ART
Azzurra Robot Team

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1 The ART team

Azzurra Robot Team is the result of a joint effort of seven Italian research groups from Univ. of Brescia, Univ. of Genoa, Politecnico of Milano, Univ. of Padua, Univ. of Palermo, Univ. of Parma, Univ. of Roma "La Sapienza", and the Consorzio Padova Ricerche which has provided resources and a set up of the soccer field in its Center in Padua. Our goal at Robocup 1998 has been to provide a flexible and low-cost experimental team to make experience before undertaking a larger project. Our long term goal is to foster the development of research and education projects on autonomous mobile robots by exploiting the RoboCup challenge.

In order to exploit everyone's experience we need to accomodate different kinds of players in terms of both hardware and software architecture. We thus have a first set of players that have been designed with a common basis and constitute the main skeleton of the team, but we also have another type of player, named Mo2Ro, which has been designed by the group at Politecnico di Milano. The ART team in action is shown in Figure 1, where one can see the player Mo2Ro close to the ball, three other middle field players in the center, and the goal-keeper defending the goal. It is obvious that such a diversity raises several problems from both the organizational and development viewpoint, but we have considered to be an interesting challenge of the overall project the ability to design players with different features, yet capable to interact with the team mates. In the following section, we first focus the presentation on the first group of players and then briefly address the second type. In the last section we describe our research perspectives within the Robocup framework.

2 The ART Players

The design of the basic ART player has been mainly guided by the goal of achieving an open architecture where new hardware and software components could be easily added. In addition, we aimed at realizing a good development environment to carry on experiments in the field, thus allowing many different technical solutions to be tested.

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Fig. 1. The ART team in action

The hardware architecture is illustrated in Figure 2. The first building block is constituted by the Pioneer mobile basis and the second is constituted by a conventional PC for onboard computing. We have reached a compromise between weight and power consumption, where the player has enough autonomy to play games.

The third building block is constituted by a wireless high bandwidth connection that we consider necessary to have a development environment that allows the programmer operating on a standard platform (connected to the robot) to obtain accurate information about the situation onboard. The wireless connection supports also the exchange of information among the players, but it is not used to transfer raw data among the players.

The fourth component is the vision system which is constituted by a low-cost frame grabber based on the BT848. At Robocup 98 we have used a very cheap color CCD camera with a resolution 380 TV lines. On the middle field player the camera is mounted in front part of the robot, while on the goal-keeper the camera points at a convex mirror provinding a 360^0 view of the field.

The remaining components are devices that we are able to connect (as indicated in Figure 2) through the Pioneer input/output ports or through an ad hoc made board on the ISA bus. Aa for additional devices, we have used a compass, infrared sensors, a bumper for the goal keeper and a kicker for the middle field player. The kicker, operating with air pressure, allows the player to choose the direction to give to the ball. In fact, it is constituted by two independent devices that allow for a kick left, a kick right and a kick straight action, when they are used simoultaneously. We consider the capability of performing kicking actions

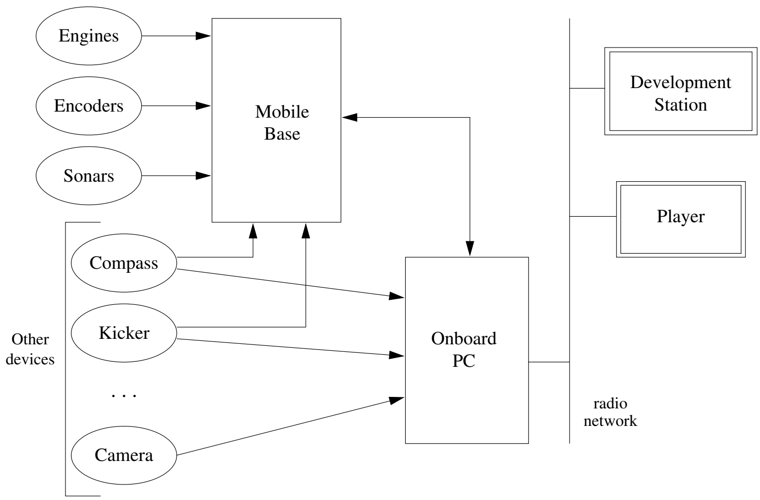

Fig. 2. The basic hardware components

essential not just to pursue the football challenge, but to provide a setting where the knowledge about the environment and the game strategy play a significant role in the robot performance.

The software architecture is centered around two main components: LINUX and SAPHIRA. SAPHIRA is an environment that has been designed to develop fuzzy controllers and is provided with the Pioneer mobile base. The features of SAPHIRA that we have considered critical for software design and engineering are Client Server Architecture and the development environment suited for rapid prototyping. SAPHIRA provides a language for specifying concurrent activities, where the primitive activities can be either programmed or implemented as fuzzy behaviours and composed as described in [6]. We have experimented different strategies for designing the control systems, either by straight activity programming and by designing fuzzy behaviours.

Figure 3 shows the main components of the software architecture. The Local Perceptual Space (LPS) is the structure where all the information about the status of the system is stored. Specifically, the LPS includes a description of static objects: goals, walls, lines and field, as well as information about dynamic objects: ball and other players. The information stored in the LPS is used by the controller to drive the actions of the agent. The other modules shown in the figure provide some details on the process of acquiring information and putting it in the LPS. The sources for new information can be either sensing devices or other agents.

The module labelled Sensor Data Processing is dedicated to the processing of data gathered from the sensors and gives as output information about the objects in the LPS, such as position, speed etc. In acquiring information from sensors a central role is played by the vision system. We have tried various approaches to extract from the images information about the objects that are in the field and are represented in the LPS. In particular, we have developed a system based

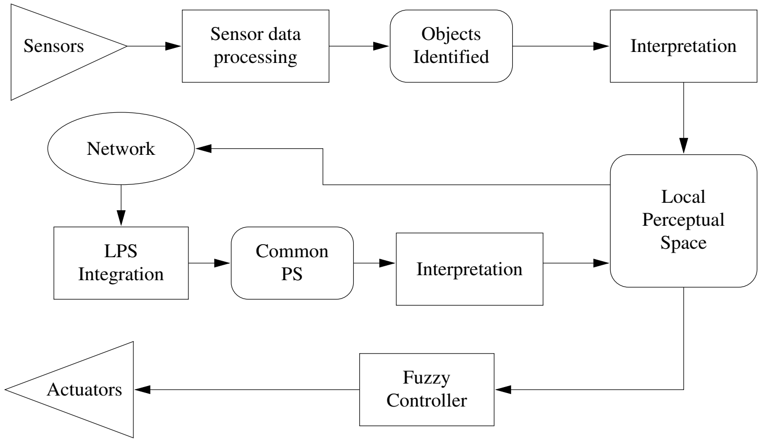

Fig. 3. The basic software components

on HSV color filtering to identify the ball and evaluate its distance and angle relative to the robot's position at a rate of 10 frames per second.

The module labelled Interpretation has the goal of turning the object descriptions obtained by the sources into the proper representation in the LPS. This process is accomplished by taking into account the reliability of the various input devices, the frequency of acquisition and specific features of the objects. Information about static objects may lead to adjustments of the position of the robot, while information about dynamic objects changes their position relatively to the player's position.

Information about the status of the system can also be acquired from other agents, which broadcast the information gathered locally to other agents. To this end, we have designed a communication protocol suitable and efficient for the selected domain, and a high-level inter-robot interface dealing with the exchange of information. However, communication failures do not block the functioning of the robot, that is able of acting on the basis of the information locally available.

2.1 Mo2Ro, a modular, mobile robot

The second type of player, called, Mo2Ro, is a mobile robot consisting of two main modules: the electromechanical base, including the electronic devices providing power supply and low-level sensor management, and the PC. It has two wheels (diam. 12.5 cm) each moved by an independent engine, and a free wheel. Its maximum speed is 100 cm/sec, and it can turn on place. The payload is about 60Kg. It has bumpers, encoders and battery level sensors. It is possible to add to the base any kind of modules, including sensorial modules (sonars, cameras) and actuator modules (a kicker and a robotic arm). The add-on modules can also extend the size of the base, relying on an additional wheel and hinging on the base. A basic fuzzy control system ensures the accomplishment of movement commands given as position and/or speed setpoints. The software architecture runs on the on-board PC (a PENTIUM 233MMX) under Linux operating system. It is based on behaviors programmed in C. The kicker is based on an idea drawn from Leonardo da Vinci's projects of pile machines. An engine mounts a cog-wheel some of which teeth have been cut off. The cog-wheel runs on a rack charging a spring-piston until a sensor detects that the teeth are present. Then the engine stops, and can be turn on again by a single bit command from the PC, thus leaving the spring piston to kick the ball.

3 Research goals

The research issues that arise in the scenario of the football game proposed for the "Middle-size" league of the RoboCup are discussed in [1]. Based on the kind of capabilities of the players we are addressing the following two issues: Sensing, Action and Control; Agent Coordination.

From the viewpoint of Sensing Action and Control we have tried to keep the player architecture as open as possible to make it easy to adapt different kinds of sensing devices and actuators. The underlying idea is to introduce many sources of information as well as different action capabilities. The approach proposed in [6] has been evolving in response to the need of controlling a much more complex robot, with different sensing devices, action capabilities and in a multi-agent environment. Many such aspects are not quite settled and we are currently proposing a possible extension through the software architecture outlined above. In particular, we emphasize the separation between the processing for acquiring new data and their interpretation according to the internal state of the robot and the knowledge about different sources of information.

However, we believe that in order to handle properly a variety of sensing and action devices, possibly trying to apply specific game strategies, a deliberative layer on top of a fuzzy control system is required. In previous work we have proposed such an approach, by relying on a declarative language for representing and reasoning about actions[3]. In the proposed setting both static and dynamic knowledge about the system is used to generate a plan, possibly including sensing actions [4], to achieve a given goal. The main issue we are investigating is to establish a proper and effective connection between the deliberative and the control level. Specifically, there is the need both to find a framework where there is a precise relationship between logical specification of actions and the underlying control system and methodologies for deciding which aspects of the control are better handled at the deliberative level. In addition, we are developing tools to support the development and debugging of the control system.

The second issue we have addressed is coordination. We have developed algorithms allowing the fusion of the multi-robot sensor data (in particular of the perception of the robots' and ball position) to reduce the overall error. These components have been integrated in SAPHIRA.

In a future perspective, we aim at the design and development of a novel distributed software architecture, not only to meet the robocup challenges, but also for more general tasks. This activity will build on the previous experiences in the field of distributed software architectures [8] and of robot cognitive modelling.Moreover,partoftheresearchactivitywillalsofocusonthesolutionof navigation and planning problems throughout forms of analogical representation and reasoning [5].

Finally, we are transferring the experience gained in participating to the Simulation League into the middle size-league on the particular aspect of getting an emergent collective behavior [7]. The limitations in the ability of performing behaviors in the case of middle-size robots, makes the overall performance of the real multirobot system weaker than the one obtained by simulated agents. However, some basic cooperative patterns have been identified and complex support actions have been experimented.

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