ISocRob'2000: A Multi-Sensor Self-Localized Cooperative Robotic Team*

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1 Introduction

ISocRob's reference functional architecture has evolved considerably since the first participation in RoboCup'98, Paris. Nevertheless, the consolidation of concepts has been frequently jeopardized by unreliable hardware and communications. This lead to significant team changes regarding EuRoboCup'2000 and RoboCup'2000 participations, especially concerning the hardware and software architectures.

This paper is organized as follows: in Section 2, the hardware and the software of ISocRob's current robots is described in some detail. The main new blocks of the functional architecture are explained in Section 3, namely the navigation system and the goal-keeper role. Finally, perspectives for future work are depicted in Section 4.

2 Hardware and Software

The most significant hardware change from previous years was the replacement of ISocRob's original robots by a team of four Nomadic SuperScout II commercial platforms. The SuperScouts include a Pentium motherboard at 233 MHz, and libraries with odometry, motion control, bumpers and sonar handling functions. Simultaneously, the Philips web-cams that were located at the front of each robot were replaced by `Ultrak KC7500CP` cameras (based on a Sony CCD), which provide better SNR, manual white balance and much better optics. The old AAEON wireless Ethernet modems whose lack of reliability caused many troubles were replaced by WaveLan Turbo 11 Mbs wireless Ethernet modems.

Another major upgrade was the introduction of a catadioptric system consisting of a tiny `MicroVideo MVC26C` CCD camera facing upwards a mirror designed to provide an omni-directional bird's eye view of the playing field. The mirror

* This work has been supported by the Portuguese Foundation for Science and Technology and Agency for the Innovation. The authors also wish to thank Carlos Sá, José Baptista and Ricardo Silva for their work on the implementation of the goal-keeper role.

was designed so that in the obtained image distances measured in pixels are related to playing field distances by a gain, therefore distances to relevant objects are easy to determine. A simple calibration process was also developed to determine this constant, using *a priori* information about the field and field line dimensions.

Objects on the field, such as the ball and the other robots, are highly distorted by the catadioptric system. However, the robots (as well as the field walls) are no longer visually detected. Instead, a sonar system consisting of 16 Polaroid sonars surrounding each SuperScout is used for that. The ball position can still be correctly determined by picking the intersection point between the orange bulb and the green field from the image.

The new front cameras are now exclusively used for ball detection. A fast version of the Hough transform was implemented to find pixel color transitions from orange to other colors that are members of a circular arc. This proved to be a robust method to detect the ball.

In the past, the setup of the thresholds to discriminate among the relevant image colors was usually a tedious and error prone process. As this setup is required before each game, even when playing at the same field, its impact on team performance should not be under-estimated. To handle this issue, an application was developed that determines the thresholds to discriminate among yellow, blue, green and orange colors from an observation of field images taken just before a game. The image is converted from RGB to HSV color scheme [1] and the saturation and value components are used to establish the thresholds that eliminate white and black pixels from the image, respectively. The colors are discriminated using the resulting image by building an histogram for the hue component and choosing as thresholds the intersection points of the gaussian distributions adjusted to the pixels corresponding to each color, thus minimizing the discrimination error. The application is used with both the catadioptric and frontal vision systems.

A kicker adapted to the SuperScout characteristics was designed, after an evaluation of alternative solutions, such as the usage of solenoids, electro-hydraulic or electro-pneumatic systems. The latter were chosen, based on the tradeoff among force, reaction speed and electrical power consumption. A pneumatic cylinder, connected to a pressurized air accumulator through an electro-valve, moves back and forth a metallic blade whose rest position helps keeping ball possession. The valve is controlled directly from the robot motherboard, allowing kick force control, an useful feature for controlled passes among teammates.

The philosophy of a multiple-thread software architecture was kept from previous work [5]. It consists of several concurrent processes (here named micro-agents to allow a consistent multi-agent view of the complete team architecture) that keep reading the sensors (vision, sonar, bumpers), sending the most recent set points to the motor controllers, processing sensor data, coordinating robot tasks, handling communications with the other robots and sending telemetry data (e.g., the state of internal variables, the primitive task currently running, an image from any of the vision systems) to an external monitoring machine.

Those micro-agents exist in all the robots of the team and communicate through a distributed blackboard (BB). New micro-agents were implemented, namely to handle self-localization and guidance algorithms. The former is capable of determining, approximately every second, the current robot posture, by processing the image taken by the catadioptric system. The latter uses this information to move the robots towards a desired posture, based on odometry.

The vision micro-agent has 3 software-selectable modes. The catadioptric system may be used to either find the ball (*up* mode) or determine the current posture of the robot (*self* mode). The *self* mode is run before a new trajectory is started and/or after a bump into an object. It provides useful information for guidance as well as teamwork purposes (e.g., relative location of 2 teammates to prepare a pass). The third (*front*) mode is dedicated to find the ball in the front camera image.

The guidance micro-agent tries to move the robot towards a posture set in the BB, while avoiding the walls and the other robots. The success or failure of each attempt is also reported to the BB.

3 Functional Architecture

The current reference architecture for the ISocRob team has been described in [3]. This architecture is being thoroughly reviewed currently, to widen its application range. Nevertheless, at least for EuRoboCup'2000, the new reference architecture will not be fully used yet, namely its higher layers. As such, the strongest impact in the old architecture comes from the availability of self-localization, which significantly changed the primitive tasks. The impact of the new navigation system on the primitive tasks is summarized in the next subsection. Subsection 3.2 describes ISocRob's new goal-keeper role, another major change with respect to the 1998 and 1999 editions.

3.1 Navigation System

The navigation system is implemented by the vision (in *self* mode) and guidance micro-agents. The self-localization method is detailed in [4].

Self-localization is performed in several occasions, e.g., when the robot starts a new trajectory towards a desired posture or after bumping into another robot or a wall. Given a desired posture (e.g., facing the ball so that it is between the robot and the goal, or the default posture for some player role) the vision micro-agent is invoked in *self* mode and the current posture is determined (if self-localization fails, the most recent posture estimate is used). Then, the robot is headed towards the desired posture using a simple feedback control algorithm which compares the desired posture with the current one, determined by odometry along the trajectory. Obstacles are detected by the 16-sonar ring placed around the robot. The potential field method [2] is used to generate repulsive forces from the obstacles and attractive forces towards the desired heading, so that the robot can navigate through a reasonably cluttered environment.

3.2 Goal-Keeper

The new goal-keeper behavior takes advantage of the catadioptric system to determine the successive ball positions on the field and fitting to them a trajectory composed of a weighted sum of affine and quadratic terms.

There are two working modes for the goal-keeper behavior:

- **Follower-mode**, when the ball is moving away from (or parallel to) the robot, where the goal-keeper follows the ball position such that the goal is conveniently covered.
- **Interceptor-mode**, when the ball moves towards the goal, where the ball interception point and speed are determined from the estimated trajectory, and the robot uses odometry to move towards the estimated interception point along a path parallel to the goal line, at a speed dependent on the ball speed.

4 Future Perspectives

The availability of self-localization opens new directions for the implementation of teamwork methodologies, as each robot may inform its teammates of its current posture, allowing the ellaboration of a global team organization, and the establishment of relational behaviors, such as passes between teammates. Cooperative navigation is also possible, as one robot that can not see the ball may be the one best located to get it, and become knowledgeable of this fact through the ball position estimates provided by its teammates. Once a robot knows its posture, the distance and angle to the ball, the determination of ball position is simple and can be improved by cooperative sensor fusion. These are topics to be handled in future work.

References

[1] R. Gonzalez, R. Woods, (1992), *Digital Image Processing*, Addison-Wesley.

[2] O. Khatib, (1990), "Real-Time Obstacle Avoidance for Manipulators and Mobile Robots", *in Proc. of the 1990 IEEE Intern. Conf. on Robotics and Automation*

[3] P. Lima, R. Ventura, P. Aparício, L. Custódio, (2000), "A Functional Architecture for a Team of Fully Autonomous Cooperative Robots", *in RoboCup-99: Robot Soccer World Cup III*, Springer-Verlag, Berlin

[4] C. Marques, P. Lima, (2000), "A Localization Method for a Soccer Robot Using a Vision-Based Omni-Directional Sensor", *in Proceedings of EuRoboCup Workshop 2000*, Amsterdam, The Netherlands.

[5] R. Ventura, P. Aparício, C. Marques, P. Lima, L. Custódio, (2000), "ISocRob - Intelligent Society of Robots", *in RoboCup-99: Robot Soccer World Cup III*, Manuela Veloso and Hiroaki Kitano, editors, Lecture Notes in Computer Science, Springer-Verlag, Berlin