FC Portugal: New Coordination Methodologies in RoboCup Legged League[1]

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Abstract: FC Portugal legged league team is the successor of FC Portus team that achieved 5th place in RoboCup 2003 and 9th place in RoboCup 2004. FC Portugal team is being developed by a research group with a long and successful experience in RoboCup (simulation, small-size and middle-size leagues) and results from the combined efforts of several research laboratories, universities and schools. It also uses several research methodologies and code from our teams in other leagues (FC Portugal – simulation and coach leagues and 5DPO – small and middle size leagues). Our 2005 team includes several research innovations (like the effective use of Situation Based Strategic Positioning, Dynamic Role Exchange, Tactical Flexibility and Automatic Color Calibration). Although we are still in the process of adapting our 2004 code to the new ERS7 robots, we already have the new robots playing on the field and we are confident that our new team will be a lot more robust and flexible in its coordination methodologies and soccer playing strategies.

1. Introduction and Research focus

FC Portugal research focus, like its predecessor team FC Portus, is on coordination methodologies applied to the legged league and on developing a common approach to all RoboCup soccer leagues. In the context of our legged team we also perform research on vision and automatic calibration, agent architectures, intelligent multi-agent communication, navigation, localization and learning applied to teams of mobile robots.

We started performing experiments with the German Team simulator [Burkhard, 2002] [Rofer, 2002] and using our expertise in the simulation league and on developing complex simulators [Reis, 2001a] [Pereira, 2004], we have built a very simple legged league simulator (with very simple models of the robots) enabling us to test different positioning strategies.

Afterwards we have bought the robots and moved our code from the simulator to the real robots. For that, we have used over the years, CMPack02 [Veloso, 2002] and UNSW03 [Chen, 2003] [Sammut, 2003] codes as the base. We have applied over the base code, several previously researched methodologies developed and tested in our teams in other RoboCup leagues (Simulation, Small-Size, Middle-Size and Coach Leagues). From FC Portugal [FCP, 2001] (champion of RoboCup simulation league in 2000, European champion in 2000 and German

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Open Winner in 2001) we introduced simple versions of SBSP – Situation Based Strategic Positioning [Reis, 2001a], [Reis, 2001b], ADVCOM – Advanced Communications [Reis, 2001a, Ferreira, 2004] and DPRE – Dynamic Positioning and Role Exchange [Reis, 2001a], [Reis, 2001b]. From our FC Portugal Coach (Coach Competition champion in 2002), we have taken our tactical structure and coaching language [Reis, 2002]. From 5DPO teams [5DPO; 2001] (small-size 3rd in RoboCup 1998, German Open Winners in 2001 and 2nd in 2002) we have taken the vision system and most of our navigation algorithms [Costa, 2000], [Moreira, 2001].

3. Vision, Localization and World State

Based on the publicly available code from RoboCup 2002 champions (CMPack) [Veloso, 2002], namely on its CMVision image processing library [Bruce, 2000] [Bruce, 2001] and on our experience and own code for small-size and middle-size leagues vision [Costa, 2000], we have developed a robust vision system including capabilities for color image segmentation and object recognition. Although not yet fully functional, this system is also capable of performing the generation of a high-level description of the image contents, including the identification of each object, its direction, distance, size, elevation and confidence. The steps performed by the vision module are typical from most of the Legged league teams (with exception of the last one):

- Construction of color calibration lookup tables;
- Capturing an image and classifying pixels into the pre-defined color classes (basically by looking up into the previously defined table);
- Image segmentation, finding blocks of the same color and their characteristics (center, size and shape) using a hierarchical, multi-resolution algorithm previously used in our Small-Size and Middle-Size teams [5DPO, 2001], [Costa, 2000];
- Object recognition and generation of an image high-level description: identifying objects based on the color blobs and converting its own coordinates to world coordinates (relative distance and direction);
- Textual image description: changing the high level image description into a text description easily understandable by humans.

We use the eight typical colors of the legged league: pink (for the beacons), yellow and sky blue (for beacons and goals), dark red and dark blue (for the robots' uniforms), orange (for the ball), green (for the field carpet) and white (for the field lines and detection of ERS7 bodies). Our robots need to detect and discriminate these colors in order to recognize the appropriate objects.

One of the main innovations of our team's vision system resides on the method developed for the construction of the color calibration tables. We have used our previous experience in designing vision systems for the small and middle-size leagues [5DPO, 2001], [Costa, 2000] and designed a very simple automatic color calibration module. Using this module, we construct the color table, based on a set of significant images autonomously collected by the robot, that walks around the field looking for colors similar to the ones available in its previous calibration. With the pictures autonomously gathered by the robot we assemble in a semi-automatic manner the color segmentation table. This system was demonstrated in RoboCup 2004 challenge (Lisbon) achieving 8th place in challenge 1.

Image segmentation is performed based on the pre-processed image resulting from our color calibration module. Our team's fast blob formation algorithm is an extension of our

hierarchical, multi-resolution algorithm previously used in our Small-Size and Middle-Size teams [5DPO, 2001], [Costa, 2000].
In the legged league the objects that must be tracked include: the four unique markers, the ball, the two goals and the other seven robots. Objects in the image are identified based on its color, shape and position. Color is the main feature used for object identification, an approach similar to that used by most other teams so far. Since our Image Segmentation module also gives some information about the shape and size of the blobs, we use this information to recognize objects and to estimate its distances, directions, elevations and headings relatively to the neck of the viewing robot.
Several localization algorithms have been proposed and tested in the context of RoboCup [Fox, 1999]. We started by using a localization method that works using high-level vision information with a Fuzzy Landmark-Based Localization algorithm similar to several RoboCup teams, inspired in [Buschka, 2000]. Given the very good results achieved by CMPack in RoboCup 2002, and its very precise localization we moved to a method similar to sensor resetting localization [Lenser, 2000] whose source code was available on the web [Lenser, 2002].
FC Portugal agent's internal representation of the world, results on the processing of various sensorial information sources fused with communicated information. The information contained in the world state includes:

- Self position – Cartesian coordinates;
- Ball position – Cartesian coordinates;
- Ball velocity - Vector;
- Teammates' position – Cartesian coordinates;
- Teammates' velocity – Vector;
- Teammates' behavior;
- Teammates' State;
- Opponents' position – Cartesian coordinates;
- Opponents' velocity – Vector;
- Opponents' behavior;
- Opponents' State.

All the above measures have an associated certainty factor, expressing the probability of the measure being accurate.
Our world state update method is somewhat different from other teams since 2004 competition. For 2004 competition we moved to a trigonometric world state fusion method. Figure 1 shows a graphical description of this method. The area defined between the interceptions of two of the agents quantifies the uncertainty of the calculated ball position (the bigger the area the bigger the uncertainty). This area is the limiting area for the presence of the ball according to the sensorial information of the two involved robots (see details in [Afonso, 2004]).

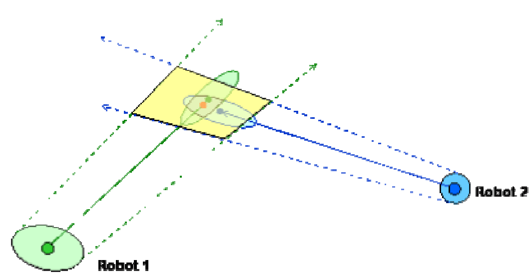

Figure 1 – Limiting area for the presence of the ball, in conjunction with the extreme vectors.

Our global World state update is similar to our simulation league team FC Portugal [FCP, 2001] [Reis, 2001a]. It uses:

- High-level perception information: obtained through camera and proximity sensors' preprocessing;
- Communicated information: Sent by the other members of the team; and
- Action Prediction: Prediction of the effects of robot actions in the environment.

These three types of information are fused together to assemble our world-state used as an input in the high-level decision module.

The communication between the robots complements the internal world state from all the robots, with additional information concerning team coordination, such as, position swap between team members or the existence of a ball pass to another team member.

4. Action and Locomotion

Locomotion is a complicated problem pointing to several possible different solutions, for a legged robot. In RoboCup, besides normal locomotion, algorithms must be developed for different types of locomotion in which the robots interact with the ball, like dribbling, kicking or defending the ball. Sony provides basic locomotion algorithms. However, several teams have early concluded that the development of their own specific algorithms for walking lead to a significant advantage in RoboCup Sony legged league [Hengst, 2001, Marceau, 2001].

We used previous developed locomotion models based on CMPack02 and UNSW03 source codes and developed new ball interaction skills: dribbling with the ball, kicking the ball (several types of kicks) and defending the ball (mainly for the goal-keeper but also to be used by other robots). For 2005 we developed a simple graphical application for developing new AIBO robot movements and moved the task of developing new movements to a Portuguese secondary school that is collaborating in this project. This enables young researchers, besides working on simple RoboCup Junior leagues, to work, since early ages in senior robotic leagues, closely supported by their high-school teachers and backed-up by university senior staff.

Our main research focus on Action and Locomotion is focused on developing algorithms for learning the best parameters for each one of the low-level skills. The learning algorithms are being developed with the use of a global vision system we have installed on our lab and special grid marks on the field. The centralized vision system provides the robots with accurate information about their movement and the ball movement and enables to measure the relative efficiency of the low-level skills algorithms (like speed and the accuracy of movement from the robot and the ball) and use reinforcement learning [Sutton, 1998] based techniques to decide on the best possible parameters for each low-level action.

5. Coordination and Team Strategy

Although the importance of team behaviors in the league has not been as critical as in the simulation or small-size league, it is very difficult to build up a competitive Sony legged team without having special concerns with teamwork. This assumption is confirmed by the fact that the previous champions CMPack, UNSW and the German Team have all implemented teamwork algorithms like multi-agent communication, intelligent perception, teammate recognition and the use of roles [Stone, 1998] [Hengst, 2001]. Also both CMPack [Veloso, 2002] and UNSW [Chen, 2002], concluded that their wins in RoboCup were due to

their better game-play tactics or high-level strategies and not due to their better low-level skills [Chen, 2001], [Veloso, 2002] [Rofer, 2004].
Also we believe being researchin in the same high-level direction as the last winners of RoboCup legged league. FC Portus began two years ago “Towards a Common Framework for Cooperative Robotics in RoboCup” [Reis, 2003] or in other words Towards a League-Independent Qualitative Soccer Theory for RoboCup [Dylla, 2005]. Having teams in all major RoboCup leagues also in Rescue gives us the perspective that a Common Framework for Cooperative Robotics is the main goal we must pursue using it for robotic soccer but always thinking in using it for other socially more useful robotic cooperative tasks.
In our present team we assign roles to our robots (goal-keeper, defender, attacker, supporting attacker, attackerB, defenderB, supporting defender, etc.). These roles are related to specific different sets of robots’ behaviors. Specific tactics will be defined to be used depending on the game current situation (namely current score). Tactics will assign appropriate roles to the players on the field. For example, a more defensive tactic may use a goal-keeper, a defenderB (defender of type B) and a supporting defender, while a more offensive tactic may use an attacker, an attackerB (attacker of type B) and a defender. Dynamic role exchange [Reis, 2001a] using positional reasoning and Wireless communication will be implemented in our robots.
Each role is defined with different behavior characteristics. These characteristics are mainly concerned with the process of action control used by the robots. Our decision process is based on extended behavior networks [Dorer, 1999], which add situation dependent motivational influence on the agents and extend original behavior networks [Maes, 1989]. Extending behavior networks enables the exploitation of information from continuous domains, keeping the main advantages of the original networks, such as reactivity, planning capabilities, robustness, accountancy for multiple goals and simplicity.
We intend to do a demonstration on RoboCup 2005 of the communication of tactical advice between a human coach and robotic team, by providing a means for the robots to recognize information on a white board hand-written by the human coach!! At each game interruption, the robots are shown the board written by the human coach identifying tactical advice contained on this board (tactic, formation and individual behaviors) and behaving accordingly.

6. Results and Conclusions

Our legged team is participating in RoboCup for two years now. Table 1 shows the results achieved by FC Portus in 2003 and 2004. The team scored 40 goals and conceded 36 in these two participations.

Games - RoboCup 2003	Result
FC Portus – Team Sweden	5-2
FC Portus – Univ. Chile	8-0
FC Portus – Cerberus	5-0
FC Portus – NuBots	0-10
FC Portus – Baby Tigers	2-2
Total	*20-14*
Quarter-Finals	
FC Portus - rUNSWift	0-12

Games - RoboCup 2004	Result
FC Portus - CMPack	1-3
FC Portus – UTS Unleashed	2-4
FC Portus - MiPal	7-1
FC Portus - Mexico	7-0
FC Portus – Dutch Team	3-2
Total	*20-10*

Table 1: Results of FC Portus in RoboCup 2003 (Padova) and 2004 (Lisbon)

Although FC Portugal is a new team on the legged league and its predecessor did not achieve very good results (5th in Padova and 9th in Lisbon) we believe that our approach may lead to very good results in RoboCup legged league in a near future. Our research group also participates in several other leagues in RoboCup, pursuing a common framework for cooperative robotics that may be used in all RoboCup cooperative soccer/rescue leagues, achieving very good results in most of the leagues (table 2).

Competition	Location	Team	League	Award
RoboCup 1998	Paris	5DPO	Small-Size	3rd Place
EuroRoboCup 2000	Amsterdam	FC Portugal	Simulation	Champions
RoboCup 2000	Melbourne	FC Portugal	Simulation	Champions
German Open 2001	Paderborn	5DPO	Small-Size	Champions
German Open 2001	Paderborn	FC Portugal	Simulation	Champions
German Open 2001	Paderborn	5DPO	Middle-Size	3rd Place
RoboCup 2001	Seattle	FC Portugal	Simulation	3rd Place
German Open 2002	Paderborn	5DPO	Small-Size	2nd Place
RoboCup 2002	Fukuoka	FC Portugal	Coach	Champions
German Open 2003	Paderborn	5DPO	Small-Size	2nd Place
German Open 2003	Paderborn	5DPO	Middle-Size	3rd Place
RoboCup 2003	Padova	FC Portugal	Coach	2nd Place
German Open 2004	Paderborn	5DPO	Small-Size	2nd Place
RoboCup 2004	Lisbon	FC Portugal	Coach	2nd Place

Table 2: Awards of FC Portugal and 5DPO Teams in RoboCup

The innovative ideas underlying our project and the encouraging results achieved in our first participations in RoboCup make us believe that, after implementing our previously developed high-level coordination methodologies in our legged team, it may be possible to achieve the top places in RoboCup 2005. The results achieved previously by our teams (FC Portugal and 5DPO) in the simulation league, coach league, small-size league and middle-size league, and the overall experience of our team in RoboCup, gives us the assurance that we still have the right team to perform this project.

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