A Multi-agent Algorithm for Robot Soccer Games in Fira Simulation League

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***Abstract*— In this paper, we demonstrate the design and implementation of a multi-agent algorithm including a set of strategies for robot soccer games in *Fira [1] simulation league*. Soccer games are pseudo matches performed on a simulator for testing real-timedecision-making schemes for cooperative multi-agent systems. One of most important issues in the soccer game is how to pass a ball among teammates. Many proposed strategies [2][3], based on *reinforcement learning methods* [21] [22][23][24] or heuristic schemes to infer the possible risks and costs, do not consider ball passing as a multi-criteria optimum problem. To determine whether passing the ball to a teammate in the goal area, a multi-criteria decision-making strategy is proposed by considering the multiple criteria, the angle of the ball to the two goalposts, the distance between the ball and the goal, and the position of the enemies. As to the formation of a team, we introduce an idea, called *virtual forces* [18], to suggest the optimum positions of team players. The optimum positions will depend on the real-time conditions such as the ball position and the positions of all enemy players. To evaluate the proposed strategies, we take the team *UvA-Trilearn*[4], the world champion in 2002, as an opponent. The results show that the proposed strategies attain better performance than *UvA-Trilearn*.**

I. Introduction

The development of robots not only provide a great deal of business opportunities of technology industry, but also have great impact on areas such as national defense, security, house-living, medical treatment, rescue works, exploitation in deep ocean, etc. According to different applications, robots can have different contribution in different areas. One of the challenging issues in robotic research is the cooperation, coordination, and negotition among distributed agents in a multi-agent system. To speed up the developement on this challenging issue, a group of Korean researchers initiate a robotics soccer game called *Fira*. Later the league becomes a well-known world competition, called *Federation of International Robot Association(Fira)*. The simulation league in Fira is proposed for the research in the domain of multi-agent system. The game is performed on a program that we called *Fira Simulation Server* which is run on a UNIX-based workstation with UDP/IP protocol. Aother eleven independent client programs will be executed on the server as the players of a team during a soccer game. The server generates the soccer field and the physical environment involved in the soccer game in the virtual world. The clients have to take noisy information generated by the server into account and return commands back to the server in order to let players take actions on the field.

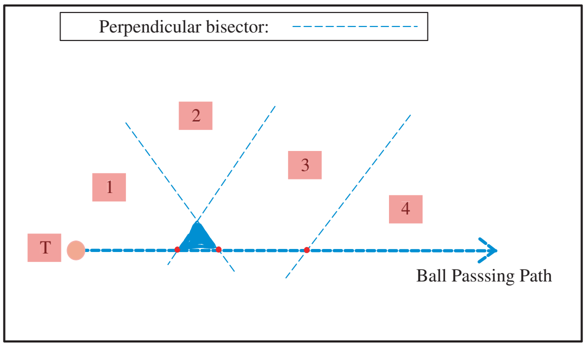

Fig. 1. Duty area arrangement for four agents

In this paper, we will develop a set of distributed strategy algorithms of robot soccer players on the simulator. The motivation is to employ a ready-made simulator and to bring out the way that each agent thinks independently under the multi-agent system, and then make the agents capable of cooperating as a team[5]. After researching lots of research works of related area, we realized how to build a real-time multi-agent system under *Fira simulation* [6], [7], [8] and its vision model, moving method, skill, etc [9]. We will make all agents run in server much more like a real man, and be able to think, compute, and execute instructions in the optimal way we endowed with. Here we include the concept of decision-making model [10], and then predict the possibility of a success kick by means of shoot-success model and decision making model. Defender goal is to ensure that all the robot soccer players map out their own path under the cooperation and find out the specific time of when to offense or defense[11], [12], [14], [17].

II. Review

A. Duty Area

In the reference paper [13], it provides a definite way to divide the soccer field into several areas, named duty areas, and each *duty area* is assigned to a player for catching or kicking the ball. The above way not only designates a player as the nearest one to the ball for approaching and catching/kicking the running ball but also prevents the farer agents from consuming too much stamina to go to the position of ball. In Fig. 1, three dotted lines from left to right represent the perpendicular bisectors of player 1 and 2, player 2 and 3, and player 3 and 4, respectively. It can be determined that player 2 doesn't have the responsibility to catch the ball if the intersection point of the two lines, the perpendicular bisector of player 2 and 3 as well as the ball passing path, falls the front of the intersection point of the two lines, the perpendicular bisector of player 1 and 2 as well as the ball passing path. In other words, the ball passing path doesn't across the duty area of player 2. On the contrary, the player 3 have the responsibility to catch the ball if the point that perpendicular bisector of agent 3 and 4 across the ball passing path falls behind the point that perpendicular bisector of agent 2 and 3 across the ball passing path. There is an exception case that player 1 and 4 always catch the ball because they locates at the first and the last areas in the areas intersected by the ball passing path.

We find that the proposed method incurs a problem as described below. By using this method, each player has the responsibility to catch or kick the ball which falls into the duty area assigned to the player. However, two players, player 1 and 3, will run to catch the ball at the same time if two duty areas overlap (e.g., the gray triangle area in Fig. 1). It might consume too much stamina of players for catching the ball. Another worse case is that the two players have no action when the ball stays the overlapped area because they think the other player will take care of this condition. Thus, the opposite players will possess the better chance to hold back the ball. As for the above-mentioned problem, we will give a solution by using the idea *Voronoi diagram* [2] [3] in Sec. 3.

B. Formation

As to the issue of transforming formation, the reference paper [19] divides the soccer field into nine areas. Players transform the offensive/defensive formations according to the position of the ball. In case of that the ball locates at defender goal area, the formation will be transformed to 4-3-3 defensive pattern (i.e., four backfielders, three midfields, three strikers), no matter whether our players hold the ball or not. The major mission is kick ball out of defender goal area. When the ball closes to opponent goal area, the formation is transformed to 3-3-4 offensive pattern (i.e., three backfielders, three midfields, four strikers). According to the ball locates at other seven areas, the current formations will be changed to the corresponding offensive/defensive patterns. The above method introduces the problem of *ping-pong effect*. The problem is that the offensive/defensive patterns will be changed frequently if the ball moves back and forth between two neighboring areas quickly. The effect will cause players to exhaust their energy due to frequently changing formations. To reduce the *ping-pong effect*, we will employ a buffer area, which is similar idea used in personal communication systems [20], as described in Sec. 3.

The reference [19] proposes a scheme for keeping a formation. One of the players will go to catch the ball as the player figures out that he is the fastest one reached the ball. All the other players will run to their tactic positions determined by the formation so these players may not give the well support or backup for the fastest player efficiently. Therefore, the formation can not keep in the best condition and the ball would be loss as well. We refer to the idea of *virtual force* proposed for sensor networks [20] in order to solve the problem. By making use of *virtual force* [18] to keep the formation, the players of a team can maintain a good offensive/defensive formation and cover each other more efficiently. The detailed scheme is presented in Sec. 3.

III. METHOLD

A. Duty Area

According to the method proposed by the reference [13], we find out the drawback that player 1 and 3 have a common area within their duty areas (the grey triangle area in Fig. 1) and the common area would induce the problem that two of the players will catch the ball at the same time or no one will catch the ball. To cover this problem, we propose a new method that divides the soccer field into several disjoint areas by using *Voronoi diagram* and each disjoint area is treated as a duty area assigned to one of team players. The detailed steps to construct a *Voronoi diagram* for the soccer game are given in the next paragraph.

First, we add three edges to these players as a triangle and find out the perpendicular bisector in each side of triangle as shown in Fig. 2. In the area that *Voronoi diagram* form, the duty area of player 1 is on the left below (Fig. 3), player 2 is on the top, and agent 3 is on the right below. Concerning the division of duty area, we provide a method of *Voronoi diagram* to divide duty area. By using the method, we can find out which player is chasing the ball through the duty area the player locates when a ball run forward to the ball passing path. However, there is a problem by using this method. When the ball passes through the duty areas of players, every player thinks that they should catch the ball and then pursues the ball. In this case, it might cause unnecessarily the stamina consumption of team members. Due to those reasons, we not only provide *Voronoi diagram* to divide duty area but also propose a method to judge the time that players get to the ball passing path. If players can get to the ball passing path and catch the ball, then players can move forward to the ball.

After catching the ball, the player must choose whether kick the ball (shoot or hold the ball) or pass the ball. When player T determines that his possibility of shoot-success is lower than other agents around him (Fig. 3) (the possibility of shoot-success for a teammate = the possibility of shoot-success for the teammate $\times$ the successful possibility that pass the ball to the teammate), he will pass the ball to whom has the highest possibility of shoot-success.

B. Formation

In the reference method of exchanging formation [19], the field is divided into nine areas. Players exchange formation

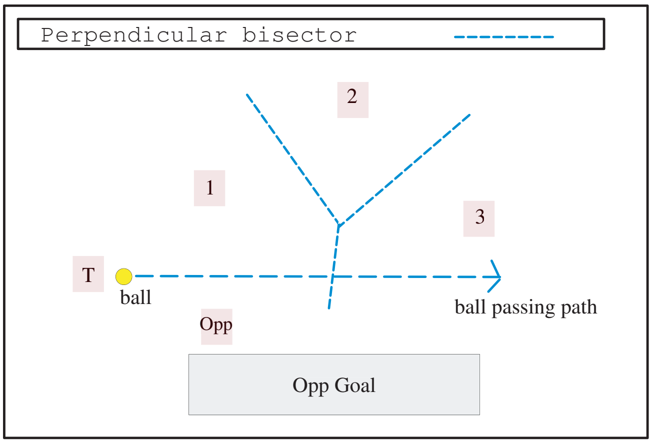

Fig. 2. Voronoi diagram

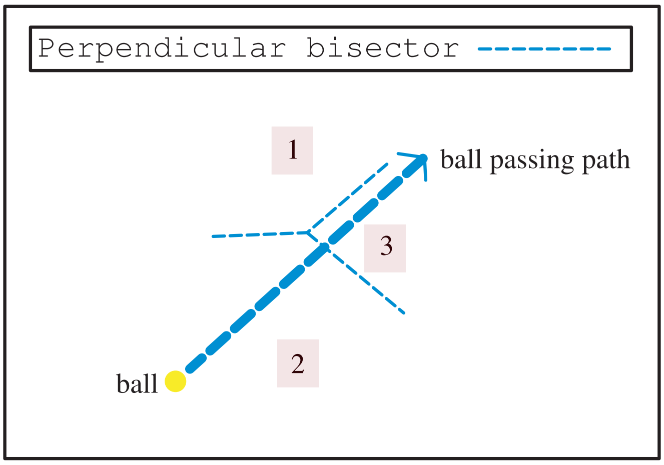

Fig. 3. Duty area

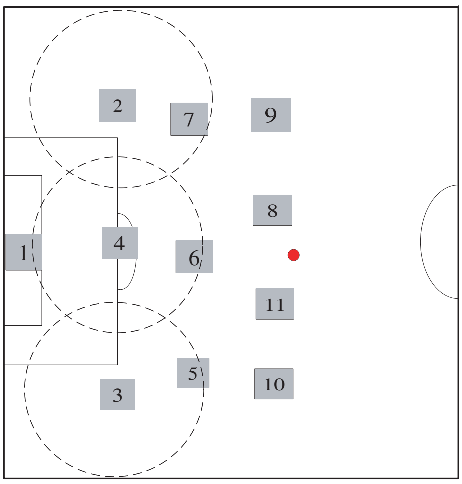

Fig. 4. When VFA radius is five meter, the illustration of duty area

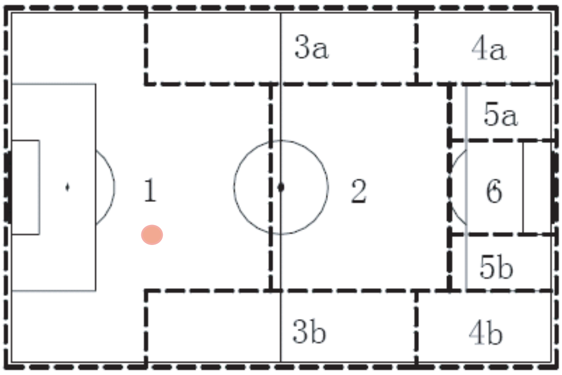

Fig. 5. The ball locates within defender goal area

according to the position of ball. If the ball locates within defender goal area(Fig. 5), the formation use 4-3-3 defensive formation (four backfielders, three midfields, three strikers) no matter which players hold the ball. The major mission at this time is that kick the ball out of defender goal area. When the ball closes to the opponent goal area, the formation exchanges to 3-3-4 attack formation (three backfielders, three midfields, four strikers). In other word, the corresponding formation will be formed according to the position of the ball. This type of methods will cause a serious problem, called *ping-pong effect* that players will keep changing formation and consume their stamina if the ball move back and forth between two areas. As for this problem, we will provide buffer area [20] as a basis to exchange formation in section 3.

Keeping formation of a team at any time will have the best chance for offense or defense. However, one of the team players will go to catch the ball while they figure out they are the fastest as well as the other players will run to their tactic positions to get ready. It might bring about only one player who close to the ball to get the ball, but other agents would not support them effectively. Therefore, the formation can not keep in the best condition and the ball would be hold back as well. This problem occurs in many references [15] [16]. For the purpose of keeping formation, we refer to the idea of *virtual force* [18] used in sensor networks in order to solve the problem. Making use of *virtual force* [18] to keep formation, and consider positions that agents stand can cover with each other or not. After we work out the *virtual force* among agents, we can get relative position of agents, too.

We divide the field into three parts like Fig. 6 so as to avoid separating too many areas. It might make agents keep changing formation. Consequently, the field is divided into defensive area (area A), attack area (area C) and middle area (area B). Area B is for agents to kick-off and hold-ball attack. In defensive area, we will adopt 7-3(Fig. 7 formation to defend to the utmost and kick the ball out of area A. We utilize 2-3-5(Fig. 9) formation in attack area. As for area B in the

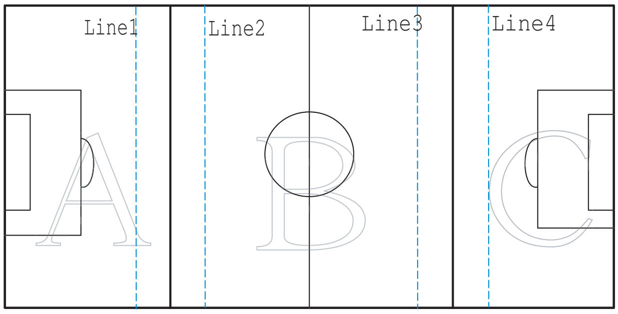

Fig. 6. Strategy based on area planning. area A is defender area. area C is opp area. area B is kickoff area.

middle, we use pre-set 3-3-4 formation of kick-off (Fig. 8). While the soccer approach to own-defense area, the number of backfielder adds to seven people, strikers are three people. When we attack to area C, the number of striker adds to five people. It is beneficial to own attack. The midfield kept in three people to support strikers to attack. As for mapping out the kick-off formation or holding back the ball, we stay 3-3-4 formation. Thus, agents would not decrease their space because of exchanging formation consequently. To reduce the times we change formation and *ping-pong effect*, we lead in a personal communication system and design an exchange area called buffer area[20]. If the ball keep moving in area A and B, the own agents will certainly continue changing formations. At this time, we provide a way of buffer area. As the ball move from area B to area A, the formation will stay the same as in area B unless the ball across Line 1 (Fig. 9). The ball approaches to defenders area field, we ought to adjust some values of *virtual forces*. While the ball approaches to own area A (Fig. 6), we should minimize the repulsion of *virtual force* among backfielders. Besides, we have to gather agents to defender goal area. Agents can kick the ball to area B as long as own backfielders or strikers catch the ball. In this way, we can relieve defensive crisis in front of the goal although the ball may catch by the opponents during passing the ball. In case that the position is out of own-defense area of area A but in area B, the possibility of losing points will decrease. The ball is in area B, at this time only kick-off and hold up the ball. In this formation, we can increase the repulsion of *virtual force*. When strikers hold ball to attack, they can get in the area C under the field or above the field. We will adjust the movement of shooting while get to the opp-goal area. In order to let agents can shoot densely in area C, we arrange midfielders behind strikers. If the ball is kicked back by opponents, midfielders can take care of the up, middle, and down area And also go to get the ball at once. The importance of backfielders here are going back to defend own-defend area in time. Consequently, we arrange backfielders in area B which near area A. Next, we utilize the duty area of *Voronoi diagram* to separate and select agents to attack.

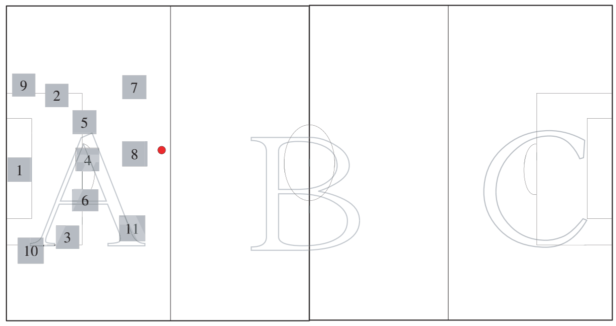

Fig. 7. Formation 7-3 is used if the ball fell in area A

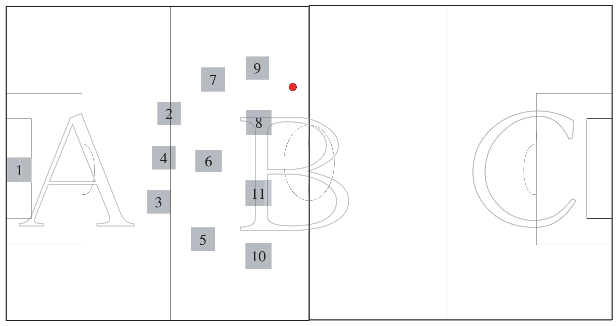

Fig. 8. Formation 3-3-4 is used if the ball fell in area B

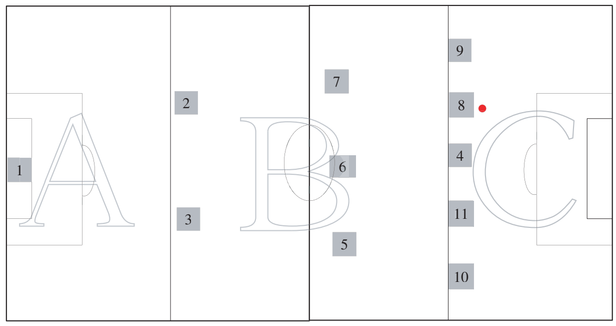

Fig. 9. Formation 2-3-5 is used if the ball fell in area C

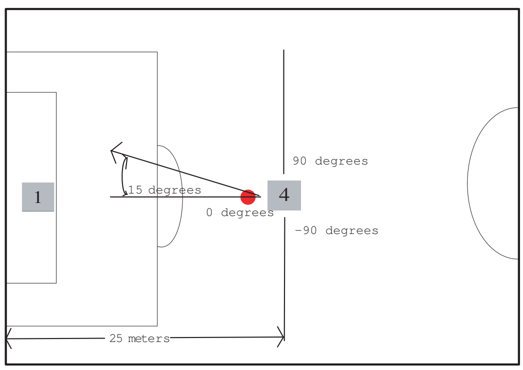

Fig. 10. The illustration of kick-angle. Player 1 is the goalkeeper, Player 4 is the shooting player. The clockwise angles are positive, the counterclockwise angles are negative.

TABLE I

DISTANCE BETWEEN BALL AND GOALLINE

Distance with goalline	distance with goalkeeper	kick angle	probability
20	10	5	0.86
20	10	10	0.85
20	10	15	0.88
25	10	5	0.68
25	15	10	0.54
25	15	15	0.17
30	15	5	0.32
30	15	10	0
30	15	15	0

IV. EXPERIMENT

In this section, we perform an experiment to learn the probability of shoot-success with various angles and distances. This may help us to design our algorithm. The experiment environment is set up on server on Linux Fedora 5 and use the program UvA-Trilearn [4] as the goalkeeper to defend the shooting player which is designed by us (Fig. 10). Then we make different experiments on shooting in front of goal, the distance to the goalline are 20 meters, 25 meters, 30 meters. Each time we pick 100 samples to analyze.

The statistics of experimental show that the probability of shoot-success will higher when the distance less than 25 meters and the angle to the goalkeeper is over 10 degree. With the distance of opp-goal become farer, the needs of angle will broader. When the distance to the goalline increases to 30 meters, the probability of shoot-success will decrease while shooting or the angle should be enlarged to 13 degree. Form these statistics, we try to calculate whether the player has the highest probability of shoot-success of all the players near him or not. If it is, the players start to shoot. We assume that our hold-ball players shoot directly, the soccer will possibly hold back by the opponent goalkeeper. Then we use our method to pass the ball to one of them (Player 1, Player2, Player 3) who has higher probability of shoot-success. Overall, the probability of shoot-success will highly increase.

V. CONCLUSION

In the paper, we propose a method to promote the shooting skills of players and utilize the way of *Voronoi diagram* to let players can judge where their duty areas are. Thus, players themselves and their teammates do not need to calculate the distance from them to the ball. It can avoid wasting periods during calculating. Players can calculate if they can hold back the ball in a short time or not and judge that whether the ball should be passed to themselves by teammates. Furthermore, we make use of buffer area to decrease the consuming stamina of team members while the formation of a team changes frequently. Finally, we compare the possibility of shoot-success and use the rule which the ball moving space is faster than players moving to raise successful opportunities of short-path passing. As to the future, we will put our emphasis on the methods to pass the ball and promoting the success possibility of shooting the ball.

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