ISePorto Team

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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.

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.

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 a Pentium based 5.25" SBC (ICP NOVA600 with an AMD K6 /2) 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 an FPGA 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.

The vision system is constituted by two USB cameras (Philips PVC740K with a new wide angular lens), 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. With this system, we can process 320x240 image scenes at 30 fps with 70% of current CPU load. 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.

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

Localisation and Control

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

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 must 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 are 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.

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, where are defined and implemented a set of manoeuvres solving specific classes of motion problems which are classified according to the patterns of the associated constraints and objectives. Those manoeuvres are the resources to the coordination level.

The set 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

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

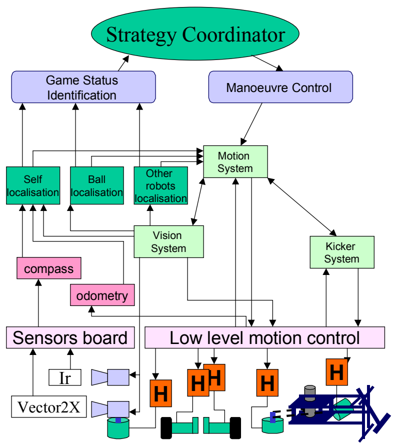

Fig 1. Robot subsystems

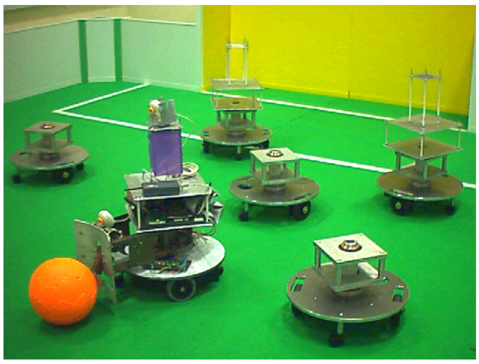

Fig2. Current team status photo

Strategy and coordination architecture

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.

Team Status

A preliminary robot prototype was implemented and currently we have designed and are integrating 5 new robots. These evolved from our initial prototype with modifications in mechanical aspects related to cost reduction and reproducibility. Thus, we have a good backup of spare parts and the possibility of making test games with 2 teams of 3 elements. Only one kicker is implemented being the others in replication process.

The vision system is stable and the software low level functionalities are developed. The axis control hardware is completed, the IR range finder ring and compass are in final integration process, and we are currently developing a new dedicated localisation vision system, based on the analysis of a line scan for relevant scene marks. Most of the processing is done by hardware in a FPGA and a dedicated microcontroller for triangularization

Currently we are working on developing tools, sensor fusion localisation of all game objects, complex manoeuvre programming and strategy game coordination.

We realised that the two year planing and project design allowed a surprising implementation progress in the short time span of only 3 months, after we obtained financing for participation in the contest.

References

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