Strategy Planning of Collaborative Humanoid Soccer Robots Based on Principle Solution

C. Y. Low [1*], M. Aldemir [2], N.Aziz [1], R. Dumitrescu [3] and H. Anacker [3]

[1] Centre of Excellence for Humanoid Robotics and Bio-Sensing, Universiti Teknologi MARA, Malaysia
[2] Siemens AS, Corporate Technology Development Center Istanbul, Turkey
[3] Project Group Mechatronic Systems Design, Fraunhofer Institute for Production Technology, Germany
*E-Mail: low.uitm@gmail.com

Summary: Collaborative humanoid soccer robots are currently under the lime light in the rapidly advancing research area of multi-robot systems. With new functionalities of software and hardware, they are becoming more versatile, robust and agile in response to the changes in the environment under dynamic conditions. This work focuses on the humanoid soccer robot teams as in the RoboCup Standard Platform League. A new approach for the strategy planning for such bipedal soccer robot teams based on a principle solution is presented. The principle solution is specified using a newly developed specification technique for the conceptual design of mechatronic and self-optimizing systems. The behavioral specification for such robots using the aforementioned specification technique is exemplified. The presented approach enables intuitive specification of team strategies and systematic realization of collaborative behaviors of the humanoid soccer robots starting from the conceptual design phase.

Keywords: Humanoid Robotics, Mechatronics, Principle Solution, Intelligent Technical Systems, Design Methodology.

1. Introduction

In the recent years, there is an increasing interest in the development of groups of robots that carry out tasks collaboratively. Such multi-robot systems will play a prominent role in the near future as they can perform tasks that single-robot systems may have difficulties to accomplish. This work focuses on the humanoid soccer robot team as in the RoboCup Standard Platform League (SPL) [1]. In the SPL, it is interesting to observe how a humanoid soccer robot can shoot, pass, dribble, localize, and search a ball. It is even more fascinating to think of how these robots can implement a team strategy collaboratively and autonomously, for instance, during formations for kick-off positioning or collectively putting pressure on one opponent.

Due to the increasing size of humanoid soccer robot team in the SPL, an effective strategy planning taking the advantages of collaborative behaviors becomes the success factor for a team [2][3][4][5]. So far most of the teams still do not take the advantages of coordination between the players. The lack of coordination between the players jeopardises the performance of a team as human-like tactics such as passing and keeping formation is impossible without coordination. In some cases, more than one player of a team try to capture the ball, blocking each others' path, and even pushing each other. Indeed, various design issues prevail during strategy planning such as those pertaining to task assignment, hierarchy and organization, reliability, deployment and formation control, and scalability of team size. A systematic approach is required to specify the decisions taken during strategy planning of these robotic soccer players.

In this paper, we present an approach for strategy planning of collaborative humanoid soccer robots based on the specification of a principle solution. The specification technique used for the strategy planning is described in Section 2. Subsequently Section 3 exemplifies the behavioral specification during the strategy planning. Finally, Section 4 concludes the outcomes of this work.

2. Specification Technique

During the system design of advanced mechatronic systems, a cross-domain system model is necessary, which combines all the essential aspects of mechanical, electrical and software engineering. This system model is the basis of the first analysis, verification and validation on the systems level and at the same time the initial point of specific concretization within the different domains [6]. To establish these requirements of model based systems engineering, a semi-formal specification technique to describe the principle solution of advanced mechatronic systems has been developed [7] (Figure 1).

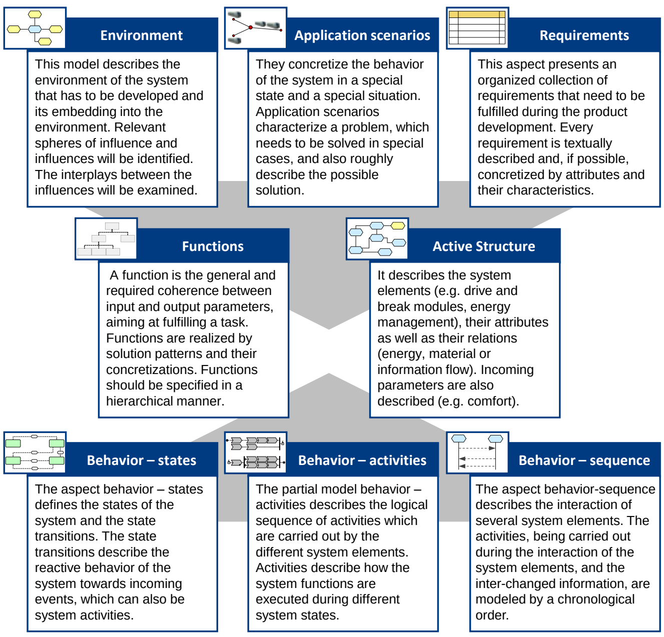


Figure 1. Partial models for the domain-spanning description of the principle solution of advanced mechatronic systems.

As shown in Figure 1, the following aspects need to be taken into account: requirements, environment, application scenarios, functions, active structure, system of objectives, shape and behavior. The aspect behavior consists of a whole group because there are different kinds of behavior, e.g. the logic behavior, the dynamic behavior of multi-body systems, the cooperative behavior of system components, etc. These aspects are computer intern represented by partial models. A software tool called the Mechatronic Modeller can be used to describe mechatronic systems using the specification technique. The Mechatronic Modeller offers a separate editor for each partial model. The partial models are intertwined and form a coherent system model. By using this specification technique, the system that is to be developed can be described in an integrated, domain-spanning way.

3. Strategy Planning

After identified the fundamental functionalities that a soccer robot should have, we can develop a strategy for the team play. This section exemplifies behavioral specification during strategy planning using the aforementioned specification technique. For the behavioral specification, the tactics used by a team (e.g. team attack, team defense, individual) and the roles taken by each of the player (e.g. striker, supporter, defender, goalkeeper) must clearly described. Due to space constraint, only the partial models behavior–state and behavior–activity are presented here.

The partial model behavior–state describes the envisaged system states, the state transitions, as well as the events that trigger a state transition. The partial model behavior–activity describes logical sequences of system activities which includes all operation and adaptation processes. Operation processes refer to the activities that are carried out within a state while adaptation processes refer to the activities that are carried out during state transitions. When an event appears, an adaptation process is triggered. After performing the adaptation process, the system takes over a new state and thus another set of operation processes are activated.

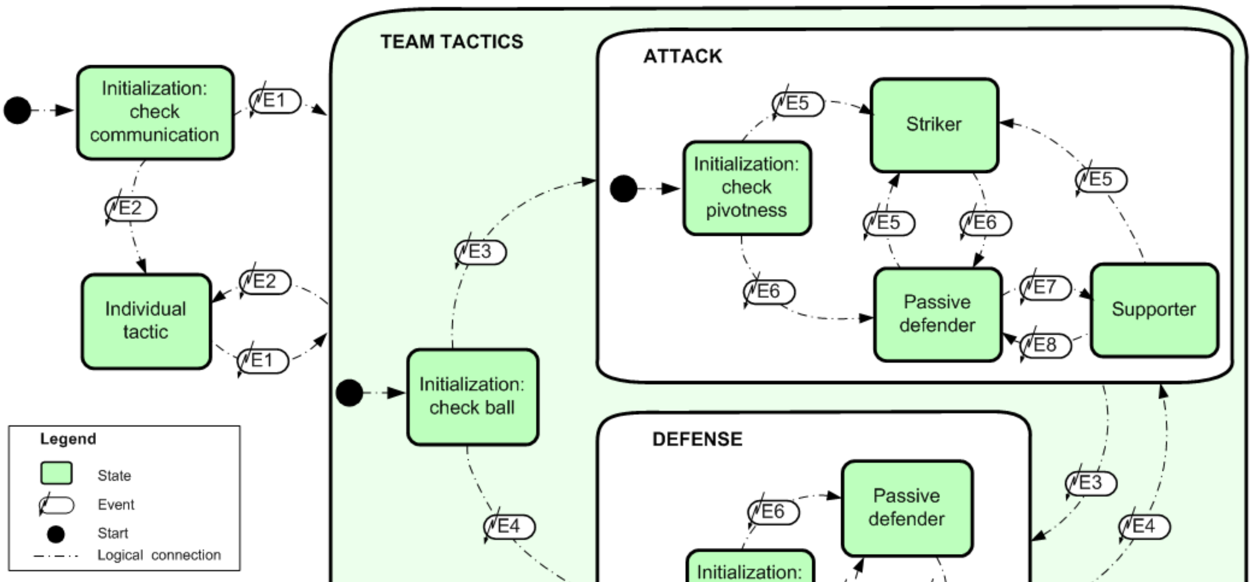
Figure 2 shows a cut-out of the partial model behavior–state for a humanoid soccer robot team. Each state in the figure corresponds to a tactic used by the team. At the highest level, there is a state that employs an individual tactic and another state that employs a team tactic. The state for team tactic consists of two sub-states, one employs a defense tactic while another employs an attack tactic. In the attacking state, a soccer robot can either be in the mode of a striker, passive defender or supporter.

A. Individual Tactic

For a coordinated team play, network connection is required for communication among the players. Refer events *E1* and *E2* in Figure 2. Thus, a player firstly checks its communication ability with the team mates. And if it cannot access its team mates, it plays completely individually until a network connection is available. Within the state "individual tactic", the player first searches the ball, and then goes to it. When it approaches close enough to the ball, it searches the opponent goal and aligns with the ball. Then, it shoots.

B. Team Attack Tactic

When a network connection is available, each player localizes itself on the field and estimates its distance to the ball, then sends this information to its teammates. This is referred as event *E3.* A state transition into "team attack tactic" takes place if any player of the team is close enough to the ball to kick it. If the visual recognition capability of the players is sufficient, the distance of the closest opponent can be taken into account.



No.	Events	Description
1.	E1	Communication ok
2.	E2	Communication out
3.	E3	Ball captured
4.	E4	Ball lost
5.	E5	Pivotness minimum
6.	E6	Pivotness not minimum
7.	E7	Striker's instruction received
8.	E8	Striker's instruction not received

Figure 2. State diagram showing tactics used in a robotic soccer game.

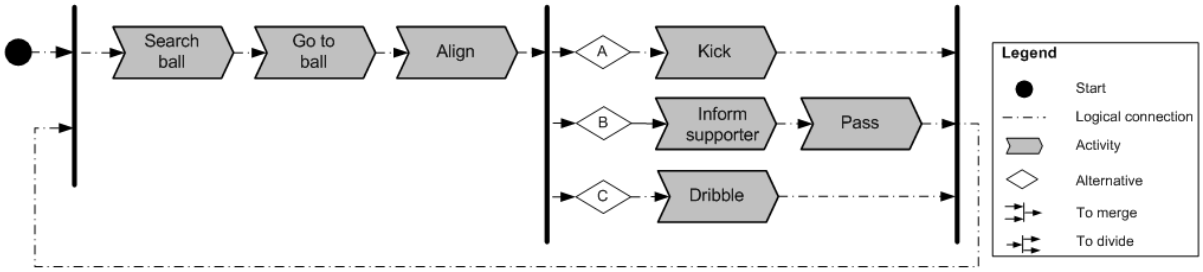


Figure 3. Activity diagram describing tasks involved in the role of a striker.

Each player also calculates its cost (pivotness) to align with the ball for a good kick towards the opponent goal. Note that it may take a player at a shorter distance but opposite orientation longer than a player with a longer distance with a matching orientation. The player with the lowest cost transits into the state "striker". The striker role is exclusive; only one player can be in this role at a moment.

The main role of the striker is shooting. Its activities are shown in Figure 3. It goes to the ball, aligns with it and evaluates the feasibility of shooting. Three alternatives are possible. Feasibility for each alternative depends on the angle it sees the opponent goal open.

Alternative A: If the player is very far away from the opponent goal, or there is another player closing its sight; it's not feasible to shoot. If the feasibility is higher than a threshold value, it shoots.

Alternative B: If not, it orders the closest teammate (supporter) to go to a position where it can pass the ball and it kicks the ball with a reduced speed.

Alternative C: If no teammate is available or they are all too far away; the striker kicks the ball with a reduced speed and walks behind it to get a better position.

The player which is neither striker nor supporter takes the "passive defender" role. They communicate with the goalkeeper and get the best position to defend the goal from counter-shoots.

Each player localizes itself and sends this information to the other players periodically, and every time after a player kicks the ball. The roles can be interchanged if the cost value of striker is higher than another player. However, a hysteresis effect must be introduced to prevent fast role switching; the cost value required to lose the striker role is be higher than the cost value required to get the striker value.

C. Team Defense Tactic

If none of the players is close to the ball to kick it soon, refer event *E4*, Team Defense Tactic is applied. The players localize themselves and calculate their cost values and share it with teammates. The player with the lowest cost gets the "active defender" role. This player goes towards the ball and tries to capture it while the other two players (passive defenders) try to close the sight of the goal in collaboration with the goalkeeper.

D. Goalkeeper

The task of the goalkeeper is taking the best position to close the sight of an opponent player. It localizes the ball (and the opponent player, if possible), and stand between the ball and the own goal. It also dictates the position of the passive defenders in order to minimize the angle the opponent can see the goal. If it detects that the ball is coming towards the goal fast, it can jump down or to the side to stop it.

4. Conclusion

The most obvious change in the rules of RoboCup SPL in the recent years was the increase of team size. It can be presumed that these rules will converge to the rules of a human football match. This emphasizes the importance of coordination. Thus a flexible approach for strategy planning is necessary in order to cope with the increased technical challenge. Following the approach presented in this paper, the strategy of the team play becomes very clear and intuitive. The approach systematizes the realization of the collaborative behavior of the humanoid soccer robots. The strategies defined in this paper will be adapted each year with new regulations, while the coordination of players will be constantly enhanced. If changes were required within the codes, the specific modifications can be recognized immediately by referring to the diagram without having to browse through the lengthy programming lines. Furthermore, contradictory specifi-cations that lead to behavioral conflicts can be avoided and thus system reliability can be enhanced.

Acknowledgements

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