Portus: A Common Framework for Cooperative Robotics – Legged League Team

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Abstract: Portus Legged League 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 two research laboratories (LIACC and ISR-P) and from our previous teams (FC Portugal – simulation league and 5DPO – small and middle size leagues). We believe to have developed a very competitive team that although being in its first steps, includes several research innovations (like Strategic Positioning and Automatic Color Calibration) and is very flexible in its coordination methodologies and soccer playing strategies.

1. Introduction and Research focus

Portus research focus is on coordination methodologies applied to the legged league and on developing a common approach to all RoboCup soccer leagues. In the context of Portus 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 have applied in our Portus team methodologies previously developed and tested in our teams in other RoboCup leagues (Simulation, Small-Size, Middle-Size and Coach Leagues). We started with the publicly available source code from CMPack02 and introduced several concepts and algorithms previously developed for other leagues and other domains. From FC Portugal [FCP, 2001] (champion of RoboCup simulation league in 2000, European champion in 2000 and German Open Winner in 2001) we have used SBSP – Situation Based Strategic Positioning [Reis, 2001a], [Reis, 2001b], ADVCOM – Advanced Communications [Reis, 2001a] 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].

We started performing experiments wit the German Team [Rofer, 2002] [Burkhard, 2002] simulator [Burkhard, 2002] and using our expertise in the simulation league we have built our own simple legged league simulator. Afterwards we have bought the robots and moved our code from the simulator to the real robots.

3. Vision and Localization

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. 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 and elevation. The steps performed by the vision module are:

- Construction of color calibration tables;
- Capturing an image and classifying pixels into eight pre-defined color classes;
- Image segmentation, finding blocks of the same color and their characteristics (center, size and shape);
- Object recognition and generation of an image high-level description: identifying objects based on the color blocks 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.

In the legged league, nine colors are used on the field: pink and green (for the beacons), yellow and sky blue (for beacons and goals), dark red and blue (for the robots' uniforms), orange (for the ball), light green (for the field carpet) and white (for the field lines and borders). 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 an automatic color calibration module. Using this module, we construct the color table, based on a set of significant images autonomously collected by the robot, who walks around the field looking for colors similar to the ones available in its previous calibration!

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 six 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]. At the moment our localization is basically performed 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, in the future we plan to change to a method similar to sensor resetting localization [Lenser, 2000] whose source code is available on the web [Lenser, 2002].

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 concluded that the development of their own specific algorithms for walking may lead to a significant advantage in RoboCup Sony legged league [Hengst, 2001, Marceau, 2001].

We are developing our own models for the basic locomotion behaviors, based on CMPack02 source code [Veloso, 2002]: forward motion, backward motion, left and right turns, and other low-level skills concerning ball interaction: 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).

Our research on this matter 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 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. Communication and World State Update

World state update in our robots works, in a similar way 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.

6. Coordination and Team Strategy

Although the importance of team behaviors in the league has not been so 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 and UNSW have 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 was due to their better game-play tactics or high-level strategies and not due to their better low-level skills [Chen, 2001], [Veloso, 2002].

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 improve the communication of tactical advice between human coach and robot team, by providing a means for the robots to recognize information on a white board. At each game interruption, the robots are shown the board written by the human coach, identify the tactical advice contained on this board (tactic, formation and individual behaviors) and behave accordingly.

7. Results and Conclusions

Although being a new team (and at the moment still facing the usual technical difficulties in a project of these kind), the innovative ideas underlying our project and the good results achieved in our first experiments, make us believe that is possible to achieve the top places in RoboCup 2003. Also, the results achieved previously by our teams (FC Portugal and 5DPO) in the simulation league[1], small-size league[2] and middle-size league[3], and the overall experience of our team in RoboCup[4], gives us the assurance that we have the right team to perform this project.

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[1] RoboCup Champions in Melbourne 2000, European champions in Amsterdam 2000, German Open winners in Paderborn 2001, Coach Competition winners in Fukuoka 2002

[2] RoboCup 3rd place in Paris 1998, RoboCup 5th in Seattle 2001, German Open winners in Paderborn 2001, German Open 2nd place in Paderborn 2002

[3] German Open 3rd place in Paderborn 2001, 1st place in several Portuguese competitions

[4] Luís Paulo Reis is and elected member of the simulation league technical committee since 2001. Paulo Costa is an elected member of the small-size league technical committee since 2001and is the chair of the small size league in Padova 2003. António Paulo Moreira will be RoboCup Sony Legged league local chair in RoboCup 2004.

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