ART99 - Azzurra Robot Team

Daniele Nardi[1], Giovanni Adorni[2], Andrea Bonarini[3], Antonio Chella[4], Giorgio Clemente[5], Enrico Pagello[6], and Maurizio Piaggio[7]

[1] Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza"
[2] Dipartimento di Ingegneria dell'Informazione, Università degli Studi di Parma
[3] Dipartimento di Elettronica e Informazione, Politecnico di Milano
[4] Dipartimento di Ingegneria Elettrica, Università di Palermo and CERE - CNR
[5] Consorzio Padova Ricerche
[6] Dipartimento di Elettronica ed Informatica, Università di Padova
[7] Dipartimento di Informatica Sistemistica e Telematica, Università di Genova

1 Introduction

Azzurra Robot Team (ART) is the National Italian Team for F-2000 RoboCup league, developed within the RoboCup Italia project. ART99 is formed by six academic groups and Consorzio Padova Ricerche. ART started with RoboCup-98, and its goal is to exploit the expertise and ideas from all groups in order to build a team where players have different features (hw and sw), but retain the ability to coordinate their behaviour within the team. ART99 obtained the second place in RoboCup-99 F-2000 league, and coordination among players is, in our view, the most significant achievement of the team.

2 Team Development

In ART99 each group was responsible either of developing a robot and/or of developing specific hw/sw components to be used by the other team groups. Each group had a local coordinator, typically a Faculty, who is listed first, PhD students and undergraduate students. The project has been managed by scheduling regular team meetings, a one-week school (Rome, February 1999), to provide the necessary background to the students involved in the project, a one-week final preparation stage in Padova.

Team Leader: Daniele Nardi email:nardi@dis.uniroma1.it

Team Members: *Univ. Genova*: Maurizio Piaggio, Antonio Sgorbissa (Phd), Alessandro Scalzo; *Univ. Padova*: Enrico Pagello, Alessandro Vaglio, Walter Zanette, Robert Rosati, Nikita Scattolin, Alberto Speranzon, Roberto Polesel, Alessandro Modolo, Mattia Lorenzetti, Paolo De Pascalis, Massimo Ferraresso, Matteo Peluso; *Univ. Parma*: Giovanni Adorni, Stefano Cagnoni(Fac.), Monica Mordonini (Phd), Carlo Bernardi, Cristiano Rota; *Univ. Palermo*: Pietro

* The project has been supported by all the institutions the authors are affiliated with, Consiglio Nazionale delle Ricerche - Progetto "Robot Calciatori", Facoltà Ingegneria "La Sapienza" Roma, Politecnico Milano, Facoltà Ingegneria Padova, Sony Italia, Vesta Pneumatics, ImageS, Tekno.

M. Veloso, E. Pagello, and H. Kitano (Eds.): RoboCup-99, LNAI 1856, pp. 695–698, 2000.
Springer-Verlag Berlin Heidelberg 2000

Storniolo (PhD), Rosario Sorbello (PhD), Carmelo Amoroso, Vito Morreale; *Politecnico Milano*: Andrea Bonarini, Paolo Meriggi, Michele Lucioni, Paolo Aliverti, Andrea Marangon, Nicoletta Ghironi; *Univ. Roma "La Sapienza"*: Daniele Nardi, Luca Iocchi(PhD), GianPaolo Pucci, Claudio Castelpietra, Giorgio Grisetti, Alberto Gilio, Luca Luminari, Piero Tramontano, Domenico Mastrantuono.

Web page: `http://www.dis.uniroma1.it/~ART`

3 Robots

ART99 includes several types of players, that are built on top of two hw bases: BaseART and Mo^2Ro. Below we briefly describe them and present the main features of each type of player that we have developed on top of them.

BaseART was developed in preparation to the 1998 RoboCup by assembling several out-of-the-shelf, low-cost components, with the goal of keeping it very standard in terms of hw and, therefore, easily extensible with new devices. The mobile basis is the Pioneer 1, where we added a conventional PC, running LINUX, for onboard computing. We have reached a compromise between weight and power consumption, where the player has enough autonomy to play games. We also have a wireless high bandwidth connection that is used during development to obtain accurate information about the situation onboard, and supports the exchange of information among the players during the game, but it is not used to transfer raw data among the players. The vision system which is constituted by a low-cost frame grabber based on the BT848. At Robocup-99 we have used a Sony XC-999P color camera with about 100^o aperture angle. The cameras are positioned differently on different types of players. Finally, BaseART provides a kicking device driven by air pressure, with two actuators differently arranged on the players, that enable different types of kicks (left, right or both).

Mo^{2}Ro is a *Mo*dular *Mo*bile *Ro*bot base designed and implemented at Politecnico di Milano Artificial Intelligence and Robotics Lab. as a general purpose robot matching the Robocup specifications, but also to support other needs. Mo^2Ro can run up to 60 cm/sec, and may have more then 40 kg as payload. The hw is functionally layered, and any module can be easily added or removed. At the first level, we have mounted, in the different implementations of Mo^2Ro: a sonar belt, bumpers, encoders, and different vision sensors; among these: two different types of omnidirectional sensors [3], and a camera mounted on top of a 5 DOF arm. Among the actuators that we have adopted up to now, we have two DC motors for movement, a kicker, and the arm. On the second layer, control and data acquisition can be done either by commercial or by home made cards, including one based on a Motorola 68HC12 fuzzy chip, for low level control.

TinoZoff is the goal keeper of ART99. The physical layout of the goalie is considerably different from the other players' structure. This goalie has a vision system based on two wide-angle cameras placed on top of it, having an aperture angle of about 70^o vertically and 110^o horizontally. This allows the robot to extend its field of view to over 200^o, considering that the fields of view of the two cameras overlap by about 20^o in the central region right in front of the

goalie. As for its cinematics, the two driving wheels are located in the middle of the chassis, one on the front and the other on the rear. This makes translational movements more precise and accidental turns less likely. Balance is ensured by a pair of spheres, on which the robot leans, that are positioned along an axis at 90^o to the wheel axis, and passing through its center. Turning is possible because the two wheels can be operated independently. Just ahead of the front wheel is a pneumatic kick device, whose air hangs just above. The vision system and the self-localization method developed for it are described in [1].

RonalTino and **TotTino** are middlefield players developed on BaseART. Their essential features from the hw viewpoint are: a specialized vision system with a camera rotating on 360^o and infrared sensors to better control the kicking when the ball is close to the kickers. The control system of these players is designed on top of SAPHIRA, an environment developed to implement the robot control both in terms of actions, realized as programs in the Colbert language, and in terms of fuzzy behaviours, that are executed by a fuzzy controller. In [5] we discuss our experience in the design of the control system for RoboCup based on fuzzy rules. We have developed several tools to support the designer in the debugging and experimental activities. We also implemented several self-localization methods relying on the vision-based recognition of the goals, on the information coming from the compass and on the vision-based analysis of the lines in the field [6]. We have compared them trying to identify the conditions under which each source of information for localizing the player is reliable.

Relè, **Bart** and **Homer** are middlefield players, developed on baseART, provided with different settings for the kicking device and characterised by a novel sw planning and control architecture based on the ETHNOS real-time programming environment [8]. ETHNOS exploits the Linux RT multithreaded operating system and provides additional support from different points of view. From the communication perspective it supports and optimises transparent inter-robot information exchange and co-ordination across wireless media. From the runtime perspective it provides support for the real-time execution of periodic, sporadic and background tasks (called Experts), schedulability analysis, event handling, and resource allocation and synchronisation. From the sw engineering perspective it provides support for rapid development, platform independence and sw integration and re-use. The whole set of sw modules for controlling the players, managing communication, as well as the vision system, have been developed over the ETHNOS' Kernel. ETHNOS' Kernel has been selected because of the flexibility of its architecture, allowing the real time scheduling of both occasional Experts, that are conditionally activated, such as the arbitration module, and periodic Experts (i.e. Vision Experts, and Map Building Experts).

Rullit is implemented on a Mo^2Ro base. Its design is centered around the omnidirectional vision sensor we have implemented for Robocup. It consists of a mirror studied to exploit at best all the camera definition both in the neighborough of the robot and at a large distance: the ball corresponds to a reasonable number of pixels from 10 to 400 cm all around the robot. The vision system is implemented mimicking natural mechanisms for fast tracking and color interpre-

tation: we have distances from all the visible, classified objects at a rate higher than 20 frames/sec. This makes it possible to implement behaviors and strategies that take advantage of the knowledge about most of what surrounds the robot. A self-localization module also has enough reliable information to provide an approximate, but satisfactory extimation of the position in most of the situations. Behavior modules are implemented in ETHNOS and a fuzzy low-level control system provides reliable actuation to the fuzzy behaviors.

4 Special Team Features and Conclusion

The most characterizing feature of ART99 has been the ability to coordinate the behaviour of players developed by different groups on different hw and on different sw platforms. This variety originates from the organization of the project at a national level, involving several research groups each one bringing its technical solutions. Coordination has been achieved through a communication layer based on broadcast TCP and on a coordination protocol based on the exchange of information concerning the state of the world and the robot's intentions. Such information was used both to adjust the robot's viewpoint of the world and to dynamically assign the role of each player (excluding the goalie). We have also set up the protocol to allow for different team strategies, but we have not actually adopted this feature during the competition.

Not withstanding the difficulties that we had to overcome to coordinate the activities of groups operating in different sites, we had two major outcomes from a nation-wide project. The first one is that the non-homogeneity of the players has been an advantage, especially considering that the Pioneer-1 based architectures have been pushed at the maximum of their capabilities. The second outcome is the focus on coordination issues that have been critical for the success of the overall team.

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