Strategy Model for Multi-Robot Coordination in Robotic Soccer

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Abstract. Soccer robots have been frequently used to validate models of multi-agent systems, involving collaboration among the agents. For this purpose, many researchers in robotics have been developing robotic soccer teams which compete in events such as RoboCup. This paper presents a strategy model for multi-robot coordination in robotic soccer teams involving ball position, team member position and opponent position for the selection of a team tactic and the player roles. This assignment is dynamical and achieved by a virtual coach. This strategy model was validated in a RoboCup Small Size League environment using Webots robot simulator.

Introduction

Research on intelligent, networked technical systems has been advancing tremendously. For multi-robot systems, their ability to achieve a common goal by distributing tasks in a team of coordinated robots has enabled them to react to problems more efficiently. However, coordination between agents is one of the crucial aspects in a multi-robot system. Recent studies in this context include coordination based on effective communication [1], implicit cooperation with shared belief [2], offline prediction model [3], Hierarchical Task Network (HTN) planning [4] and strategy planning based on principle solution [5]. Robotic soccer games provide an avenue to verify these research findings [6]. For instance, various leagues addressing different research challenges have been organized in RoboCup. One of the leagues is the Small Size League which focuses on the cooperation and control of multi-agent in a highly dynamic environment. Coordination among multi-robot system in soccer games such as RoboCup Small Size League is challenging due to its dynamic game environment. Coordination is required, for instance, in performing cooperative search and identification of ball, cooperative localization of teammates and opponents, cooperative two-dimensional mapping, and cooperative team play. It has been observed that lack of coordination between the robots has caused reduction on the team performance. It is not possible to implement human-like tactics such as passing and keeping formation without coordination. A more complete presentation about different strategies to Robot soccer coordination is presented in [7].

Function Orientation

A function is the general and required coherence between input and output parameters, aiming at fulfilling a task. For the setting up of function hierarchies, there is a catalogue with functions which is based on Birkhofer [8] and Langlotz [9]. Functions are realized by solution patterns and their concretizations. A subdivision into sub functions is taking place until useful solution patterns have been found for the functions. The functionality to play soccer is decomposed into six functions which are then further decomposed into sub functions.
- **To move**: This function fulfils the locomotion tasks. These tasks require the ability of the robot to orientate itself with reference to a specific object and to move forward or backward.
- **To localize**: This function refers to the ability of the robot to know where it is, which is essential for implementing team strategies. It should also find the position of the ball.
- **To kick**: This function enables a robot to shoot a ball towards a goal or to pass a ball to a teammate.
- **To recognize**: This function refers to a perceptual ability that relies on vision for sensing to enable a robot to correspond to its surrounding and organize its behavior. Through visual skills, a robot must be able to distinguish teammates and opponents, the ball, the field lines, and the goalposts.
- **To communicate**: This function refers to the ability to pass messages between robots in a team or between a robot and a referee. It enables passing orders between the players such as searching for ball or going to a specific location in line with the current playing strategy.
- **To generate trajectory**: This function defines the path for the movement of the robot, not only for obstacle avoidance and minimum time to go to the ball, but also to ensure that when the robot reaches the ball, it will be more or less aligned with the ball.

### Strategy Model based on Tactics

In this strategy model for robot soccer, the tactics developed include defensive defense, defensive attack, offensive defense and offensive attack. A tactic is adapted when the team that possesses the ball changes, or when the soccer ball changes its location from one zone to another within the soccer field, according to the conditions presented in the Table I. As shown in Fig. 1, these zones include a defensive zone where the goalkeeper of self-team is located, a middle zone, and an offensive zone where the goal of the opponent team is located. When a new tactic is deployed, new roles are assigned for the team players. These roles include defender, supporter and attacker, which are dynamically assigned. Nevertheless, the goalkeeper is considered a static role.

![Fig. 1. Division of zones in robotic soccer field](image)

The implementation of the strategy was developed using Webots, a robotic simulator which uses Open Dynamic Engine (ODE) in virtual reality environments. Webots provides different sensors including GPS, the coordinates of the players and ball, they are used as knowledge base for this strategy, also Webots provides the virtual scene to VRML world description. The procedure used in the strategy is presented as follow.

1. Coach reads coordinates of the ball and players and assigns the tactic.
2. Given the tactic selected in the step 1, coach assigns one role to each player.
3. Players execute behaviors determined by the tactic and the roles assigned in the step 2, above the field of game and modifying the conditions of the game.
4. After a constant time $T_1$, repeat step 1.

### Table I. Selection criteria of tactics

<table>
<thead>
<tr>
<th>Tactic</th>
<th>Ball Zone</th>
<th>Ball Possession</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defensive Defense</td>
<td>Defender</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>No</td>
</tr>
<tr>
<td>Offensive Attack</td>
<td>Offensive</td>
<td>Yes</td>
</tr>
<tr>
<td>Offensive Defense</td>
<td>Offensive</td>
<td>No</td>
</tr>
<tr>
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<td>Defender</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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**To move**: This function fulfils the locomotion tasks. These tasks require the ability of the robot to orientate itself with reference to a specific object and to move forward or backward.
Fig. 2 shows a state diagram describing the behavior for a soccer robot team. At a high level, there is a state that employs an individual tactic and another state that employs a team tactic. In a team play, one employs a defense tactic while another employs an attack tactic. In the attacking state, either defensive attack or offensive attack is possible. In the defense state, either defensive defense or offensive defense is possible. The events that trigger a state transition are also indicated. A tactic is selected depending on the ball position (defensive zone or middle zone, E6, or offensive zone, E5), and the team that possess the ball (E3 and E4).

For this strategy, it is considered that the opponent team has the ball possession in two cases, when an opponent player has the ball, or when the ball is alone in the field (no team has the ball possession). The tactic is global and involves the players except the goalkeeper, which has a static role. Rules for tactic selection are summarized in Table I, and they can be easily programmed in any supported language (C in this case). The algorithm for the tactic selection is executed by the virtual coach who owns the position of the ball and the players. For the assignation of the roles, virtual coach executes an algorithm for the assignation of the roles, remembering the goalkeeper is a constant role.

**Defensive Defense Tactic**

This tactic is deployed when the self-team does not own the ball (E4), and the ball is in the middle or the defensive zone (E6). In this tactic, the player nearest to the ball goes by its interception, and this robot becomes the defender. The player nearest to the opposite goal becomes the attacker and goes to the line of the middle soccer field, waiting for a pass if the ball is intercepted. The last player becomes the supporter, and it must go to block the opponent player nearest to the own goal to prevent opponent pass. An example of the formation in this tactic is shown in the Fig. 3, and it presents a possible position that would take the player if this tactic were activated. Yellow and blue robots are the self-team, and red and blue robots are the opponent team. Defender goes to the ball, attacker goes to middle field and supporter blocks the other opponent robot in the self-area. P is the goalkeeper, D is defender, M is supporter and A is attacker.

**Defensive Attack Tactic**

This tactic is deployed when the self-team has the ball possession (E3) in the defensive or middle zone (E6). For the role selection, the robot with the ball becomes the supporter, which must send a pass to the attacker and then go to support the attacker. The attacker is the player nearest to the opposite goal, which must find the ball that is sent by the supporter. The other robot becomes the defender and is placed in the penalty spot. When the attacker receives the ball, a new tactic is
determined and it implies a role change or at least a change in the player behavior. An example of the formation of this behavior is presented in the Fig. 4, where hypothetical player positions are presented, in that case the supporter has the ball and the attacker is waiting for a pass from the supporter. The defender would wait in the penalty spot.

**Offensive Attack Tactic**

This tactic is deployed when the self-team possess the ball (E3), in the opponent half soccer field (E5). The player with the ball becomes the attacker, the player nearest to self-goal is the defender and it must stay in the penalty spot in case of counterattack by the opponent team. The other player is the supporter and goes in the same line (width of the soccer field) with the attacker, but in the opposite side, if there is not an opponent obstructing the ball’s trajectory towards the opponent goal (different to goalkeeper), attacker must shoot the ball to the opponent goal, the possible formation in this situation is presented in the Fig. 5, where a possible position of the players is presented.

In case of an opponent player blocking the line between the attacker and the opposite goal, the attacker must send a pass to the supporter, a possible formation in this hypothetical case is presented in the Fig. 6. If the ball is caught by the supporter, new roles would be assigned where the supporter becomes the new attacker, and the attacker in last tactic becomes the new supporter.

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**Fig. 3.** Role assignment in a defensive defense tactic

**Fig. 4.** Role assignment in a defensive attack tactic

**Fig. 5.** Role assignment in an offensive attack tactic. The attacker shoots the ball to the opponent goal.

**Legend**
- Self team
- Opponent team
- P: Goalkeeper
- D: Defender
- A: Attacker
- M: Supporter

**Fig. 6.** Role assignment in an offensive attack tactic. The attacker shoots the ball to the supporter.

**Fig. 7.** Role assignment in an offensive defense tactic
**Offensive Defense Tactic**

This tactic is deployed when the ball is not in possession of the self-team (E4) but this is located in the offensive zone (E5). In this case, attacker becomes the player nearest to the ball, and tries to intercept it. Defender must be in the own field (away of the goalkeeper area) and must intercept any opponent’s shoot towards its own goal. The supporter blocks another player near to the own field, to prevent a pass between the player of the opponent team. This hypothetical situation is presented in the Fig. 7, where a possible formation of the players is shown.

**Simulation of Strategy**

This strategy model was simulated using a world of the Small Size League in Webots robot simulator as shown in Fig. 3 to Fig. 7. This world provides the location of all players and the ball to the virtual coach. A binary archive is provided with the strategy for each team, the binary supplies to Webots the angular velocity (positive or negative) of each wheel in each player. Differential wheeled robots are used in this league. The strategy was programmed in C.

Many behaviors were implemented in the robots, for the execution of different tactics. As shown in Table II, the behavior of the individual robot differs not only according to their respective role but also the tactic currently deployed by the team. The goalkeeper behavior was predetermined by the simulator. Likewise, a random behavior was predetermined, in this behavior robots makes random movements, the last behavior was used in some simulations by the opponent team.

Behaviors which were programmed for the strategy include:

- *To go to the ball:* Robot goes to the ball until a short distance (0.07 m) in front of the ball.
- *To go to the center of the soccer field:* Robot goes to this point and stays there.
- *To block opponent player:* Robot must identify the second opponent player nearest to the ball and go to block it.
- *To go forward with the ball:* Robot must send the ball to the offensive zone.
- *To go to defensive zone:* Robot goes to a determined defensive location and stays there.
- *Waiting for the ball:* Robot stays in a determined side of the field waiting for a possible pass of a team member, or for ball recuperation.
- *To send a pass:* Robot sends the ball to another robot (which is waiting for the ball), when the opponent goal is blocked by an opponent player.
- *To shoot the ball:* Robot shoots the ball to the opponent goal.

<table>
<thead>
<tr>
<th>Tactic</th>
<th>Role</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Defensive Defense</strong></td>
<td>Defender</td>
<td>To go to the ball.</td>
</tr>
<tr>
<td></td>
<td>Supporter</td>
<td>To block opponent player.</td>
</tr>
<tr>
<td></td>
<td>Attacker</td>
<td>To go to the center of the soccer field.</td>
</tr>
<tr>
<td><strong>Defensive Attack</strong></td>
<td>Defender</td>
<td>To block opponent player.</td>
</tr>
<tr>
<td></td>
<td>Supporter</td>
<td>To go forward with the ball.</td>
</tr>
<tr>
<td></td>
<td>Attacker</td>
<td>To go to the center of the soccer field.</td>
</tr>
<tr>
<td><strong>Offensive Defense</strong></td>
<td>Defender</td>
<td>To go to defensive zone</td>
</tr>
<tr>
<td></td>
<td>Supporter</td>
<td>Waiting for the ball.</td>
</tr>
<tr>
<td></td>
<td>Attacker</td>
<td>To go to the ball.</td>
</tr>
<tr>
<td><strong>Offensive Attack</strong></td>
<td>Defender</td>
<td>To go to defensive zone</td>
</tr>
<tr>
<td></td>
<td>Supporter</td>
<td>Waiting for the ball.</td>
</tr>
<tr>
<td></td>
<td>Attacker</td>
<td>To send a pass or to shoot the ball.</td>
</tr>
</tbody>
</table>
Conclusion

A strategy model taking into account of the dynamic changes in a robotic soccer game has been presented in this paper. In this model based on RoboCup Small Size League, different robots can take over an appropriate role depending on the instantaneous conditions of the game, such as the ball position or the position of opponents, with the possibility that the robots change their role if the conditions of the game changes. In the proposed strategy, a virtual agent named coach selects an appropriate tactic and subsequently assigns roles to the players. Except for the goalkeeper, all the roles can be dynamically assigned to all the robots in the game during run time. This strategy allows the robots to react through the roles they take over in response to the instantaneous game conditions.

Acknowledgments

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References