Design of the ISePorto Robocup Middle-Size League Robotic Soccer Team: Control, Localisation and Coordination

Alfredo Martins
Institute for Systems and Computer Engine…

J.M. Almeida
Instituto Superior de Engenharia do Porto

E. Pereira Silva
Instituto Superior de Engenharia do Porto

Proceedings of the 10th Mediterranean Conference
on Control and Automation - MED2002
Lisbon, Portugal, July 9-12, 2002.

Design of the ISePorto Robocup Middle-Size League Robotic Soccer Team: Control, Localisation and Coordination

A. Martins*, J. Almeida*, E. Silva, J. P. Baptista

*Instituto Superior de Engenharia do Porto
Rua de S. Tomé 4200 Porto, Portugal
e-mail: {amartins,jma,eaps,jpaulo}@dee.isep.ipp.pt,

†MED2002 Conference
e-mail: med2002@isr.ist.utl.pt
http://www.isr.ist.utl.pt/med2002

Keywords: control applications, robocup, robotic soccer, mobile robotics, vehicle control.

Abstract

This paper describes the design and implementation status of the ISePorto robotic football team for participation in Robocup Middle Size League (F2000). The objectives guiding the project were the applications and research in hybrid control and coordination systems. The system has also an educational support role. A special attention is made to the custom design to allow the execution of complex manoeuvres and team coordinated behaviours. The robot has different pass, shot, and manoeuvre capabilities providing high level tactical and strategic planing and coordination. The current team status is also covered.

1 Introduction

The ISEP Autonomous Systems Lab. (LSA) robotic football team provides an excellent tool to develop and demonstrate the research in the areas of interest associated with autonomous systems. These are mainly sensor fusion, mobile robotics navigation, nonlinear hybrid feedback control and coordination. Additionally to the research interests, the laboratory has a strong educational purpose, being the robot team a good support to curricular and extra-curricular work in the areas of mechatronics, electronics and embedded systems.

The remaining of the paper overviews the robot design, the control and navigation issues, coordination and strategy guidelines finishing with the current team status.

2 Robot Design

The team robot was designed and implemented from scratch in order to be a suitable testbed for advanced multirobot coordinated control. The mechanical design has taken in account the requirements to execute complex manoeuvres and therefore not posing harsh limits on the control, navigation, or coordination developments.

The robot is constituted by three parts: a circular mobile base, a kicker connected to a structure that rotates around a central vertical axle and on top a computational an electronics module fixed relatively to the base with a pan mounted camera. The system is mechanically modular; it can be used in different configurations, such as different kicker designs with the same base. The base contains two differential traction 24 V DC motors with optical encoders for motor control and vehicle odometry, two 12V lead acid batteries, the kicker rotation motor and the motor power drives. The kicker uses a DC motor and mechanical spring with a camber and was designed to allow different kick strengths ranging from small passes to goal shots. This, coupled with the rotation allows the robot to perform complex manoeuvres.

The main computational system is consists of a 5.25" SBC (ICP NOVA600 with an AMD K6-2 300MHz or ICP NOVA7896FW with a 900Mhz Celeron) and IDE 24Mb Flash disk. Each robot communicates with the team and the host visualisation computer by an ethernet wireless modem (OTC AirEsy2405 at 2.4 GHz), to be changed to new modems compliant with IEEE 802.11.

The motor control is made in a custom designed multi-axis control board, comprising a FPGA (FLEX 10K10) and dedicated microcontroller (T89RD2). It communicates with the main CPU trough a PC104 connector (ISA bus). The PC104 form factor reduces size and it is a reliable connection system. The board implements 4 axis PID control at 2 KHz (traction, kicker rotation and shot), receiving encoder information and providing a sign magnitude PWM control signal to the power drives. Additionally, this board interface a magnetic compass (Vector 2X), and an optical switch to calibrate the angle of the rotating kicker with respect to the robot base.

The onboard computer runs a Linux operating from the flash disk, with a modular and hierarchic threaded software architecture [3], [4].

3 Vision System

The vision system uses two USB cameras (Philips PVC740K with a new wide angular lens from Marshall Electronics optics). One mounted on a central pan unit and used mainly for long range vision and localisation and the other fixed to the kicker to be used for fine ball control.

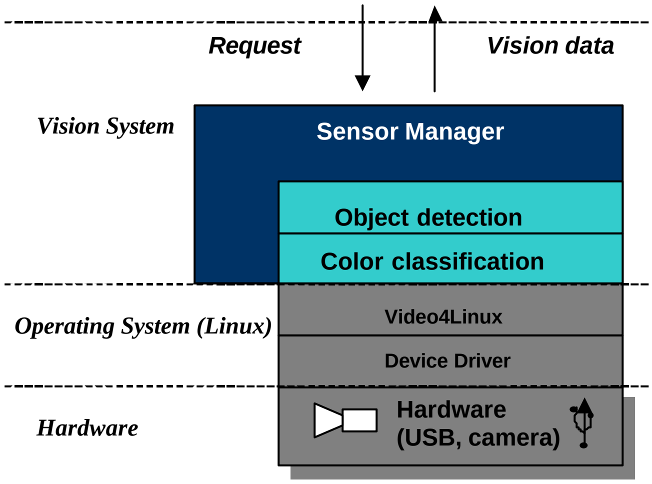

Figure 1 - Vision system architecture

The main characteristic of our vision system is the ability to perform a fast global analysis of the all image in order to decide where to conduct a more detailed one. An additional improvement is accomplished with the integration of the prediction the landmarks in the grabbed image or where the camera should point. Additionally the robot has a custom developed ring of IR range measuring sensors for short distance obstacle detection (up to 0.8m) and a magnetic compass.

4 Localisation

In the Robocup to achieve good team play capabilities, is required a good robot localisation and control.

Besides the robot self-localisation it is also necessary to perform adequate ball (and if possible other players) localisation.

The ball position estimation uses a Kalman filter tanking in account the robot model and the information received from the vision system. Adaptive ball detection algorithms are used for different cases of ball position and occultation in the image.

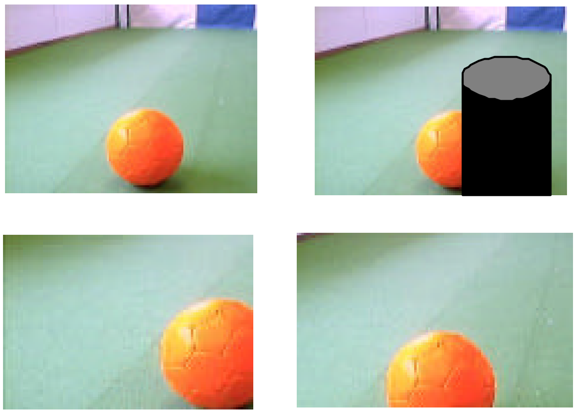

Figure 2 - Different ball position and partial view within the image frame.

An updated ball position estimate is maintained in the robot internal state.

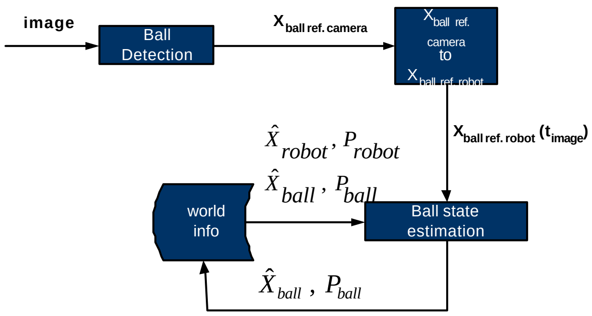

Figure 3 - Ball localisation process.

The self-localisation is mainly done by the fusion of vision measures of world landmarks (goals, corner and ground marks), internal sensors (odometric and magnetic compass) and external vision measures, using Kalman filtering methods. We plan to test fusion algorithms based in covariance intersection [6].

Furthermore, each robot have a world state with some knowledge of position, attitude and his derivatives, with some uncertainty measure for all the game moving objects. This is accomplished with distributed sensor fusion, where the vision sensors play a key role in sensing. Also, a distributed dynamic camera allocation and managing is under study.

In the presence of communications problems, the desired information must be perceived individually by each player. In the last case, in spite of an obvious degradation of the world model, some team coordination must be accomplished by the perceived information of our robots.

5 Control

The motion control architecture approach [1] is based in atomic parameterised hybrid feedback controller, also known as manoeuvre. These controllers incorporate both continuous and event driven feedback. This approach involves the atomic parameterised hybrid controllers synthesis. A set of manoeuvres solving specific classes of motion problems is defined and implemented. These are classified according to the patterns of the associated constraints and objectives. Those manoeuvres are the resources to the coordination level. The sets of manoeuvres that are being synthesised are:

Motion without ball:

- Move to location avoiding obstacles
- Block goal path
- Approach ball with defined attitude
- Move to maximise target vision information
- Goalkeeper block goal path

Coordinated robot and kicker motion:

- Smooth ball reception

Ball guidance:

- With robot rotation around ball centre
  - Straight line
  - Curve
- With directional shoot and defined strength
  - Interception and kick
  - Lateral pass with kicker rotation

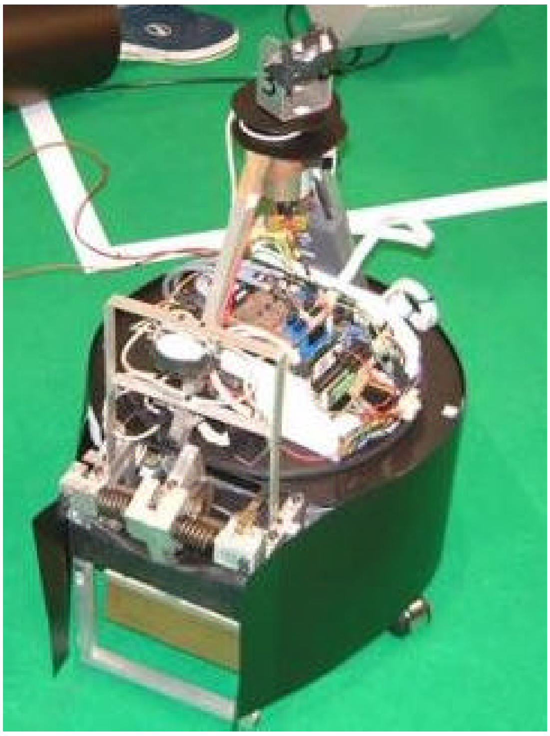

Figure 4 - Robot photo

In the following figure overall control system architecture is presented.

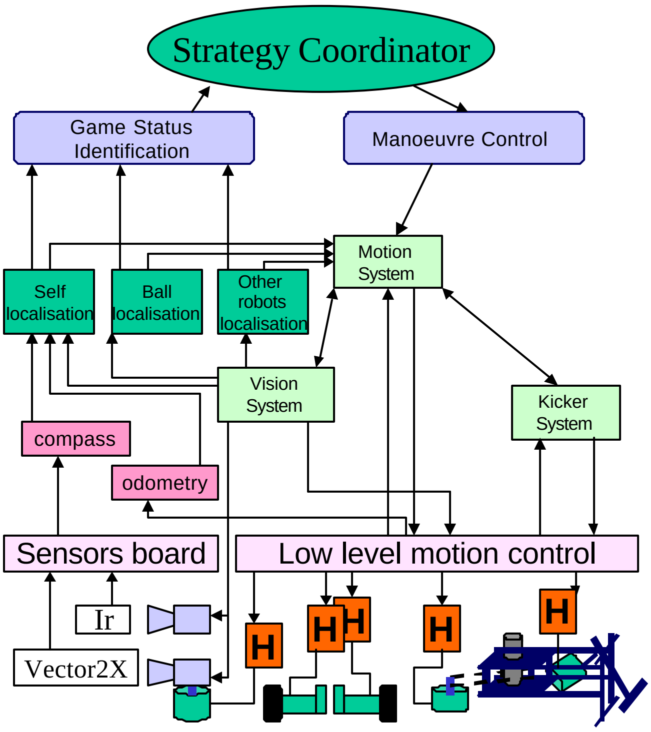

Figure 5 - Robot subsystems

6 Coordination Strategy

The team game evolution is coordinated in structural way [2], [5], by defining the tactical function (goal keeper; defence; middle field; attack) for each robot .The robot adopts the corresponding tactical policy accordingly to its perception about the companions in the field. The player has one main place in the overall strategy (as consequence of its tactical position), but this can be reconfigured dynamically. Only one robot has the possibility to adopt the goal keeper position.

The overall strategy solution results from the composition of the decisions taken in a distributed way by the operational robots in the field. The analysis of the vectors: game phase, ball possession and current topology formation in conjunction with the current robot game role and its perceived topological position determines the coordination level for each robot. An evaluation of the next action to be taken is made by the maximisation of hypothesis success.

The coordination level is implemented by a modular and distributed controller synthesis trough the composition of discrete observers (corresponding to the analysis vectors) and a discrete controller parameterised by the adopted tactical functionality

7 Current Team Status

We have a full team plus a spare robot ready. We have stable versions of the axis control, motors power drives, compass, kicker control, power distribution, and power monitoring boards. The old NOVA-600 SBC are being replaced by the new NOVA-7896FW boards, and a new IR range finder ring is in final tests.

Figure 7 - Team photo

8 Conclusions and Future Work

The robotic soccer team ISePorto design is presented.

This complex mobile robotics is a motivating example to the research and development of control and navigation. The control and navigation architecture for the robots is described.

This hierarchic architecture entails the use of hybrid control automata in order to achieve complex behaviours.

The coordination and game strategy issues are also referred.

The team status is still at an initial development stage, with a vast number of areas to be developed. In these we could name the other players localisation, game status observer development, team topological formation classifier, additional control manoeuvres and game control/API software development.

Acknowledgements

The authors would like to thank the LSA team for their efforts and dedication in developing the robots and support on the participation of competitions and events.

References

[1] J. M. Almeida, F. L. Pereira, J. B. Sousa, "A Hybrid Feedback Control System for a Nonholonomic Car-like Vehicle" *IEEE International Conference on Robotics and Automation*, Albuquerque, New Mexico, (1997)

[2] E. P.Silva, F. L. Pereira and J. B. Sousa, "On the Design of a Control Architecture for an Autonomous Mobile Robot", *chap. 15, in Advances In Intelligent Autonomous Systems*, ed. S.G. Tzafestas, Kluwer Academic Publishers, (1999).

[3] E. P. Silva, J. M. Almeida, A. Martins, et al, "Multi-task Real-Time environment for an autonomous mobile platform", *PO-ROBOT Project Final Report*, (1999).

[4] J. M. Almeida, E. P. Silva, A. Martins, et al, "Functional Layer of the control architecture *PO-ROBOT Project Final Report*, (1999).

[5] E. P. Silva, F. L. Pereira, J. M. Almeida, "Coordination and Organisation layer", *PO-ROBOT Project Final Report*, (1999).

[6] Covariance Intersection Working Group (CIWG), "A Culminating Advance in the Theory and Practice of Data Fusion, Filtering, and Decentralised Estimation".

[7] Jose Almeida, Alfredo Martins, "Designing a Middle Size League Team - The ISePorto Case", *in RoboSoccer Tutorial - 10th EPIA*, (2001)