A Study on Multi-Agent Behavior in a Soccer Game Domain

S. R. Mohd Shukri, and M. K. Mohd Shaukhi

***Abstract*—**There have been many games developing simulation of soccer games. Many of these games have been designed with highly realistic features to attract more users. Many have also incorporated better artificial intelligent (AI) similar to that in a real soccer game. One of the challenging issues in a soccer game is the cooperation, coordination and negotiation among distributed agents in a multi-agent system. This paper focuses on the incorporation of multi-agent technique in a soccer game domain. The better the cooperation of a multi-agent team, the more intelligent the game will be. Thus, past studies were done on the robotic soccer game because of the better multi-agent system implementation. From this study, a better approach and technique of multi-agent behavior could be select to improve the author's 2D online soccer game.

***Keyword*—**Multi-Agent, Robotic Intelligent, Role Assignment, Formation.

I. Introduction

ROBOT soccer is a challenging platform for multi-agent research. It involves topics such as real-time image processing and control, robot path planning, obstacle avoidance and machine learning [1]. Since the inauguration of the FIRA Microsoft competition in 1996 and the RoboCup competition in 1997, robot soccer games had been popular among the educational institutions around the world. Other than providing business opportunities in technology industry, the development of robots has also been widely used in security, medical treatment, national defense, exploitation in deep ocean, etc.

One of the challenging issues in robotic research is the distributed agent in cooperation, coordination and negotiation, named the multi-agent behavior. In a collaboration team, the agent needs to act autonomously and effectively in a required complex and dynamic workplace. These agents need not only act at an individual and collaborative skills but must also accurately perceive and act upon a quick changing and noisy environment.

The objective of this paper is to investigate past research work done on the cooperation of the multi-agent robot soccer game domain and to illustrate how the study can improve a simple 2D soccer game. The rest of the paper is organized as follows. Section 2 presents a survey on the previous and existing research on multi-agent behavior in the robot soccer game domain. Section 3 discusses the main approach and comparisons of studies done in section 2. Section 4 and 5 illustrate the author's soccer game development and the basic work of multi-agent algorithm respectively. Finally, the rest of it concludes the paper.

II. Research Work

This section surveys on many of multi-agent system research works from the viewpoint of a system architecture and concepts used for the decision-making process.

Park et al.[2] developed a multi-agent system for robot soccer game using a centralized / decentralized and online /offline architecture. Centralized works when one agent acts as a supervisor to integrate all available data and plan the behavior of other agents. Individual agent is decentralized when they make plan for themselves according to their own sensor and data collected from other agents. All paths for the agent are planned offline before they move in the game. A real-time path planning is created during online for all the agents by using an effective algorithm.

Horak et al.[3] and Nisikata et al.[4] use a similar approach as Park et al.[2] in terms of the coordination of the cooperation among other agent in a game. Horak proposed a control agent on a higher level that controls other agent by determine the required behaviors to other agents based on the response from the dynamic game environment. Nisikata work is based on the effectiveness of argumentation as a mechanism for agent interaction. A coordinator that controls the argumentation will decide on formations, roles and tactics of the game. The arguing capabilities are in the form of communication, collaboration and decision-making done in the reactive and deliberative argument.

Garcia et al.[5] build the architecture for the robot soccer game with four layers consist of communication, logical, sensorial and cognitive. The cognitive layer models the behavior of the team robots that perceive the environment through information offered by the sensorial layer. The decisions on communications between the multi-agents are made through direct message, blackboard or multi-agent cooperation protocol.

Compared to Garcia et al.[5], Al-Jarrah et al.[6] use a peer to peer and broadcast communication as an inter-agent communication. This type of communication is based on request and reply that enable information transfer and negotiation for action decision among the agents. The decision making process is based on a machine learning and online decision unit. This online decision unit works using a neural network and heuristic algorithm for passing, shooting and strategic policies while the machine-learning unit runs offline in the background to improve decision-making process based on a trained neural network data. The decisions made from this step are forwarded to the action unit that updates the agent state.

Unlike most of the other research mentioned previously, Bruce et al.[7] focus his research more on the fast adaptation and response time to the changing environment among the multi-agent team. They believe that the system performance as a whole can still be poor if the players cannot move quickly to the target destinations by avoiding potential hostile obstacles. Therefore, a motion control is used to bring the agent to the target point with desired target speed and orientation. While a method on Rapidly Exploring Random Trees (RRTs) proposed by Steven et al.[8] is used to help to tackle the problem of real-time path planning on the navigation and obstacle avoidance. This method may also be possible to overcome the real-time path planning mentioned in [2].

Brogan et al.[9] developed a system behavior from the observation of a prerecorded examples of group movements in a multi-agent group. Future actions are anticipated from these behavior observations. The behavior are developed and retargeted to different groups based on the position information of high-dimensional player data using a data-driven predictor. The motivation of this approach came from learning by example and motion-capture technologies but with a simplified representation on predicting player movements.

Wang et al.[10] conducted a research on the minority game strategy in team competition, focusing on how and when. The strategy is to capture various acts of behavior in the multi-agent competitive environment using a grid-like environment, called *Dynagrid*. The Minority game (MG) model is introduced to act as a decision-making mechanism for regular and irregular motion effectiveness. The formulation of the MG is presented in terms of the representation of theoretical MG outcomes; the integration of the measurements in *Dynagrid* with MG outcomes and the specification of agents on behaviors, strategies, measurements, etc.

Sng et al.[1] did a research on strategy for collaboration in robot soccer. The strategy for team formation and role assignment; such as attack, pass and shoot the ball; are based on the multi-cost function and the fuzzy logic based reasoning.

Wu et al.[12] conducted a research on a multi-agent algorithm for robot soccer games in Fira Simulation League. The algorithm focused on the role formation of each agent and ball passing among the multi-agent based on a multiple criteria decision-making. A *virtual forces* is introduced to enable each player to switch role as offensive/defensive mode depending on the position of the ball and the enemy. The decision on passing the ball among the agent are solved using a *Voronoi diagram* where a duty area will be assigned for agents that are close to the ball without calculating the distance between the agent and the ball.

III. Multi-Agent Approaches

This section discussed the approaches implemented on the multi-agent in the soccer game domain based from the review of past research work mentioned in Section 2.

The most critical factor in a soccer game for collaboration and cooperation between multi-agents is the role assignment and formation of the team. Role assignment is the tasks or duty given to the player to dribble, pass, shoot or chase the ball. A good approach works with good strategy in mind; eliminating the need of exhaustive computation time, space, thus considering the efficiency of the effectiveness of the game. On the other hand, team formation is crucial for a winning or losing strategy besides determining a specific role task during formation between the agents. The cooperation between these two factors into multi-agent behavior is studied for wiser selection on the decision-making strategy.

A. Role Assignment

A simple approach proposed by Veloso et al.[13] in role assignments whereby the robot will only be active if the ball is nearby and inactive if it is not within the close range position of the ball. The evaluation function used is the obstruction-free-index that give the facilities on either shooting or passing the ball during active mode. For this matter, only one parameter; the distance of the ball to the agent is taken into consideration to activate the role assignment.

In [4], the approach use a reactive argumentation for the decision making process among the multi-agents. The counterarguments done in the deliberative arguments produce reactive arguments for task like role assignment. However, Al-Jarrah et al.[6] mentioned that in a dynamic, real-time domains with unreliable communication complex negotiation protocols may take too much time or infeasible due to communication restrictions.

Work done in [1] use a multi-cost function for role assignment to avoid players from having the same task in the game. Unsolved problem like this may lead to a collision among players when they are attacking for the ball. Several input parameters are taken into account in order to assign a role to an agent. Parameters considered as input to the fuzzy arbiter are the distance of the player to the ball, the orientation of the player to the ball, the obstacle along the path towards the ball and the shooting angle towards the target goal. The objective is to simply score the goals. The role for a ball passing, shooting or attacking is given if the role assigned given to the agent is high. High means, according to Sng et al.[1] is, if the distance to the ball is near, orientation is front, shoot angle is perfect or path obstacle is none. The higher or lower role depends on the "OR" operation used in the algebraic sum operation between the arguments input involve. This approach can be a good strategy for role assignment as it considers all the important elements. However, there can still be a possibility that more than one agent are set to a high role given the same task.

Wu et al.[12] proposed a strategy for role assignment that could solve common problem as mentioned in [1] on having similar task during the game. What could happen is that both players given a similar task might catch or not catch the ball at all. So a duty area is assigned to a player by dividing the soccer field into several disjoint areas using a Voronoi diagram. This duty area will take the nearest approach on which player to catch or kick the ball and prevents far players from consuming too much stamina on going to the ball.

Work done in [6] studies on the algorithm for passing and shooting policies. In shooting algorithm, the distance input between a shooter and a goalie and the shooting angle are taken as trained neural network data. This is to know which sets are the most popular used as a training data. This has been proven by a success rate of 87.5% from the experimental work done. The passing algorithm helps in determining which visible teammates should the ball be pass to. A heuristic approach is used to calculate the opponent's goal location, agent who has the ball, all visible opponent's locations and the closest distance to the visible opponents locations. From this survey, we could see that there is a balance of computation that saves time in the decision making process. Only critical factor of passing strategy is use for real-time calculation while shooting strategy is learned offline.

B. Team Formation

Permanent role fixing causes undesirable behavior such as a defensive player not going for the ball even though the ball is near but outside its defense zone; or a forward player giving up its possession of ball when it incidentally enters a defense zone [1]. For this reason, studies has been done on formation strategies; offensive and defensive role, from previous work and research introduced in Section 2.

Information history gained during the soccer games helps in the decision-making process for team formation. Work done in [9], [3] and [10] used the same approach in their soccer game research. In [10], players make the next move based on history of previous actions and the result is presented in a sequential binary series. The behaviors are defined according to a winning and losing side. The winning side choose reactive behavior where agents chase its target regardless if there's a teammate or not, while the losing side choose the coordinated behavior where the role of defensive mode is played. The tradeoff with this strategy is the limited resources (history) throughout the different round in the game. However, it is best learned in making binary decision for interacting agents to gain immediate payoffs.

To ensure the agent in its best position during the game, Park et al.[6] used a heuristic approach for calculation. The parameters that are used for the input in the strategic positioning algorithm are the same in role assignment except with the use of shooting angle. The flexibility of moving to proper positions is based on role agent and status of the ball. The computation for strategic position is decreased by giving pre-defined positions on cases such as kick-in, corner-kick and goal-kick position.

Work done in [3] uses a simple approach for offensive/defensive formation. Players form a V-formation to offense when the balls are moving towards the opponent goal and defense in a circle form when the ball is moving near to its own goal. However, formation done on every time step during the game for both teams could be quite exhaustive compared to Veloso et al.[13] and Wang et al.[10] that use similar approach on a winning or losing strategy. The approach used is that the team acts as a defensive if it is winning and when not much time is left. But if the team is losing during the last hours, the robot will switch to the offensive mode. This strategy solved computation time as in [3] since the calculation for formation is effective only during the last minute of the game based on time and score.

Approach on switching from offensive and defensive formation that depends on the position of the ball could produce a ping-pong effect as studied by Wu et al.[12]. If the ball moves back and forth between the two areas of the opponent and own goal, the players will keep on changing formation that can consume stamina. In order to solve this matter, a buffer area is build between the two different of region area making the changing of formations not to be taken effect immediately at each time. The optimum positions of the player will depend on the ball position and the positions of all enemy players.

Formation strategy presented by Sng et al.[11] use the fuzzy arbiter of the distance, orientation and obstacle along the path to give agent the best position including the left and right sweeper of the team. Most of the research illustrated in this paper for formations did not consider much the obstacle along the path.

C. Implication of the Multi-Agent Approach

Which is the best method that really supports the cooperation among the multi-agent? The context that should be looked into here is the architecture and the decision making process discussed in Section 2. A good architecture and decision-making model are important keys in a required winning game strategy because both work as a core brain of a game.

But what are the main concerns to consider? Does one look into the cooperation among the multi-agent more or just simply the shooting strategy in a game as the main goal? Based on the investigation done in this paper, without a solid cooperation among the multi-agent, a shooting strategy could not be achieved effectively. Coordination of the multi-agent is the one that determines most of the task given in a simulated soccer game by taking account important elements into consideration. Without this factor, the team structure in a dynamic environment game could not be strategically organized as the game involves multiple agents as a team player.

Is role assignment more important than formation in a multi-agent behavior? Formation can only occurs when role assignment is determined for the entire agent in the team. Although inputs to consider for role assignment are more than formation, the offensive and defensive mode could not be created without first having the role of each player as an individual. The game will only be in action by giving role assignment to every agent in the game where then later, could lead on the forms of team formation. Team formation is basically a winning strategy between two teams played in a soccer game that could eliminate exhausted computation throughout the entire game play. Both factors are important to eliminate computation time and space for the efficiencies of the game.

IV. Development of the Soccer Game

In this section, work on the multi-agent online 2D soccer game using agent and *WinSocks* programming is being introduced. The coding involves network programming over two human-players and a multi-agent behavior for the team player. The network involved in the game will not be explain much detail, as it is not the focus of the study for this paper. Since the soccer game development is still a pilot version, the study on the survey done in Section 3 could help on the ideas of approaches and techniques to improve the multi-agent behavior for the 2D soccer game.

A. Multiplayer Mode

Multiplayer mode is the ability of a soccer game to be played across the Local Area Network (LAN) by two different human players at two different computers. One acts as a host, another act as a client. A client will connect to the host by putting the IP address of the host. To make this applicable, Winsock programming is used. One human player will control one player in one team while the other human player will control another in the opposite team. The computation engine is non-existent (not functional) on the client as when it is run in client mode, all it does is relay keystrokes and various inputs to the host's modular input system. All calculations will therefore be done on the hosts, and the results are returned to the client at fast intervals. This is done so that there is not much lagging created between host and client. If both are set to run calculations independently, synchronization errors have a chance of occurring and the game will not be synchronized. Theoretically, the response time between calculations on the host machine and the display on the client machine is very dependant upon the network latency of the connection rather than the bandwidth. Therefore, network solutions with low inherent latency are much more preferred rather than one with a higher bandwidth but lackluster latency.

B. Game Strategy

In this online 2D soccer game, AI is applied to players that are not controlled by the user. The AI is designated for player movements and how they react if they are close to the ball.

This approach is similar to [5] where the agent will only be active if the ball is close by. As a start, a simple strategy is implemented on shooting and passing the ball and how other teammates or opponent react to it. As this is an online soccer game, the user is the one who controls the ball most of the time. The agent controlled by user will dribble the ball to the location desired. If there is another agent, its teammate near to him, and the goal is still far, the agent will pass the ball to the nearest agent; else the agent will keep on dribbling the ball. If the goal is near, the agent will automatically shoot the ball.

For formation strategy, the multi-agent will be given a specified region in the field according to its role. For now, there is only 3 vertical parts whereby one agent is assigned to one location, acted as an attacker or a defender. These agents will only move inside their own region. The defender agent will try to block the opponent's view that has the ball. So far, roles formation are fixed for the multi-agent, unless if the agent has the ball, it can always act as an attacker.

C. Ball Movement

The study of the ball movement is based on trigonometric calculation of vectors. Calculations is done when the ball interact with other players on the field. Ball speed is currently set as a constant value upon contact with a decaying velocity as it moves. When the ball touches other objects, for example, the ball should move accordingly as a real ball would do. It would bounce back or reflected to the other sides.

V. Results and Discussion

Compared to a real soccer game, this game will only have four players on each team. Three of them will be positioned as field players and one will be the goalkeeper. It is more reminiscent of a *futsal* game instead, with the only variation being the implementation of goalkeepers one each side. So, on the field, the maximum players allowed are 8. The goalkeeper will stay at the goal line and will move only on the line. It will block the ball from getting across the line. Two of the field players will also have AI embedded while another one will be control as the human player/user. The human player can choose which of the 3 field players to control based on who is the nearest to the ball. The difference between the controlled player and other AI players is that there will be a yellow ring on the human-controlled player. Figure 1 below is a screen shot of the developed 2D online soccer game system using Visual Basic (VB).

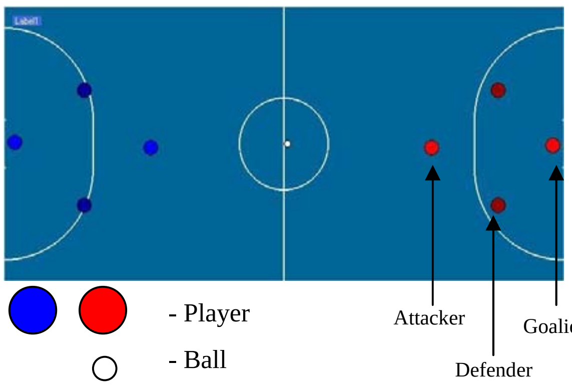

Fig. 1 Game field and the multi-agent

This will be the first phase of the soccer game. More intelligent behavior are going to be added with a better approach for cooperation and collaboration between the multi-agents in the future. The approach and method discussed in Section 2 had given a broad idea on the most common practice of multi-agent behavior in a soccer game agent environment. Therefore, improvement will be make on the multi-agent behavior part for the soccer team that can adapt well with an online game platform.

VI. Conclusion

Robotic soccer is an example of such complex tasks for which multiple agents need to collaborate in an adversarial environment to achieve specific objectives [13]. Thorough studies had been done on techniques and approaches of multi-agent behaviors for the robotic soccer games by other researchers. There are many strategies that can fit well in a highly dynamic environment of a soccer game but efficiency of the results is still an unsolved issue. From the literature survey, a conclusion had been made that an approach with better intelligent and less computation time for real-time calculation is highly recommended. Therefore, the system development will be improved by doing further research on the machine-learning unit and fuzzy logic based reasoning as in [1] and [6]; both for shooting, passing and formation strategy to improve the system on the multi-agent cooperation. By doing more studies in these two approaches, a good architecture and decision-making process on the multi-agent behavior; especially on team formation and role assignment could be embedded in the system implementation of the soccer game in the future. With that in mind, a good winning strategy could also be form in the game later.

Appendix

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