CHITA Hominids
RoboCup 2010 Standard Platform League
Team Description Paper

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1 Introduction

CHITA Hominids is the **CHI**lean-**ITA**lian joint effort in RoboCup Standard Platform League, formed by the groups: UChile (Chile) and SPQR (Italy).

The UChile robotics team is an effort of the Department of Electrical Engineering of the Universidad de Chile in order to foster research in mobile robotics. The team is involved in RoboCup competitions since 2003 in different leagues: Four-legged 2003-2007, @Home in 2007-2009, Humanoid in 2007-2009, and Standard Platform League in 2008-2009. UChiles team members have served RoboCup organization in many ways: Javier Ruiz-del-Solar was the organizing chair of the Four-Legged competition in 2007, TC member of the Four-Legged league in 2007, TC member of the @Home league in 2009, Exec Member of the @Home league since 2009, President of the RoboCup Chile committee[1] since 2008, and co-chair for the RoboCup 2010 Symposium. UChiles team members published a total of 20 papers in RoboCup Symposia, in addition to many other publications about RoboCup related activities in international journals and conferences. Among the main scientific achievements of the group, we recall three important RoboCup awards: RoboCup 2004 Engineering Challenge Award, RoboCup 2007 @Home Innovation Award, and RoboCup 2008 @Home Innovation Award. The UChile team includes three experienced PhD students, and several undergraduate students.

SPQR[2] is the group of the Faculty of Engineering at Sapienza University of Rome in Italy, that is involved in RoboCup competitions since 1998 in different leagues: Middle-size 1998-2002, Four-legged 2000-2007, Real-rescue-robots 2003-2006, @Home in 2006, Virtual-rescue since 2006 and Standard platform

[1] www.robocup.cl
[2] spqr.dis.uniroma1.it

League (Nao Division) since 2008. SPQR team members have served RoboCup organization in many ways: Daniele Nardi is member of the RoboCup Trustees and was RoboCup Symposium co-chair in 2004, Luca Iocchi is Exec member of RoboCup@Home since 2008 and was RoboCup Symposium co-chair in 2008. SPQR team member published a total of 13 papers in RoboCup Symposia (including a best paper award in 2006), in addition to many other publications about RoboCup related activities in other international journals and conferences in Artificial Intelligence and Robotics. SPQR team includes four experienced PhD students (including two non-Italian members) and several undergraduate students.

Among all the scientific achievements, it is worth mentioning that the 2009 Special Issue on Humanoid Soccer Robots of the journal *Robotics and Autonomous Systems* contains three articles by members of SPQR and UChile teams devoted to Nao soccer robots [4, 16, 18].

This report presents the motivation for building a joint team and the main research activities for developing humanoid soccer robots.

2 Motivation

There are many motivations for forming a joint team: 1) scientific motivations in exploring research areas not well developed in RoboCup (specially in the field of cooperative heterogeneous robots); 2) scientific motivation in the assessment of well-studied techniques (e.g., color based object recognition); 3) improved motivation for the students participating in the project that have to face also an internal competition.

In this section we discuss the first two points for the **CHITA Hominids** team.

2.1 Collaborative World Modeling and Behaviors

The development of methodologies and algorithms that allow collaboration between heterogeneous robots that do not share the same control software is an important feature for robotic soccer and has demonstrated successful results (e.g., [12]). Heterogeneity of the robots comes from the fact that the partner teams are not going to share their software, but they are going to investigate how to get a competitive team of robots, in which the players have different control software. We do believe this is a great challenge that can bring new ideas to the robot soccer community. As a first approach, the joint research will focus on having a collaborative world modeling and collaborative behaviors between the players.

Some work has been done in the direction of using observations collected by a team of robots regarding one object in order to improve the estimation of the state of that object. Less research have been done in the direction of how the observations of other robots regarding a mobile object can be used by a single robot to improve the estimation of its own internal state. We believe these two fields of research can be extended to a more complex problem [1]: how the observations between teammates and their observations of landmarks and other objects can be mixed, in order to generate an improved and complete world model which takes advantage of all this information.

As for cooperative behaviors, we are interested on the problems of role switching and robot positioning, and how these tasks can be achieved with or without sharing information. In particular, we think the differences in abilities and behaviors between agents, a consequence of using different control codes, open a challenging and interesting problem: how these different abilities and behaviors influence the performance of the agent playing different roles, and then, how the roles should be distributed taking into account not only the state of the game, but also these differences between the agents.

2.2 Color based object recognition

Color based image segmentation and object recognition has been one of the main topics of reasearch for robotic soccer since the first years of RoboCup. However, many different techniques are used (almost one for each team) and it seems we are far from considering the problem solved and to adopt a standard method available to all the teams. This is also demonstrated by the large number of new papers submitted and published every year in the RoboCup Symposium and elsewhere. The members of **CHITA Hominids** team will take advantage of the joint team to test different color segmentation algorithms presented in the literature, to produce a benchmark for robotic soccer color based object recognition, to provide a method for evaluating these systems and to write a final report about such an experimental activity, hoping that it will be helpful for all the teams.

3 Research in humanoid soccer robots

The research carried out by the two groups for developing humanoid soccer robots are described in the following, grouped in three sections: software architecture, perception and behaviors.

3.1 Software architecture

SPQR and UChile have developed their own software architecture, but with different focus. OpenRDK is a modular framework developed by University of Rome for rapid development of robotic applications, that has been used on many different robotic platforms with the main goal of providing a middleware and a development environment for general purpose robotic applications. University of Chile has developed a modular hierarchical hybrid control architecture. The architecture allows for the coordination of multiple robots, the management of robot hardware resources, the integration of active vision mechanisms, and it implements communication and synchronization mechanisms between the software modules.

OpenRDK During the development of many RoboCup applications (ranging from middle-size, to legged, rescue and @Home robots) we have gained a lot of experience and developed a set of reusable modules. Except for the AIBOs, that have a specific platform and operating system, all the other robots and robotic applications have been developed by using an open source framework, OpenRDK[3] [2] (formerly, SPQR-Robot Development Kit (RDK) [7]), which has support for Nao since 2008.

OpenRDK allows for an effective interaction among modules that compose a robotic application, easy development of complex applications, and for advanced mechanisms for remote inspection and debugging. OpenRDK is not in alternative with NAO robot libraries (i.e., Naoqi), but instead it povides a higher layer over it, with support for modular design, development and remote debugging.

UChile Robot Control Architecture University of Chile has developed an hybrid control architecture for biped humanoid robots [17]. Although the architecture is designed to be general-purpose, the short-term goal is to use it in robot soccer applications. The architecture is modular and hierarchical. It organizes the main robot-control functionalities in four parallel modules: perception, actuation, world-modeling, and hybrid control. The hybrid control module is decomposed in three behavior-based hierarchical layers: planning layer, deliberative layer and reactive layer, which work in parallel and have very different response speeds and planning capabilities. The architecture allows (i) the coordination of multiple robots and the execution of group behaviors without disturbing the robot reactivity and responsivity, which is very relevant for biped humanoid robot whose gait control requires real-time processing, (ii) the straightforward management of the robots resources using resource multiplexors, and (iii) the integration of active vision mechanisms in the reactive layer, under control of behavior-dependant value functions from the deliberative layer. This last feature adds flexibility in the implementation of complex functionalities, as the ones required for playing soccer in robot teams.

The hybrid control module is organized in three behavior-based hierarchical layers: planning layer, deliberative layer and reactive layer, which work in parallel and have very different response speeds and planning capabilities. The planning layer is in charge of the long term planning, and it uses information from other robots in order to determine the robot mission and role, and the coordination with other agents. The deliberative layer executes the mission defined in the planning layer using deliberative behaviors, each of them organized as state machines, where each state is implemented as a single behavior or as a behavior-tree. The deliberative layer configures the primitive behaviors available in the reactive layer, and sets up the parameters needed by those behaviors. It uses behavior-dependant value functions (VFs) to score the primitive behaviors, which allows implementing active vision mechanisms. Finally, the reactive layer decides directly the actions that must be executed when resources from the robots are available. The robot resources are managed by resource-multiplexers

[3] `openrdk.sf.net`

(MUXs), which make decisions in real time. The described architecture is implemented using the robotics library, UChileLib. This library provides several functionalities regarding computer processes and communications, and it allows the development of modular software. UChileLib makes use of the Boost Libraries, it is OS independent, and it can been compiled and executed in Windows or Linux.

3.2 Perception

Although color segmentation received a lot of attention in RoboCup, many different techniques are being developed by each team, and a general optimal solution does not exist yet. Also UChile and SPQR have developed their own techniques in the past, and one main goal of the joint team is to compare different methods for color based object recognition.

UChiles Vision System UChiles vision system includes an automatic on-line color segmentation technique that makes extensive use of the spatial relationships between color classes in the color space has been developed [9]. Using class-relative color spaces the system is able to remap color classes from the already trained ones. For achieving that, the system uses feedback information from the detected objects using the remapped (or partially trained) classes. The system is able to generate a complete color look-up table from scratch, and to adapt itself quickly to severe lighting condition changes. In addition, the vision system incorporates a spatiotemporal context integration module that increases the robustness of the vision system [15]. The module computes the coherence between a given detection (object candidate) with other simultaneous detections, objects detected in the past, and the physical context. A Bayesian model integrates all these information sources.

Dynamic color segmentation and object recognition SPQR has developed a dynamic color segmentation method [11] that is able to provide robust and efficient color segmentation with very few calibration effort. Moreover, SPQR has developed a hierarchical approach for examining the image pixels: first a set of *sentinel pixels* that are non-uniformly spread on the image are analized; then, for those pixels that activate some condition, a region growing approach is used to analize adjacent pixels and then these regions are grouped in blobs that are then analized for object recognition. This approach provides for similar results with respect to complete scanning of the image, but it significantly reduces the computational time.

These methods were effectively used on AIBO robots with more limited processing power and have been succesfully ported to Nao robots.

Localization SPQR approach to localization uses a probabilistic technique based on particle filters, using both the well known Sample Importance Resampling (SIR) filter, and the Auxiliary Variable Particle filter (APF). As a result of many experiments performed [14], we have detected situations where one strategy is better than the other as well as hints about the use of sensor resetting, that is common in this kind of implementations. We have thus integrated in the localization technique information about the game state (or in general about the task state) aiming at choosing the localization strategy and parameter setting that are more suitable for the current situation. Localization is based on perception of known landmarks: beacons, goal poles, lines and corners, for which different sensor models are used in the particle filter implementation.

UChile has improved classical self-localization approaches by estimating, independently and in addition to the robots pose, the pose of the static and mobile objects of interest. This allows using, in addition to fixed landmarks, dynamic landmarks such as temporally local objects (mobile objects) and spatially local objects (view-dependent objects or textures). Moreover, the estimation of the pose of objects of interest allows the robot to carry out certain tasks, even when having high uncertainty in its own pose estimation. This is especially valuable when performing attention-demanding tasks, like tracking a ball. Another nice feature of the proposed system is that the robot is able to correct its odometry even when it is totally lost. In this sense, this approach goes in the direction towards performing tasks with much less use of global localization, as humans certainly do. Furthermore, the estimation of the fixed-landmarks pose allows having global measures of the robots localization accuracy, by comparing the real map, given by the real (known a priori) position of the fixed-landmarks, with the estimated map, given by the estimated position of these landmarks. Finally, having an estimation of the pose of the objects allows easily implementing active vision behaviors. Object pose estimation and robot self-localization are implemented using Bayesian filters. In the current implementation [8], several extended Kalman filters, one for estimating the pose of each object of interest and one for estimation the robots own pose, are used.

3.3 Behaviors generation

Parametric biped gait and policy gradient learning Humanoid biped locomotion has been the biggest challenge in the Standard Platform League with Nao robots. Many teams have developed their own walking module for better performance and stability. Although RoboCup 2010 Naos have a very effective and stable walking engine, there is still a big advantage in having robots faster than the opponents.

SPQR team has developed a static parameterized biped gait model that controls the legs and arms in order to make NAO track arbitrary curvilinear trajectories. We have decided to adopt a static gait model, since no accurate dynamic model of NAO is available at this time. The developed motion control scheme presents a fundamental novelty with respect to most works in the field of humanoid gait generation: the motion control scheme that we propose is valid for generic curves of radius $R = v/\omega$. This includes the particular cases of pure rectilinear (ω null, thus $R = \infty$) and pure rotational (v null, thus $R = 0$) walks. With this approach, our walk reproduces a natural-looking human walk.

In order to optimize the parameters of the walking gait we adopted machine learning techniques and in particular we devised a novel extension of the Policy Gradient algorithm [4]. An experimental activity for comparing our walking engine with the Nao 2010 standard walk is ongoing.

Petri Net based behavior control The behaviors of a complex soccer robot require to be represented by plans with high representation power, in order to express all the capabilities of the robot. SPQR has devised a formalism, called Petri Nets Plans (PNP), which is enough expressive to describe plans with all the above mentioned features (see [19, 20] for further details). As a difference with other approaches based on extensions of transition graphs, we clearly distinguish action specification from action implementation, obtaining a framework which permits easier debugging: first, the semantic is well defined and easily verifiable by automated verification programs; second, we have a high granularity of actions which are grouped by functional properties and physical resources used.

The plan execution module based on PNP formalism has been successfully used in all our robotic applications (Four-Legged soccer, Rescue and @Home), providing a high flexibility and being easy to use, thanks to graphical tools for writing, verifying and debugging plans.

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