, therefore, he must place himself in the goal in such a way that he can cover most of it. So, at cycle 0 the goalie will try to align himself with the bisection line of the angle formed between the ball position and the two goalposts. The aligning algorithm is as follows:

- If the angle between the goalie and the bisection line is not near 90º (or 180º), then the goalie's predicted action will be to turn to such angle, or at least to the angle that enables him to get to goalpost most near of the ball just with dashes. This condition is only valid if the difference between the new direction and the old has some relevance.
- If the angle is good, than the player will only have to decide if the goalie will go front or back, depending of his present direction, or if he will stay at it's current position, whatever puts him closer to the bisection line.

This behaviour makes step one independent of the position to where the ball will be shot.

3.2.2 Step two

At second step, the player assumes that the goalie will see the ball moving and can now calculate the correct direction that it has taken. Therefore, the goalie's natural movement will be to try to catch the ball as fast as possible.

The sequences of moves that the player predicts the goalie will make are either:

- a sequence of dashes or,
- one turn and then a sequence of dashes.

This is the most realistic approach to the defense method used by the goalies. The turn of the second sequence cannot be replaced by a turn in step one because only in step two the goalie knows where to the ball is going. The above sequences are not restrictions of the algorithm, but simply results of it; i.e. the algorithm checks what the goalie can do at a given cycle, and if he thinks that the player will not get the ball considering the present direction, then the predicted move will be to turn to a better intersection direction, but only if the new direction is really better, that is, the goalie can catch the ball with the new direction, or at least gets to the intersection point in less time.

3.3 Prediction models

The prediction mechanism can be very computational intensive if the models used have more information than the one really necessary. This section describes the three models used in the prediction mechanism.

3.3.1 The goalie model

The goalie model used considers the players as dynamic objects with position, velocity, direction, velocity decay and maximum acceleration that can be made. The model does not take into consideration other characteristics such as: the looking direction, stamina, effort, or player's turning momentum and turning limitations. Though this can be seen as a huge simplification, it still gives the goalie a big realism, and the results obtained based on this model are very similar to the real goalie's movement

3.3.2 The ball model

The ball model used is the same of the server: the ball starts with a given direction and speed, and in each cycle it's speed is reduced by a given factor.

3.3.3 The player's shooting model

The player that shoots the ball is considered only to set some of the initialisation parameters of the algorithm. Even though the player knows how he wants to kick the ball and with how much power, since there are always error factors associated to both player and ball, it is most likely that the player will not be able to shoot the ball at maximum speed. One other characteristic to have in mind is the player's kick_rand factor; this factor must be incorporated in the prediction result.

Figure 1 represents the predicted movement of the goalie. In each part the image shows the ball (small dotted circle), the goalie and the shooter (big circles, with one half white – the front side - and the other black). The big rectangle is the small goal area.

The first part (a) represents the step one of the algorithm. Even though the goalie doesn't know to where the ball is going, he must place himself in the best possible position: as closest to the bisection line (blue line) as possible. The red line represents the goalie direction and the green lines are the ball-goalpost lines. Since the angle between the goalie direction and the bisection line is about 90º, then the player will try to get closer to the bisection line by dashing backward.

Part b represents the cycle after the player shoots the ball (the beginning of step two). The shooter thinks that for not being able of getting to the ball on time if continuing in the present direction (point A, pointed by the green arrow) the goalie will turn to the most far-end position that enables him of catching the ball before she goes into the goal (point B, the red arrow). If for the time gap given by equation 2 is bigger than a given threshold, then the shooter believes the goalie will continue to point A.

$$(ballTimeToA - goalieTimeToA) - (ballTimeToB - goalieTimeToB) \quad (2)$$

Part c represents the remaining of step two. The goalie will desperately try to catch the ball by dashing forward.

This 3 part scheme has not been generated by any computer program, and it meants to be a demonstration on how the movement prediction algorithm works, so relative velocities shown can be erroneous, but still illustrative of the general idea.

3.4 The shooting evaluator

After computing the probability of the goalie catching the ball, the player can finally evaluate a possible shoot. Each possible shoot is evaluated as follows:

- Determine goalie catching probability;
- Determine ball going out of the goal bounds probability
  - This parameter highly dependent on the player's kick_rand factor and the shooting angle;
- Determine the possible interference of other opponents in two phases:
  - At the shooting place;
  - Throughout the ball path to the goal;
- These parameters are then added in a weighted sum, where the goalie catching probability has a very heavy height (about 50%).

The player then decides from a set of actions the most suitable to be performed, which enables the player to still make unsuccessful shots, but only if there is no other best action.

4. RESULTS

This evaluation method has proven to be effective in all the tests made. A first release of this algorithm was used during RoboCup2003, with fair results, but still with some implementation flaws. The release now made has improved enormously the scoring/shooting ratio.

In order to take the necessary statistics of the effectiveness of the shoot evaluation method developed, four one on one games took place (just one attacker against one goalie), all against the UvA 2003 goalie. The one on one strategy was chosen to prevent additional noise to the experiment. The noise would result from the interaction with other players (teammates or opponents). The server parameters were also changed, to disable stamina losses, so every shoot attempt could be considered independent from the previous. Each experiment consisted on 6000 cycles time, in which the ball was placed around the goal area by a human operator. The operator only interfered in the play when the play mode changed from play_on. The attacker was chosen by the coach to allow different heterogeneous players to be tested. The results from the four games (two with the evaluator of FC Portugal 2002 and two with the new shoot evaluator) are shown in

In FC Portugal 2002 Shoot Evaluator, the factor relative to the goalie catching the had a scale from 0 to 4, meaning 0, the goalie will catch the ball, and 4, the goalie will most probably not catch the ball. The FC Portugal 2003 Shoot Evaluator extended this scale by two values (from 0 to 6), and the same meaning. Tables 1, 2, 3 and 4 represent the number of shots made in each scale factor interval that whether hit the ball post, enter the goal, when out, or was catch by the goalie. Two other columns concern the number of times that the shot was catch by the goalie because of a world state error or a defective kick. A world state error occurs every time that a player decides he can shoot to a given position thinking that the goalie is at a position that is not his actual position. This usually happens when the player doesn't look at the goalie for some cycles, and the goalie continues to move towards the best covering point between the ball and the goal. In a simulation game, this situation would be very rare, since the teammates could say the correct position of the goalie to the attacker, but since the attacker is on a one on one game, he must rely only on his knowledge of the world state. The defective kick situation happens when the player misses the kick, i.e. after the shot, the ball's speed is considerably lower than the desired speed.

From the values on tables 1, 2, 3 and 4, one can extract some statistical analysis, such as the one

Table 1: FC Portugal 2002 Shoot Evaluator. kick_rand factor = 0.0507

Goalie Evaluation	Total shoots	Ball Post	Goal	Out	Goalie Catch	World State flaw	Defective Kick
3-4	56	1	22	19	14	0	8
2-3	17	0	5	2	10	0	0
1-2	0	0	0	0	0	0	0
0-1	1	0	0	0	1	0	0
Totals	*74*	*1*	*27*	*21*	*25*	*0*	*8*

Table 2: FC Portugal 2002 Shoot Evaluator. kick_rand factor = 0.0281

Goalie Evaluation	Total shoots	Ball Post	Goal	Out	Goalie Catch	World State flaw	Defective Kick
3-4	71	2	28	16	25	10	0
2-3	19	2	5	0	12	0	0
1-2	1	0	0	0	1	0	0
0-1	4	0	1	0	3	0	0
Totals	*95*	*4*	*34*	*16*	*41*	*10*	*0*

Table 3: FC Portugal 2003 Shoot Evaluator. kick_rand factor = 0.0219

Goalie Evaluation	Total shoots	Ball Post	Goal	Out	Goalie Catch	World State flaw	Defective Kick
5-6	31	2	16	1	12	6	6
4-5	5	1	1	2	1	0	1
3-4	2	0	1	0	1	0	1
2-3	3	0	0	2	1	0	0
1-2	0	0	0	0	0	0	0
0-1	10	0	3	0	7	0	0
Totals	*51*	*3*	*21*	*5*	*22*	*6*	*8*

Table 4: FC Portugal 2003 Shoot Evaluator. kick_rand factor = 0.0938

Goalie Evaluation	Total shoots	Ball Post	Goal	Out	Goalie Catch	World State flaw	Defective Kick
5-6	25	2	13	0	10	4	5
4-5	8	0	3	2	3	0	1
3-4	5	1	1	2	1	0	0
2-3	3	0	1	0	2	0	0
1-2	0	0	0	0	0	0	0
0-1	4	0	1	1	2	0	0
Totals	*45*	*3*	*19*	*5*	*18*	*4*	*6*

Table 5: Joint table crossing the top evaluation results from the previous tables. For spatial reasons, FCP2002 and FCP2003 were used, instead of the FC Portugal 2002 or 2003 Shoot Evaluator

Shooter	Total Shots	Ball Post	Goal	Goalie Catch	Out	World State Flaw	Defective Kick	Effectiveness	Effectiveness without Errors
FCP2002	127	3	50	35	39	10	8	39,37%	45,87%
FCP2003	56	4	29	1	22	10	11	51,79%	82,86%

Table 6: The efficiency of a shoot based on a given goalie Evaluation

Goalie Evaluation	Effectiveness	Effectiveness without errors
5-6	51,79%	82,86%
4-5	30,77%	36,36%
3-4	28,57%	33,33%
2-3	16,67%	16,67%

found in Table 5. Since the scale value used on the two evaluators is different, the statistics collect are only of the maximum evaluation possible (interval 3-4 in FC Portugal 2002 and 5-6 in FC Portugal 2003). The *Effectiveness* column is accuracy of the shots made, and the *Effective without errors* represents the same accuracy if the World State Flaws and Defective Kicks were ignored. From the tables, the kick_rand factor can also be considered almost irrelevant, since the algorithm compensates the goalie catch probability regarding the kick_rand parameter which enables the attacker's behavior to be independent from this parameter.

As Table 5 shows, the new Shoot Evaluator is about 12% more effective than the old one. If the player's world state model was always accurate (or at least more not so imprecise) and the ball speed after a shot turned out just how the player planned, then the efficiency of the new shoot evaluator would almost duplicate the one of the old evaluator.

From Tables 3 and 4, one can easily calculate the effectiveness of a shoot made based on a given goalie evaluation (See Table 6)

From Table 6 results that if the goalie catch parameter is evaluated in a value from 5.0 to 6.0, then there is an 82% probability of scoring (or 51 % if the errors are to be accounted). More interesting is the fact that the 4-5 interval has a scoring probability near the 3-4 interval of the old evaluator.

5. CONCLUSION

First of all, there must be made a comparison between FC Portugal shoot evaluator model and UvA's optimal scoring model. The UvA model used for computing the probability of the ball getting out of the goal bounds is a far more theoretical approach than FC Portugal's, which is understandable giving the importance given to that factor by the UvA player.

As for FC Portugal's model, the most important factor is the probability of the goalie catching the ball. Therefore, its computing method is not purely mathematical but also conditional. Of course, one can (almost) always come up with a mathematical approach to a problem, but in this case, a mathematical approach would have to be very generic and would definitely result on a computing intensive operation. Another remark that must be done stresses the different goalie models used: UvA's model had only an initial position and was "*behavior independent*", in what concerns the goalie's own positional strategy. The FC Portugal's goalie model relied on several other parameters to insure that the goalie's positional strategy would be compensated by the shoot evaluation algorithm: goalie's speed and direction are two important factors that *must* be taken into consideration.

The results presented demonstrate that the performance of the Shoot Evaluator approach based on goalie movement prediction is better than the performance of his predecessors.

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