Vision, Localisation and Control of the ISePorto Robotic Soccer Team

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Abstract

This paper describes the control and localisation 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.

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 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 robot has also a custom developed ring of IR range measuring sensors for short distance obstacle detection (up to 0.8m) .

3. Development System

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

A specific distribution was developed for the vehicles and the standard Linux kernel was modified in order to provide some real-time functionalitities and additional development tool support.

These modifications include:

- High resolution clocks
- Preenptive Kernel
- Linux-Trace Toolkit Support

In addition a remote variable inspector and logging tool is being developed.

4. 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.

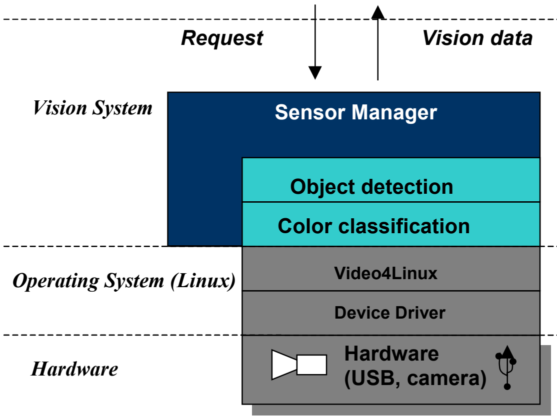

Figure 1 - Vision system architecture

The colour classification algorithm uses a pre-determined set of regions in the YUV in order to detect the game relevant colours. This process is still very sensitive to lighting conditions. In the following image a single colour calibration is compared with the multiple colour classification needed for the system.

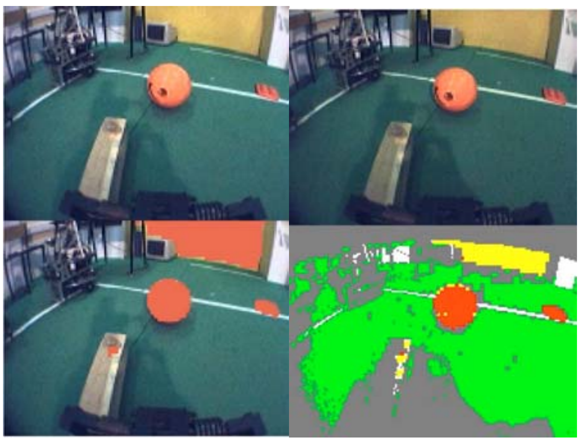

Figure 2- Single colour calibration and multiple colour calibration (kicker camera).

As can be seen, there are overlapping regions in the colour space. In the second case, some previously well classified points are wrongly classified. It exists a trade-off between high computing time and precision in the colour classification that imposes harsh restrictions on the vision system capabilities.

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.

The object detection is performed on the colour-classified image. The objects classified are:

- Ball
- Corner flags
- Goal
- Team colour marks
- Obstacles

The ball is detected using a blob based algorithm. This provides information regarding ball centroid and bounding box for all possible clusters.

The other objects are detected along specified scan lines. An hierarchical approach is taken to eliminate false detections.

Figure 3 – Horizontal scan line in the original image (head camera).

Due to wide angular characteristics of the lens used (needed for convenient field of view) the image received has a significative distortion. This distortion exists in both cameras but is more relevant on the kicker camera.

The distortion is taken in account in the scan lines. For example a horizontal line (see the blue line in the previous figure) is computed in the distorted space, and the result is used in the scan. The information obtained in the distorted space is then converted to a corrected image coordinates .

5. 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 taking 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.

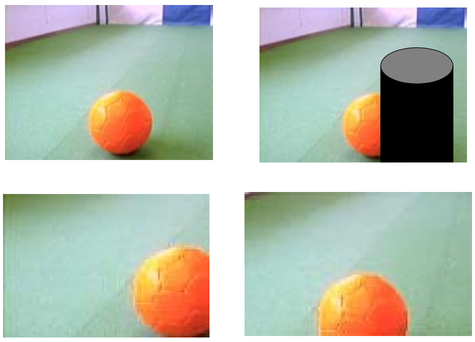

Figure 4 - Different ball position and partial view within the image frame.

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

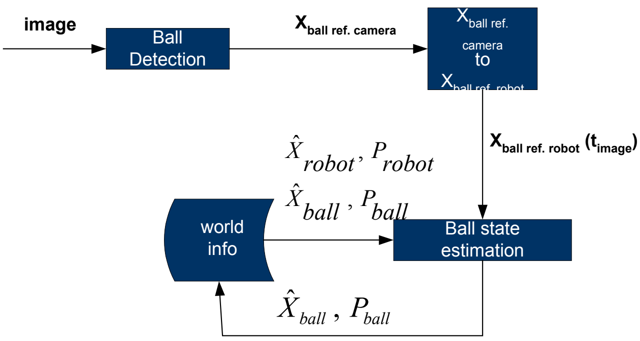

Figure 5 - Ball localisation process.

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.

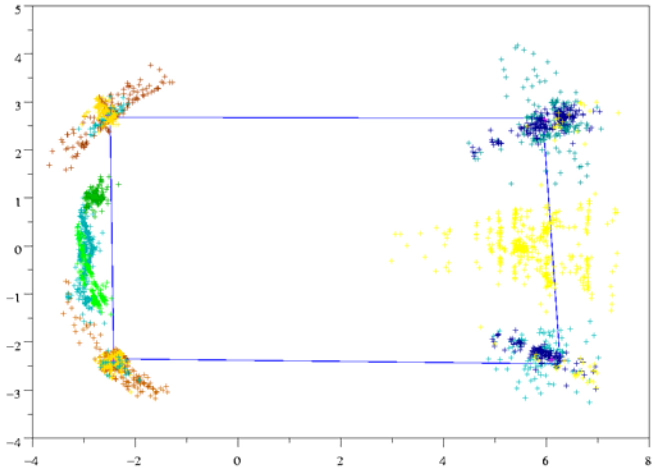

Figure 6 – Corner and goal vision data

In the previous figure, we can see a 2D representation of the raw data measures of the angular and distance of the 4 corner flags, and two goals.

For the corner flags, we can see the result of using the angular velocity and an estimated delay in the image acquisition to correct the angular of the corner measures, measures draw in yellow and blue

In the next table, are shown some statistics for the all the corners.

Angular statistics	E(θ_corr)	STD(θ_corr)	E(θ_w0)	STD(θ_w0)	E(θ)	STD(θ)
BYB1	23.83	0.77	24.11	0.37	23.80	2.39
BYB2	-21.06	0.84	-21.35	0.61	-21.22	2.30
YBY1	132.92	1.31	132.84	0.32	132.24	7.62
YBY2	224.48	1.33	224.16	0.28	225.42	7.48

Distance	E(d)	STD(d)	E(d_w0)	STD(d_wo)
BYB1	6.54	0.29	6.50	0.20
BYB2	6.54	0.50	6.74	0.48
YBY1	3.71	0.13	3.65	0.04
YBY2	3.39	0.10	3.36	0.08

Table 1 – Statistics for corner measures

It can be observed in the previous table the statistics for three scenarios. Each line corresponds to a different corner . The situations analysed for the same data are, the raw measurements statistics (E(θ), STD(θ)), the subset of measures taken with null camera angular velocity (E(θ_w0), STD(θ_w0)) and the overall corrected estimates taking in account the camera angular velocity and delay in the image capture.

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.

6. Control

The motion control architecture approach [1], [7] 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

As an example in the next figure a state diagram is presented for a simple attack manoeuvre.

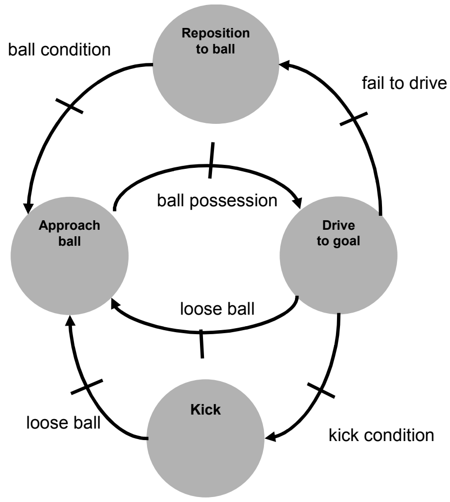

Figure 7. Simple attack manoeuvre.

In this case, the attack manoeuvre has four discrete states. Each one corresponds to a continuous control mode. The attack is subdivided in four possible phases: approach ball, reposition to ball, drive to goal and kick.

This hybrid automata (see [8],[9] and [10] for a formal treatment on hybrid systems) uses game specific events related with the robot, ball and target goal, as triggers for the discrete state jumps (more precisely the guard conditions detects these events and the reset relations are the identity). The robot initially approaches the ball, and when has control of it, drives the ball towards the target goal. The first control law provides the approaching movement and the second defines the angular velocity and orientation of the kicker in order to preserve ball control and drive it to target. In the event of losing the ball, the robot executes a different control mode to re-approach the ball from a direction compatible with the target ball. If the robot has ball control and some kicking condition is met (minimum distance and good goal probability of success) it kicks the ball.

Figure 7 - Robot photo

In the following figure overall control system architecture is presented.

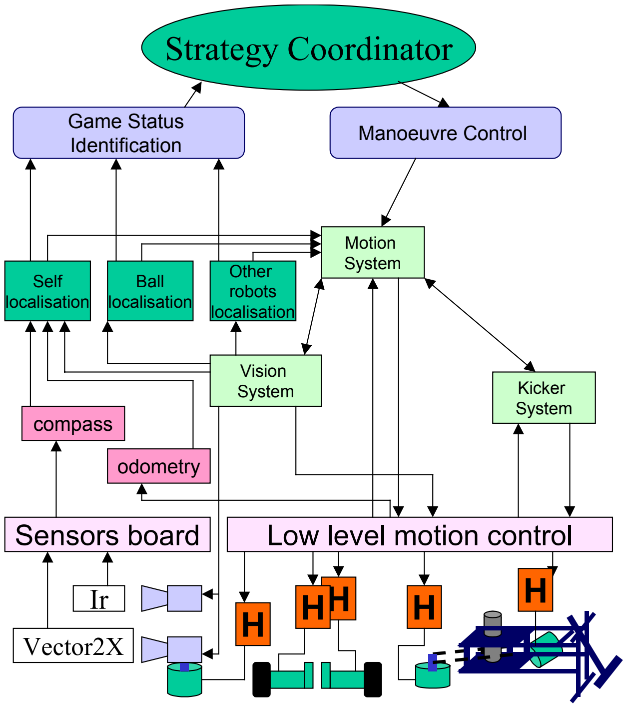

Figure 9 – System architecture.

7. 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

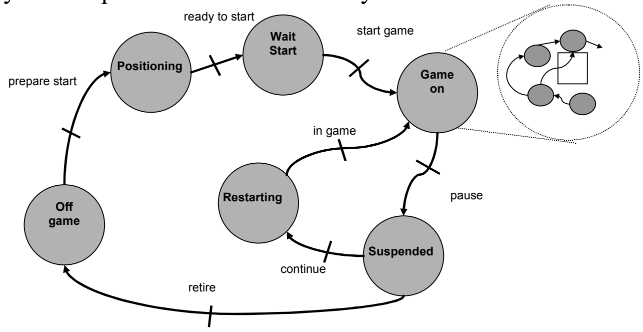

Figure 10 – Coordination high level automata.

In the previous figure a high level automata for the vehicle coordination is presented. This automata depicts the discrete game status. The robot can be either off game, or in several game and pre-game situations. These range from the positioning phase in the beginning before game, the waiting to start (already positioned in the field) and a general playing phase. It can also be temporarily suspended and return to game (for instance in a substitution or repair). Each game phase can be itself a complex hybrid automata with different discrete states. The hierarchical structure of the control architecture allows the modularity and incremental development of the system. In addition provides the execution of complex behaviours and refinement in the overall coordination strategy.

Figure 11 - Team photo

8. Conclusions and Future Work

The control and localisation for the robotic soccer team ISePorto design is presented.

We have a full team plus a spare robot ready. The team has participated in several competitions namely in the German Open 2002 held in Paderborn, Germany and Robótica 2002 in Aveiro, Portugal.

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.

Acknowledgement

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.

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