XIII WORKSHOP EN AGENTES FÍSICOS

WAF 2012

SANTIAGO DE COMPOSTELA

3RD - 4TH OF SEPTEMBER, 2012

CENTRO SINGULAR DE INVESTIGACIÓN
EN TECNOLOXÍAS DA INFORMACIÓN (CITIUS)

UNIVERSITY OF SANTIAGO DE COMPOSTELA

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Foreword

As organizers of the 13th Edition of the "Workshop of Physical Agents (WAF)" we want to give a warm welcome to all the attendants to the University of Santiago de Compostela (USC). We hope that *this city*, end of the way of St. James followed by countless pilgrims during more than a thousand years, and *this university*, one of the eldest in Spain and that has been always committed to research and the generation of knowledge, provide inspiration and a working atmosphere favourable for the workshop.

This conference represents an excellent platform to present research in all areas related with robotics and its application to industry (robot learning, computer vision, human- robot interface, SLAM, robot navigation, etc.). This yearly forum, although small, has became a reference, and so far every year succeeds in creating nice atmosphere for interaction and discussion of ideas. The series of *WAF* were the initiative of a Network of research groups, *RedAF*. Nevertheless, this workshop was never limited to certain research groups, on the contrary, WAF was always a forum for the discussion of ideas, open to technological centres, companies and researchers from anywhere over the world. During these last years, WAF has grown up, strengthening its place in the Spanish conference calendar as an important robotics event. We hope that the WAF edition this year helps to consolidate the importance of this workshop, in the sense that all the attendants see it as something beneficial for their research.

WAF2012 coincides with the opening of an important research centre at the University of Santiago de Compostela (USC): *Centro Singular de Investigación en Tecnoloxías da Información de Universidade de Santiago de Compostela (CITIUS)*. This research centre is part of the Network of Singular Research Centres of Campus Vida at the USC, which has been acknowledged as an International Campus of Excellence by the Spanish Ministry of Education. The CITIUS brings together an important number of researchers working in 10 different scientific programs, two of which are Service Robots and Ambient Intelligence. The CITIUS houses an important and large robotics laboratory where the demonstrations will be carried out during the workshop. The CITIUS has played a deciding factor in the organization of WAF 2012, not only because most of the organizing committee are researchers in this centre, but also because it has sponsored the workshop. In the same vein, we would like to thank the help of Paulo Félix Lamas, head of the CITIUS, for his support, good ideas, and his unquestionable contribution so that this Workshop takes place successfully.

WAF 2012 has benefited greatly from the help and support of many people. We want to thank the members of the scientific committee who provided relevant reviews for all the submitted papers, and which we hope the authors have found useful. We also would like to thank the help of other people who were very relevant to the organization of this workshop, in particular Alberto J. Bugarín Diz for his good advice and help on some important organizational aspects, and Senén Barro Ameneiro for his great contribution in the organization of the special session *Robots en el escaparate: presente y porvenir.* This session is meant to put researchers in touch with enterprising people responsible of new robotic companies. We believe that sharing challenges is a good way of improving collaborations and promote transfers from research to commercial technologies. Of course we definitely want to thank the help of Miguel Angel Cazorla Quevedo and Vicente Matellán Olivera, without their great work RedAF and WAF would never exist.

Finally, we would also like to thank the authors for their contributions and the effort preparing their papers. We hope that the attendants to this workshop find it inspiring, useful, and somehow helpful for their future work. It would be magnificent if this workshop seeds new ideas, and provides us with extra tools to draw the shape of the new robotics solutions able to support citizens in key aspects. We also would like encourage you to submit to future editions of WAF.

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Santiago de Compostela, September 2012

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A Survey of Team Strategies in Robot Soccer, Focused in Standard Platform League

Jose Guillermo Guarnizo, Juan Francisco Blanes, Martín Mellado, Jose Simo, Manuel Muñoz.

***Abstract*—Soccer Player Robot is frequently used to validate models of multi-agent systems, involving collaboration among the agents. For this purpose, many researchers in robotics have been developing soccer player robot teams which compete in events like the Robocup. In this paper a survey about Multi-Agent systems applied to Robot-Soccer is presented, focusing in strategies implemented in Standard Platform League. An introduction regarding the Robocup and the Nao Humanoid Robot is also included. Subsequently, a strategy of soccer player robot team involving ball position and opponent position on the field is proposed. The assignation of the role of agents is dynamical.**

***Index Terms*—Robot soccer, nao, multi agent systems. standard platform league, survey, strategy.**

I. INTRODUCTION

ONE OF THE most recent topics in robotics is the use of multi agent systems in different fields of applications, wherein many agents are cooperating in complex applications, looking for a common goal. A formal definition of agent is a computer system located in an environment, with the capability of making some changes in order to meet defined objectives, as autonomous actions [1]. A software agent has the capability of modifying a software environment, usually this is called by an-other software and uses its results for a computer process. Many applications of software agents have been researched in special in informatics, for example to optimize shared resources, web security, information filtering and browsing, e-commerce and others [2], a perspective in the use of agents is presented in [3].

The field of the multi-robot systems (hardware agents), is focused in the designing of frames for collaboration among robots. For example in [4] is shown applications of mobile robots collaborating in task allocation, box pushing and cooperative manipulation, multi-target observation, traffic control and path planning. In [5] are shown different applications of quad-rotors as multi-agent systems. Special application of the multi robot systems in industry is the collaboration in manipulation of processes, for example in cell of manufacturing systems [6]. Other important field in multi-robot systems is swarm robotics, which consists in the study of the coordination of a large number of biological inspired simple robots. Many researchers about swarm have been related in [7], for instance, former studies in biological behaviors, chaos theory, swarm navigation, and others.

One way to validate different frames, or models of multi-agent systems, is the Soccer player robot. The Robocup Federation is an organization created in 1997, its main purpose is to promote science and technology by the use of soccer games played by robots and agents. Different competitions are stimulated to foster the researches in muti-agent systems, like robot coordination, agents communication, artificial vision, navigation or walking robots.

In this paper is presented a review of the state of art of multi-agent strategies applied to Soccer player robot, focusing in the strategies used in Standard Platform League, which nowadays uses robots Nao. As well a proposal of strategy to soccer player robot team is proposed, the strategy involves a dynamical assignation of the role of players, depending on game conditions. This paper is organized as follow: in II is presented a brief explanation about Robocup and its leagues, and a brief description of the Nao robot, in III a general review of cooperative strategies in multi-agent systems, applied to Soccer player robot, focusing in the strategies validated using Nao Robots, in IV is presented a proposal model of multi-robot system applied to strategies for Soccer player robot, in VI are presented future trends and conclusions.

II. THE ROBOCUP AND NAO ROBOT

The Robocup is an international soccer player robot competition where different Universities or robotics research centers participate. Research results are presented in robotic behaviors, multi-agent systems, computer vision, or walking robot. The Robocup is organized in 5 different leagues of competition:

- Soccer Simulation League, where robots are simulated in 2D and 3D environments, there is a high level of abstraction in sensors and actuators.
- Small Size League consisting of wheeled robots with 15 cms in height, which are controlled from external computer via wireless devices. A camera positioned above the match field is used to determine the location of the robots.
- Standard Platform League uses standard autonomous legged robots, all teams use the same robots with identical

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hardware, focusing the research in the design of algorithms with limited computational power.
- Middle Size League uses wheeled robots, 80 cm in height, fully autonomous with their own computers and sensors. Robots are not standard, as a result, research in software and hardware is highly promoted.
- Humanoid League uses biped and fully autonomous robots, and focuses on the development in hardware design robots.

The Standard Platform appeared in 1999, using AIBO robot until 2008, which were replaced by NAO robot of Aldebaran, showed in the Figure 1. In the Standard League, Robots are autonomous, and only limited wireless communication (bandwidth of 500 Kbps) is allowed among the robots, or between the robots and the Game Controller. No human intervention is admitted.

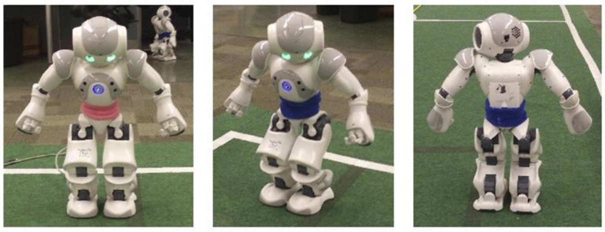
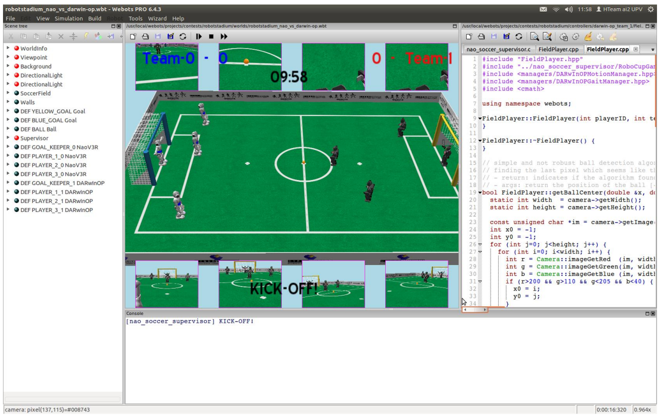


Fig. 1. Nao Robot of Aldebaran Robotics.

Nao is a humanoid robot designed by the French company Aldebaran Robotics. Nao is 57 cm height and 4,5 kg weight. Nao has 25 DOF (Degrees Of Freedom), two DOF on the head, 5 DOF in each arm, 1 DOF in the pelvis, 5 DOF in each leg, and 1 DOF in each hand. Its total mass is 4346.1 g. Nao is equipped with 1 gyro meter of two axis, 1 accelerometer of three axis, 2 CMOS 640 x 480 pcx cameras, 4 microphones, 2 bumpers, 2 ultrasonic sensors, 1 tactile sensor, 8 pressure sensors, hall effect sensors for sensor position (not present in versions H25 of Nao) and 1 infrared sender and receiver [8]. Nao has a custom 32 bits GNU LINUX OS Distribution. The access of the device is managed is by a middleware software called Naoqi. A Robot Soccer environment with Nao Robots, using Webots is shown in the Figure 2.



```
#include "FieldPlayer.hpp"
#include "../nao_soccer_supervisor/RoboCupGar
#include <managers/DARwInOPMotionManager.hpp>
#include <managers/DARwInOPGaitManager.hpp>
#include <cmath>

using namespace webots;

FieldPlayer::FieldPlayer(int playerID, int te
}

FieldPlayer::~FieldPlayer() {
}

// simple and not robust ball detection algor
// finding the last pixel which seems like th
// - return: indicates if the algorithm found
// - args: return the position of the ball [-
bool FieldPlayer::getBallCenter(double &x, do
  static int width  = camera->getWidth();
  static int height = camera->getHeight();

  const unsigned char *im = camera->getImage(
  int x0 = -1;
  int y0 = -1;
  for (int j=0; j<height; j++) {
    for (int i=0; i<width; i++) {
      int r = Camera::imageGetRed  (im, widt
      int g = Camera::imageGetGreen(im, widt
      int b = Camera::imageGetBlue (im, widt
      if (r>200 && g>110 && g<205 && b<40) {
        x0 = i;
        y0 = j;
      }
```

```
[nao_soccer_supervisor] KICK-OFF!
```

Fig. 2. Robot-Soccer Standard environment, in Webots.

For 2012 a soccer match in the Standard League, shall be played by two teams with four players each one. A blue or pink waistband is used in the robots of the same team, for identification process. The soccer match is played on a field consisting of a green carpet, with white lines above, and two and second half are 10 minutes each, and a half-time break of also 10 minutes. It is possible to penalize a robot in case of a fault, removing it from the field during 30 seconds, some instructions such as the start of the end of the of the soccer match are given through an agent called Game Controller.

Many simulations of Nao Robots are run by Webots Simulator [9], developed by Cyberbotics Ltd. It allows realistic simulations using a virtual world, and languages such as C, C++, Java, Python or Matlab. Webots has a number of essential features for mobile robots including wheeled, legged and flying robots, libraries of sensors and actuators, and models of commercial robots like Aibo, Darwin or Nao, among others.

III. STRATEGIES OF MULTI-AGENT SYSTEMS APPLIED TO ROBOT-SOCCER

In Robot Soccer, coordination is a very important topic. Non-coordinated strategies present problems like fellow team members going by the ball at the same time, obstructing themselves, or not protecting other zones of the game field. One important reason for the use of cooperation strategies is the possibility to coordinate attacks to opposite goal, by ball passes, or coordinate the defense of self goal, covering opposite players or intercepting opposite passes.

In [10] Robot Soccer is presented as a multi-robot system which includes uncertain dynamics and hostile environment, where the Robots operate making coordination of the multi-robot system in a real challenging problem. In Robot-Soccer, the Strategy (or team strategy) is the plan of the robot team, expecting to win a game. For example strategies can be defensive, offensive, or no strategy in case of lack of communication. Tactic is referred to the organization of the team for the game. Roles involve the individual location on the field, action of the players and the specification of behaviors (goalkeeper, attacker, defender). Behaviors are produced by skills of the robot, like movement, kicking the ball or finding the goal.

A. *Robot Soccer strategies*

Many researches have been presented with multi-robot strategies to Robot Soccer, for example in the work presented in [11], a method which accomplishes whole tasks is proposed. This consists in plural subtasks that coordinate multiple behaviors by reinforcement learning. Artificial vision is used. This system is centralized due to the data acquisition and control algorithm are executed by a computer, and transmitted to the player robots. Veloso and Stone [12] presented an architecture for a Robot Soccer team which participated and won in the Small Size League in Robocup - 97. Their proposal involved low level individual behaviors, strategic team behaviors, and roles based in behaviors. A real time communication and adversarial PTS (Periodic team Synchronization) paradigm is presented in [13], which was validated by simulation in Robot

Soccer. A Research presented in [14], proposed a strategy of robot soccer based on coordination graphs, which assign the roles to the players, based on the actions of the other players. This algorithm was simulated in a 2D environment, with centralized algorithms with communication among agents. Case-based approach is used for coordinate robot behaviors in a soccer match. This work was focused on a case of coordinated attacking passes between robots, in presence of opponents [15], formation tactics were not presented.

An example of how neural networks can conduct two collaborative agents shooting in simulation, is presented in [16], in this proposal the neural network uses the positions of the assistant player, the shooter player and the goal. Although this paper presents a model of collaboration between agents, does not involve the strategy of the whole team, or selection of roles or tactics, and it could be only applied to a pass for shooting the ball. In [17] was developed a framework to locate agents for supporting cooperative multi-agent performance in dynamics environments, in this case, the framework was modeled and simulated in small size league. However, it did not present a complete decentralization. In this model are involved the actions requirements and agent capabilities. One strategy can be designed for the interaction between the goalkeeper and the rest of the team. This research is published in [18], and it is implemented in the Middle Size League Azurra Robot Team, in the RoboCup F2000.

Artificial immune systems (bio inspired and evolutionary algorithm based on the behavior of the vertebrate immune system) have been used for Robot Soccer strategies, for example in [19] is modeled an immune network based in cooperative strategies for Robot Soccer system, which selects proper behaviors for the player, from shot, pass, kick, chase, track and guard, this model was validate on the SimuroSot Middle League, a 5 vs 5 platform in FIRA. Using the same simulator, [20] presented a strategy of the goalkeeper by danger theory, which is a novel computational model of the Artificial Immune Systems. In [21] is presented a review of the changes in multi agent systems, and the development of cooperative algorithms used in robot soccer competitions, which exemplifies behaviors of robots in a dynamical adversarial environment.

B. Strategies in Standard Platform League

One difficulty in Standard Platform League consists in limited computational resources for programming complex behaviors. One possible solution is Finite State Machines (FSM), which can be used for multi-agent behaviors, with lower computational costs. For example, in [22] is exposed the use of FSM for switching tactics combined with Petri Net Plans (PNP) for the implementation of roles, in a four-legged Robot Soccer Team Kouretes (Standard Platform League, using Aibos). The example of the Finite State Machine is shown in the Figure 3, where the selection of the tactics depends on the current situation of the game. A FSM is executed in each robot individually when a robot wins or loses the ball, the ball position changes, or the attacker location changes. The FST guarantees a unique role for each player. The Finite State Machine is triggered using information provided by the sensors of the same robot.

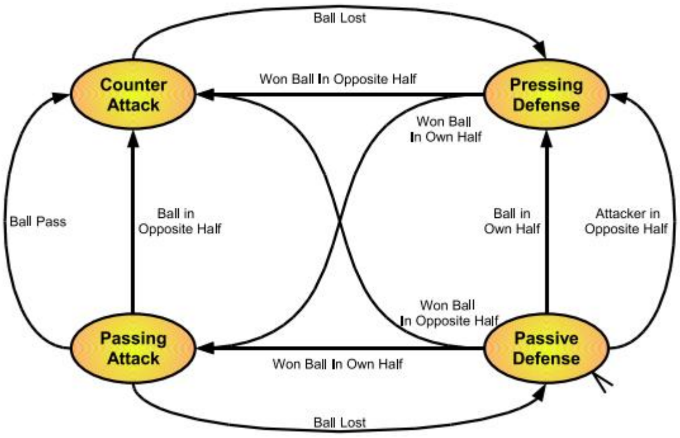


Fig. 3. FSM for switching tactics [22].

In [23] the complete strategy is implemented using PNP, Sub-Plans are also used for a higher modularity and readability. Other important concept used is Multi Robot Plans, which are PNPs implemented in single robots, enriched with synchronization constraints among the actions of other robots. Each action in Multi Robot PNP is labeled in a unique ID of the robot which performs it. Each robot involved in a Multi Robot PNP divides that in a single agent plan for the execution. An example is presented in the Figure 4, where a Multi Robot PNP involving two robots is presented, decomposed in two single Robot Plans, and synchronized by a sync operator which establishes a communication link between the robots involved, to exchange information and synchronize the execution. To present an example, in the particular case of the Figure 4, one robot moves to a side of a table to lift it. At the same time, other robot reaches the other side, sync operator ensures that the table will be lifted only after the robots have successfully finished the previous phase.

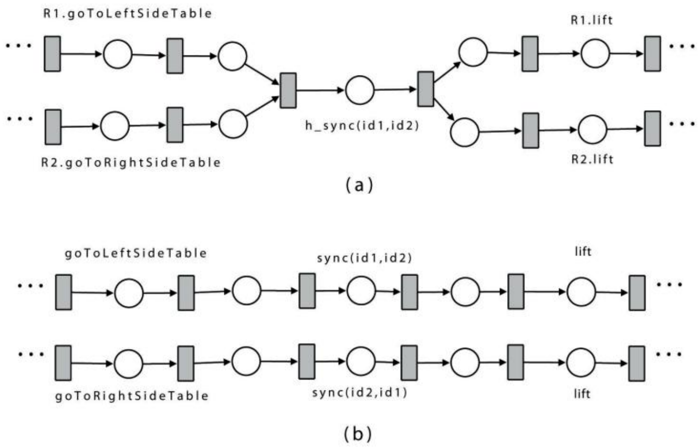


Fig. 4. Multi Robot PNP. In (a) is presented a Multi Robot Plan, in (b) is decomposed in two singled robot plan using sync operator for synchronization. [23].

The Joint Commitment theory is involved in the design of the cooperative behaviors embodied in the PNP. The concept of commitment establishes among the team members that decide to perform teamwork. Team members committed to the execution of a cooperative behavior will continue their individual action execution until one of the following conditions hold: Behavior was concluded, behavior will never conclude (It is impossible) or Behavior became irrelevant. Joint Commitment theory was implemented and validated in Aibo Robots for cooperative behaviors, for example, a pass execution.

Aibo was used as well to validate in Robot Soccer a novel reasoning-based case for the action and coordination selection in multi robot tasks [24], In this case a Multi-Robot architecture is proposed along with a coordination mechanism involving the evaluation candidate cases to solve a multi robot target, through different measures to overcome the real world characteristics, including adversarial components.

Neural networks were implemented using Aibo in Standard Platform League, generating dynamics formation strategies for robotic soccer applications based on game conditions [25], regarded to favorable or unfavorable for the robot team. The game policy is defined as a coach, establishing the attitude of the team for defending or attacking. The neural network was trained based on the experience acquired in previous games, and it computes the game condition. In this work, the game conditions are accumulated along the game, during last period of time T. The game conditions are evaluated based on the experience in the game each time T, it is calculated by counting of actions of the players, like shoots, goals, change of positions, change of roles, time in each role, goals executed by the player, goals executed by the team, goals received, and others. These game conditions were determined by a human expert. The neural network used was a perceptron with 3 layers. Based on the result of a figure called attitude the roles of the players are assigned, the attitude is calculated by a metric which is evaluated by the game conditions. Depending on the attitude, a new formation is assigned by each player by a captain of the team (Robot Player), and communicates its result to other players. A general structure of this model is presented in the Figure 5.

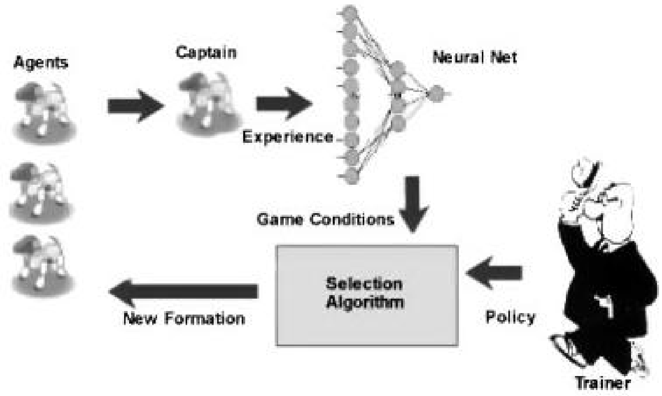


Fig. 5. General Structura of the model proposed in [25].

In the Standard League for Nao Robots is presented a Multi-Humanoid modeling of the world in [26]. In this paper is presented a modeling approach which differentiates among the motion model of different objects, in term of their dynamics, involving cooperation among the robots. In this world modeling, objects are categorized as static, passive, actively and foreign. The confidence of the models is classified like valid (when the position and classification of the object is certain), suspicious (when the validation of the information by other robot is needed), and invalid (when the object could not be sense). When an object and its confidence are obtained by a robot, this information is transmitted to the other players of the team. In [27] is presented a dynamic selection of roles in a robot soccer team. This model is validated using Aibo robots, where the players are divided in roles. These are assigned dynamically, excepting the goalkeeper. Each robot evaluates by heuristic functions (like ball distance, location, etc.) the assignations of the roles and also broadcasts this information to the teammates. Each role has specific behaviors to perform.

In the research presented in [28], fuzzy inference system is used in Nao to handle the roles in behavior structure. The results were validated in 3D simulation.

Other simulation with Nao which uses FSM for the behavior control in the strategy for Robot Soccer, using Webots, is presented in [29]. In this case, an example of the states and transitions of a player is shown in the table I, and the model of FSM for the behaviors of the robot is presented in the Figure 6. For example (see Table I and Figure 6) the state E6 (Adjust Position) is analyzed, in this state the robot seeks for the first post of the goal and adjusts the position, finding the center of this. One of the previous states of E6 is E4 (Ball localization), and its previous transition is T7 (Ball is close). The other precious State of E6 is E5 (Walk to the ball), when the transition T9 (Ball at the feet is done), the FST switch to E6. If the robot is in E6, when the transition T8 (Ball is lost) occurs, the robot switch to state E3 (Seek for the ball). In case of transition T12 (Robot has fallen) appears first, robot switch to state E8 (Stand up). In case that the transition T10 (Robot is positioned) is presented, the robot switch to state E7 (Kick to goal).

States	**Transitions**
E_1 Seek for the opposite goal	T_1 Goal not found
E_2 Self localization	T_2 Goal found
E_3 Seek for the ball	T_3 Robot located
E_4 Ball localization	T_4 Ball not found
E_5 Walk to the ball	T_5 Ball found
E_6 Adjust position	T_6 Ball is away
E_7 Kick to goal	T_7 Ball is close
E_8 Stand up	T_8 Ball is lost
	T_9 Ball at the feet
	T_{10} Robot is positioned
	T_{11} Succesful kick
	T_{12} Robot has fallen
	T_{13} Robot has stood up

Table I. States and transitions of the FST of [29].

In [30] is presented a robotic behavior based architecture, which was implemented firstly with finite state machine, and subsequently using activation tree. In general, FSM are commonly used for implementation of the Robot-Soccer teams strategies in the Standard Platform League, for instance FSM have been implemented in teams like B-Human Team [31], SpiTeam [32], WPI Warriors Team [33], L3M SPLTeam [34]. Some reports shown variations in the FSM, for example Cerberus Team implemented a FSM based planner, involving Market Based Approach [35], CMurfs Team implemented FSM for behaviors, and cognitive agent which processes the Robot State, generates Robot Commands and handles network communications [36], Tjark team using a FSM to the decision making system [37], UPennalizers team implemented three different FSM for the control of the game state, head behaviors and body behaviors [38]. Other implementations of the behaviors have been done by SPQR+UCHILE team, which use Petri Net Plann [39], or Nao Devils team which implemented an Artificial Immune Network for behavior control [40].

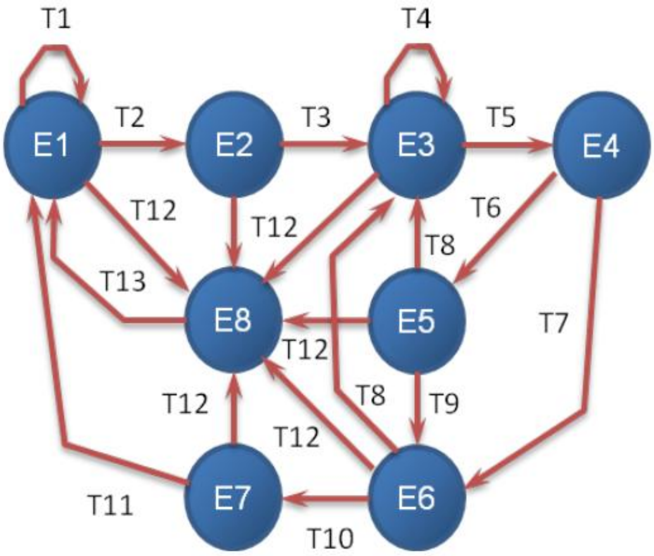


Fig. 6. FSM implemented in [29].

IV. PROPOSAL OF STRATEGY

In this section a robot soccer strategy, which involves the position of the ball and opponents for role selection, is proposed. In this strategy model, the tactic is evaluated when the team that possesses the ball changes, or when the soccer ball changes its location moving from one zone to another within the soccer field. Likewise new roles for team players are assigned dynamically. Defensive defender, defensive attacker, offensive defender and offensive attacker are the tactics included in this robot soccer strategy. Roles change in the robot when a new tactic is evaluated, these roles are defender, supporter or attacker, on the other hands, the goalkeeper is considered a static role.

For the tactic selection, the soccer field has been divided into three different sections, it is shown in the Figure 7. Zones have been defined as follow: The defensive zone where the goalkeeper of self team is located, the middle zone, and the offensive zone where the goal of the opponent team is located.

Fig. 7. Division of soccer game for strategy proposed.

The tactic is selected depending on the ball position (defensive zone, middle zone or offensive zone), and the team that possess the ball. 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 presented in Table II, and they can be easily programmed in any supported language. The algorithm for the tactic selection is executed by the goalkeeper, because it is the only role that is constant along the game, moreover the goalkeeper owns the position to see all the zones of the field at the same time. In case of goalkeeper failure, the algorithm for tactic selection will be ruled by the player with the attacker role.

Tactic	*Ball zone*	*Ball possession*
Defensive Defender	*Defensive*	*Opponent*
Defensive Defender	*Middle*	*Opponent*
Defensive Attacker	*Defensive*	*Own*
Ofensive Defender	*Ofensive*	*Opponent*
Ofensive Attacker	*Middle*	*Own*
Ofensive Attacker	*Ofensive*	*Own*

Table II. Selection of tactics.

A. Defensive defender tactic

This tactic is presented when the opponent has the ball in the middle or the defensive zone. 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 Figure 8, and it presents a possible position that would take the player if this tactic were activated. Nao robots are the same team, and Darwin robots are the opponent team. Defender goes to the ball which is in possession of Darwin Robot, attacker goes to middle field and supporter blocks the other Darwin robot in the self area.

Fig. 8. Example of roles in defensive defender tactic.

B. *Defensive attacker tactic*

This tactic is presented when the self team has the ball possession in the defensive zone. 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 players behavior. An example of the formation of this behavior is presented in the Figure 9, where hypothetical players position 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.

Fig. 9. Example of roles in defensive attacker tactic.

C. *Offensive attacker tactic.*

This tactic is presented when the self-team possess the ball, in the opponent half soccer field. 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 balls 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 Figure 10, where a possible position of the players is presented.

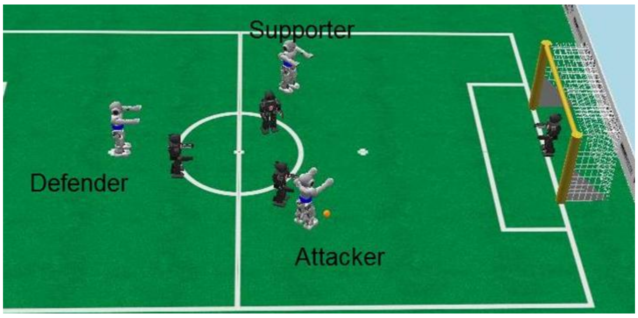


Fig. 10. Example of roles in offensive attacker tactic. In this case attacker shoots the ball to opponent goal.

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 Figure 11.

Fig. 11. Example of roles in offensive attacker tactic. In this case attacker shoots the ball to supporter. If supporter catches the ball, he becomes new attacker and shoots to the opponent goal.

If the ball is caught by the supporter, new roles would be assigned where the supporter becomes to the new attacker, and the attacker in last tactic becomes the new supporter.

D. *Offensive defender tactic.*

This tactic is presented when the ball is in possession of the opposite team in the offensive zone. 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 opponents shoot toward its own goal. Supporter blocks other player near to the own field, to prevent a pass between player of the opponent team. This hypothetical situation is presented in the Figure 12, where a possible formation of the players is shown.

In order to implement this model, it is necessary that each robot obtains a map of the game field, obtaining the ball position, its own position, the position of the fellow team members, and the position of the rival team members. This map could be created by using the vision system of the Nao robot, including both cameras which Nao owns, algorithms such particle filter combined with the odometry of the robot are usually used for this purpose. Additional

Fig. 12. Example of roles in offensive defender tactic.

hardware requirement necessary for the implementation of this proposal strategy is a wireless communication system, in Robocup the communications process among the robots, and between the game controller and the robots is allowed, although the bandwidth is limited to 500 kbps, subsequently the robots communications process is very limited. In case of tactic selection by the goalkeeper, when a transition occurs the goalkeeper activates the algorithm for this purpose and selects a new tactic, a communication signal must be sent to other players to communicate the new tactic selected, each tactic must be identified by an ID. Goalkeeper sends to other players a monitoring signal every second, and each player must respond, to ensure that the communication between them is active, in the event that the monitoring signal were not sent by the goalkeeper, the attacker assumes the role for the strategy selection, and it sends the monitoring signals until the signal of the goalkeeper appears again.

For role selection in every tactic change, each robot calculates its own distance to the ball and to both goals (own goal and opposite goal). When robots calculate the different distances, they would send their distance information to goalkeeper (or attacker in case of goalkeeper failures), which assigns new roles depending on the distances and the game conditions explained in each tactic section (V-A, V-B, V-C, V-D). Although the hardware requirements (computer vision, mapping and wireless communications) are strongly necessary for the correct implementation of this proposal, the algorithms for tactic selection are straightforward to implement without a high computational cost. This is a semi centralized model, due to a central robot that selects the tactics and assigns the roles (avoiding possibility of conflicts in the selection), but the information for role selection is given by each player. An important advantage is the dynamical tactic assignation that depends on the instantaneous game conditions. Some robustness is presented with the possibility of changing the player that selects tactics and roles (goalkeeper to attacker), in case of goalkeeper failure. Other special characteristics of this proposed model include the execution of different behaviors in different roles, for example, supporter could make a pass to attacker, it could block a rival player or could go towards the ball, depending of the selected tactic.

For the hardware implementation of the proposed model, special requirements for computer vision and computational processing have to be considered carefully. A computer vision system could be used to create maps of the world, and to estimate players and ball positions. In case of the goalkeeper. which determines when the tactic change, the algorithms for these estimations require high computational processing, which is limited in older versions of Nao. More recently versions of Nao Robot include Atom Processor with more speed and memory than previous versions, and it also includes two cameras with higher specification. These hardware improvements are necessary to obtain the best performance in the implementation process of this model.

V. CONCLUSION AND FUTURE WORKS

In this paper, a general review on collaboration models among robots in robot soccer was presented, focusing on strategies implemented in the Standard Platform League of the Robocup, due to hardware limitations and decentralization of the Nao Robots which are used in this League. It was also presented a proposal of strategy for a team of the Standard Platform League, involving dynamic roles selection, depending on ball position in the field and the position of the opponents. This strategy is easy to implement using the language supported. This model is a semi decentralized system, because decisions of tactic changes and roles assignation are executed by one robot, avoiding more complexity in the model involving conflict resolutions in these decisions, but information of game conditions necessary to determine new roles are acquired by the whole team.

In future works, the strategy presented will be validated by simulation using Webots. Subsequently a multi-agent system for robots cooperation will be presented. This model will involve characteristics such as the possibility to use in general purpose, learning, decentralization, and directed to robotic systems with limitation in sensors, actuators and computational resources. Nao Robots in Standard Platform League presents an adequate frame for the validation of a model with last characteristics. It is proposed an offline learning in coordination process, for example in the roles selection, or behaviors, or uncertainty models in location, for robustness.

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