UChile Kiltros 2008 Team Description Paper

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Abstract. Our robotics group has teams in three leagues: Humanoid, Standard Platform League (SPL), and @Home. Taking advantage of this, we want to contribute to the transfer of relevant developments between the different RoboCup leagues. This year our new developments for the two-legged SPL include: (i) a new methodology for designing fall sequences with low impact in the robot joints, (ii) the proposition of new methodologies to be used in the vision system of our robots (task oriented active vision and context-based perception), (iii) the development of an omnidirectional gait for the Nao humanoid robots, and (iv) the development of an automated referee for the league, which uses a completely autonomous service robot as referee. In addition, a large amount of our efforts have been dedicated to the software adaptation of our control library, originally designed for AIBO robots, to the new Nao humanoid robots. Furthermore, we have depeloped a new robot control library that is platform independent.

1 Introduction

The UChile robotics team is an effort of the Department of Electrical Engineering of the University of Chile in order to foster research in robotics [1]. The main motivation of the team is the participation in international robotics contests that provide standard problems to be solved, where a wide range of technologies can be integrated and examined. Through the participation in these contests, the team can share knowledge with other research groups, and test the quality of the developed technology. The participation in contests complements other scientific activities of the group (papers' publishing, industrial projects, etc.). The group has also developed several educational programs with children using robots [2].

The UChile team was created in 2002, and it has participated in all RoboCup world-competition with its former four-legged team since 2003. In 2007 the group also participated in the humanoid and @Home leagues (in the RoboCup world competition). In 2008 the team's main challenge is to participate in the new two-legged competition of the SPL (Standard Platform League). Among the main scientific achievements of the group, it is worth to mentioning the obtaining of two important RoboCup awards:

- *RoboCup 2004 Engineering Challenge Award* for the article "UCHILSIM: A dynamically and visually realistic simulator for the RoboCup four legged league", where our realistic simulator of robots was described; and
- *RoboCup 2007 @Home Innovation Award*, which honor outstanding technical and scientific achievements as well as applicable solutions in the RoboCup @Home league, for the development of the personal robot *Bender*.

As a RoboCup research group, we believe that our contribution to the RoboCup community is not restricted to our participation in the RoboCup competitions, but that we should also contribute with new ideas to the community. In this context, our team has been one of the teams that have presented more articles in the RoboCup symposia since our first participation in 2003. Table 1 summarizes the papers that have been accepted for oral and poster presentations in these symposia. In addition, we have presented soccer-related articles in other conferences and journals (some of these works are available in our website [1]). It is our intention to continue contributing to the RoboCup symposia, by reporting our new developments in the SPL and humanoid league. This year five of our articles were accepted at the RoboCup 2008 symposium. From them, four are directly related with the two-legged SPL: robot referee for humanoid soccer games [8], design of fall sequences for humanoid robots [9], task oriented active vision for legged robots [10], and context-based vision for soccer environments [11].

One of the major ideas behind dividing RoboCup soccer among several leagues was to address specific problems in each league, which later could benefit all leagues. As a group having teams in both, the humanoid and the SPL, we can build bridges between both leagues. In this line of thought, we intend to integrate some of the developments in distributed control of networked robot from the SPL with the hardware and robot control developments from the humanoid league. Moreover, in the SPL there are high standards of soccer control software, which can also be transferred into the humanoid league. It is important to mention that our SPL team is one of the 16 that already classified for the RoboCup 2008 world-competitions.

In relation with our first participation in the SPL two-legged competition, we are focused in the adaptation of our whole robot control library (originally developed for AIBO robots, using OPEN-R SDK) to the new humanoid platform (Nao robot, using URBI and NaoQi SDK). In addition, our new developments include: (i) a new methodology for designing fall sequences with low impact in the robot joints, (ii) the proposition of new methodologies to be used in the vision system of our robots (task oriented active vision and context-based perception), (iii) the development of an omnidirectional gait for the Nao humanoid robots, and (iv) the development of an automated referee for the league, which uses a completely autonomous service robot as referee.

Table 1. UChile articles in RoboCup Symposia.

RoboCup Articles	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*
Oral	*1*	*2*	*1*	*1*	*2*	*3*
Poster	*1*	*1*	*1*	-	*3*	*2*

2 Software Architecture

As we have already mentioned, our software architecture is based on the robot control library developed for our four-legged team (see detailed description in [12]). However, several modifications to the software have been developed, especially with the objective to have a platform-independent control system that allows us to control all the robots of our team, modifying as little as possible the implementation. In this sense, the software architecture has been divided in two stages: the platform-independent software stage, which implements the algorithms to realize the needed autonomous tasks that depends on the desires high level objectives, and the platform-dependent software stage, which implements all the communications between the robot's hardware and the platform independent stage. This platform dependent stage is currently implemented in URBI and will be implemented in NaoQi.

The platform-independent stage is divided into four task-oriented modules: vision, localization, strategy and motion control (actuation) (see figure 1). The vision and motion control modules operate in each robot locally. The localization module is distributed, it operates in each robot, and a global estimate of the overall ball localization is generated in a distributed fashion. The strategy module is also distributed, and allows the sharing of global information among the robots.

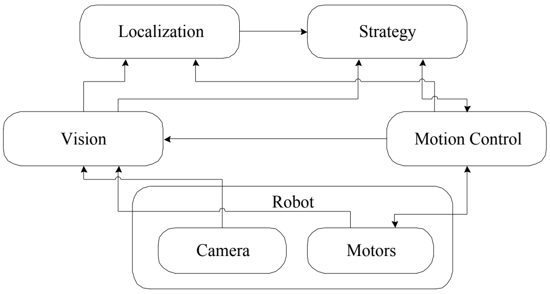

Fig. 1. Modular organization of our system. In the bottom the low-level processes of vision and motion control. On top the high level processes of localization and strategy.

On the other hand, the platform-dependent stage is actually based on URBI, which is a standard software for robot control. Due to the fact that URBI compatibility includes both, NAO robots and Nao for Webots simulation environment, our software can be ported between these instances without effort, which is an important achievement that allows facilitate the work of carrying out simulated tests and then transferred them to the real robot.

This platform-independent architecture separated of the platform-dependent one will allow us to have unique control software for all robots of our team, just enabling or disabling the corresponding modules depending on the needs.

2.1 Vision Module

The basic functionalities of the vision module (objects' perception, lines perception and visual sonar) have been already tested in world and regional RoboCup competitions. More advanced features are being tested (robot detection using boosted classifiers, context - dependent color segmentation, spatiotemporal context-based filtering of perceptions, and improved robot self-localization using landmarks' poses tracking and odometry error compensation). The basic functionalities are described in the following paragraphs.

Beacons, Goals and Ball Perception. Landmarks (beacons and goals) and ball are perceived using a color based vision method. Robot relative distances and angles are estimated using a segmented image that is built using a look up table and the a priori knowledge of the field objects colors. Our color-based vision system is described in detail in [13].

Visual Sonar and Lines Perception. Using the idea of the visual sonar, images can be analyzed very quickly using scan virtual rays; lines perpendicular to these scan rays can be easily found. Thus, in order to detect a pixel that lies on a line, we check the difference in the Y channel of adjacent pixels in the scan rays. The Y channel describes the luminance of the pixels in a YUV image; strong variations of Y channel indicate a transition from any dark color to white. The image is crossed using a grid of lines perpendiculars to the image horizon. The horizon of the image is obtained by compensating the camera rotation and inclination using the measures of the robot encoders (head and body inclination angles). Due to light variations or a poor segmentation, erroneous detection could be generated. Thus, detections are verified using a voting process: for each point on the detected lines, it is calculated a Y channel gradient and a relative distance to that line; points with similar gradients and distances generate votes for a line. If that line has more than three votes, then those points are validated. Alternatively the Hough Transform could be used for implementing this task. Detected line points are characterized by: the line class and the vertical and horizontal angles, measured from the robot reference system. Using the vertical and horizontal measured angles we calculate the relative position of a line point to the robot. Using the robot pose this relative position is transformed in an absolute position.

2.2 Localization Module

The *Localization* module estimates the robot and the ball pose using visual perceptions, odometry, and information received from teammates (ball position). These estimations are communicated to the *Strategy* module and to the teammates. For the estimation of the robot pose we combine the representation capabilities of the Monte Carlo Filters with the efficiency and accuracy of Kalman Filters (MC and EKF Self-Localization blocks, respectively). Using EKF we obtain a fast convergence time, while using MC we obtain stability and robustness. All robot pose estimation hypothesis are mixed in the re-sampling step of the MC algorithm (altogether only 50 particles are employed). The ball pose estimation is implemented in the EKF Ball Localization block, which fuses ball perceptions with ball estimation information communicated by other robots. In our implementation the estimated robot pose influences the ball pose estimation, since both are implemented using a single EKF, whose state vector includes robot and ball information. However, we impose the constraint that the ball estimation cannot influence the pose estimation (in the Jacobian matrix of the observational model some values are set to 0). This localization system is detailed explained in [5].

2.3 Strategy Module

The implemented strategy, as in human football, is based on communication and cooperation between players with different roles. Each robot takes decisions based on its perceptions and the information it receives from teammates. In addition, each robot communicates its internal strategy state to the teammates. In this way, every robot of the team knows the current strategy state of all its partners [7].

A role is defined as a state machine with transitions triggered by a combination of sensorial information, internal strategy state, and messages received from other robots. The role assignment is dynamic and the necessary conditions for a role transition are of the same kind of those for state transitions. States have a set of conditions defining the behavior to be executed. The behavior output is an action executed by the *Motion Control* module; typical actions are walk to specific locations with some orientation, and different kinds of kicks.

The strategy philosophy is common to all the field players, which are focused on going to the ball, one player at the time. The closest robot to the ball (the distance measurement takes into account not only the absolute distance but also the angle, in order to favor players that are already looking towards the ball) goes to it, and attempts to kick the ball towards the opposing goal. The other players take up supporting positions. After any player kicks the ball, everyone looks towards the kick target place. At any time during the game, except while attempting to kick the ball, the players attempt to locate themselves if their position uncertainty becomes too high.

Behaviors. They are aimed to select a given action to be executed by the robot. In our implementation, there are three kinds of behaviors: low-level behaviors, complex behaviors and high-level behaviors. Low-level behaviors are the simplest behaviors, they do not use sensorial information and they have a direct connection with the motion control module. Complex behaviors are basically decision trees, which, considering the inner robot state, sensorial information, and the information received from teammates, choose the low-level behavior needed to accomplish the desired complex behavior. Finally, high-level behaviors are directly related to a specific state. Thus, each robot state has a corresponding high-level behavior. High-level behaviors are decision trees used for choosing the best complex or low-level behavior to be executed. All implemented behaviors are fully described in[7].

Roles. The players have five dynamic roles *attacker*, *supporting attacker*, *defender*, *supporting defender* and *goalie*.

States. Each role is defined by a state-machine with four or five states and several transitions (see figure 2). These states and transitions are described in [7].

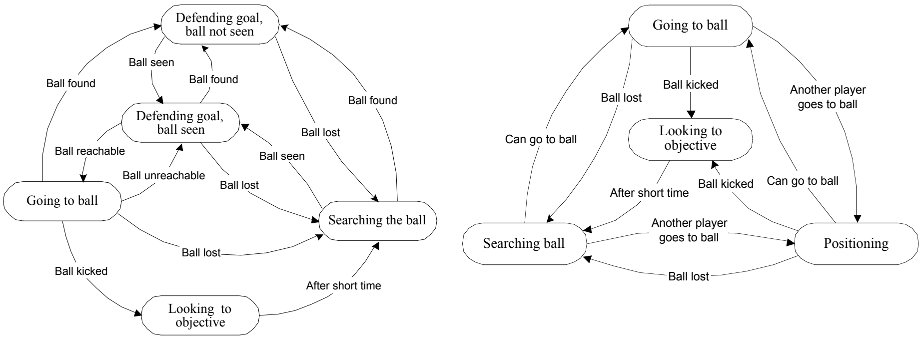

Fig. 2. Transition-state map for the goalie (left) and the field player (right).

2.4 Motion Control Module

This module is in charge of controlling the robot motors according to instructions provided by the strategy module and it is also in charge of generating odometric estimations of the robot displacements. The structure of this module has been already described in our last year TDP [12]. One important new feature of our actuation module is the ability of flexibly mix different movements of different subsets of motors (compared to our previous implementation where only fixed subsets, head and legs, existed). We have implemented an omnidirectional gait for the Nao robots, which is based on [14]. Due to the fact that the kinematics of the Nao robot is totally different from the one of the robot presented in [14], we had to adapt the existing transform from a virtual leg to motor angles to make it fit to the Nao geometry.

3 Lines of Research of Interest for the Standard Platform League

We are developing the following research lines, that we believe are of interest for the league teams:

Probabilistic Decision Making. We have proposed a probabilistic approach to decision making, which addresses decision tasks such as kick selection and passing. The proposed methodology is based on the maximization of a game situation score function, which generalizes the concept of accomplishing different objectives as kicking or passing. Experimental results in our robot soccer simulator (4against4 matches between AIBO robots) show a noticeable improvement in scoring effectiveness achieved by a team that uses the proposed approach for making decisions [4]. Currently we are reformulating our system by complementing our ideas with the use of a MDP (Markov Decision Process) framework. We intend to use our reformulated system in our new team of Nao robots.

Bayesian Context-based vision for soccer environments. Having as a main motivation the development of robust and high performing robot vision systems that can operate in dynamic environments, we propose a bayesian spatiotemporal context-based vision system for a mobile robot with a mobile camera [11]. We choose as a first application for this vision system, the detection of static objects in the RoboCup soccer domain. The system has been validated using real video sequences and has presented satisfactory results.

Automatic On-Line Color Segmentation. We have proposed an automatic on-line color segmentation system that makes extensive use of the spatial relationships between color classes in the color space [3]. 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. The system is also able to deal with intersecting color-classes by making use of the concept of soft-colors, and to solve ambiguities later on using the pixel-context [6]. We are optimizing the system for real-time use in soccer games, with AIBO and Nao robots.

Collaborative World Modeling. Some work has been done in the direction of fusing observations of a given object collected by a team of robots, in order to improve the estimation of the state of that object. However, the fusion of observations collected by a team of robots in order to improve the estimation of the own internal states has not been addressed. We believe that both ideas can be extended towards a more complex problem that exploits our recently developed robot detection module

[1]: how the observations between teammates and their observations of landmarks and other objects can be fused, in order to generate an improved and complete world model, which takes advantage of all this information. In this world model the state of all the robots and the rest of the mobile objects should be considered. It is important to remark that although the collaborative world model is global, each robot builds it locally. Our current modeling approach is described in [5].

Collaborative Behaviors. We are interested in to develop collaborative behaviors between robots that belongs to the same team, but do not share the same control software (code). Under this restriction, we would like to investigate 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.

Design of fall sequences for humanoid robots. The management of falls – e.g. how to avoid an unintentional fall, how to fall without damaging the body, how to achieve fast recovering of the standing position after a fall - is an essential ability of good soccer players. Given the fact that one of the RoboCup main goals is allowing robots to play soccer as humans do, the correct management of falls in legged robots, especially in biped humanoid robots, which are highly unstable systems, is a very relevant matter. However, to the best of our knowledge this issue has almost not been addressed in the RoboCup community. Having this motivation, we have developed a methodology for the design of fall sequences that minimize joint/articulation injuries, as well as the damage of valuable body parts (cameras and processing units) [9]. This methodology has been validated in humanoid robots using a realistic robot simulator.

Probabilistic Task Oriented Active Vision. A mobile robot has always some degree of uncertainty about its world model. The reduction of this uncertainty is very hard, and depends on the tasks that the robot is accomplishing. This is especially true in robot soccer where the robot must pay attention to landmarks in order to self-localize, and at the same time to the ball and robots in order to follow the status of the game. In [10], an explicitly task oriented probabilistic active vision system is proposed. The system tries to minimize the most relevant components of the uncertainty for the task that is been performed and it is explicitly task oriented in the sense that it explicitly considers a task specific value function. As a result, the system estimates the convenience of looking towards each of the available objects. As a test-bed for the presented active vision approach, we selected a robot-soccer attention problem: goal covering by a goalie player.

Development of a robot referee for humanoid soccer games. One of the RoboCup main goals is allowing robots to play soccer as humans do. A natural extension of this idea is having robots that can referee soccer games. With this purpose, we have developed a robot referee for robot soccer [8]. This robot referee is specially intended to be used in the RoboCup SPL 2-legged league, and in the RoboCup humanoid league. The referee is a completely autonomous service robot that moves along one of the field sides, uses its own cameras and onboard computer for analyzing the game, and communicates its decisions to the human spectators using speech, and to the robot players using wireless communication. The robot uses a video-based game analysis toolbox that is able to analyze the game actions at 30fps. This toolbox includes robots, ball, landmarks, and lines detection and tracking, as well as refereeing decision-making. This robot system is validated and characterized in real game situations with humanoid robot players.

Acknowledgements

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