# SPQR RoboCup 2016 Standard Platform League Team Description Paper

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June 3, 2016

## 1 Introduction

SPQR Team[1] has been 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 League (SPL) since 2008.

SPQR Team members have served RoboCup organization in many ways: Daniele Nardi served as Exec, Trustee, President of RoboCup Federation from 2012 to 2014 and was RoboCup Symposium co-chair in 2004; Luca Iocchi is Exec member of RoboCup@Home, Trustee and was RoboCup Symposium co-chair in 2008. SPQR Team members published a total of 18 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.

This report describes the main achievements of the past years and research activities planned for the 2016 development.

## 2 Team Description

### 2.1 Team Members

The SPQR Team is composed by two faculty members, one post-doctoral research associate, one PhD students, one research assistant, and 6 master and undergraduate students. Currently, we own six robots: five NAOs V4.0 and one NAO V5.0. The team leaders for Robocup 2016 are Domenico D. Bloisi and Vincenzo Suriani.

[1] See http://spqr.dis.uniroma1.it

## 2.2 Basic Abilities

**Perception, Localization and Locomotion** Historically, SPQR developed a dynamic color segmentation method [2] that is able to provide robust and efficient color segmentation with very little calibration effort, as well as a hierarchical approach for examining the image pixels using a set of sentinel pixels that are non-uniformly spread on the image. The approach provides similar results with respect to complete image scanning, but it significantly reduces computation time. A benchmarking methodology for evaluating robotic soccer vision systems was also developed in [1]. We provided a public repository with data sets (with ground truth), algorithms and implementations that can be dynamically updated and a set of evaluation metrics, error functions and comparison results. Objects (ball, goal posts, field lines, and robots) were recognized through a combination of color and shape, using specific recognizers activated according to the game and player situation. For example, goal recognition and robot detection were disabled when the robot was tracking the ball and the ball was close to it, while ball recognition and tracking were disabled when the robot was static and it was looking for landmarks for localization. Since 2013, we are using another software architecture properly designed for the SPL league, the **B-Human** architecture. This software easily communicates with the *low-level* of the robot allowing us to focus on our research topics.

**Reinforcement learning Goalkeeper dive handler -** In RoboCup 2014 SPQR Team participates to the Open Challenges introducing a reinforcement learning technique to improve the timing behavior for a goalkeeper robot. The goal was to increase the number of saved balls by optimizing its dive times. As any reinforcement learning formalization, the agent iteratively learns an optimal policy which maps every possible state in a consequent action and adjusts its training parameters evaluating the gained rewards. Our team implemented and compared two different learning algorithms: one based on policy gradient techniques and another one on genetic algorithms.

**Approaches -** The way a robot approaches the ball is of outmost importance during a game. In fact, a good positioning at the end of the approach-phase highly increases the chances of a more precise and powerful ball-kicking. Last year, we employed policy gradient techniques to improve the current ball-approach behavior and learn the best relative positioning of the robot with respect to the ball and the desired kick-angle.

**Robot behaviors with extended knowledge base** There have been many changes in SPQR Team robot behaviors during last years. This year we are working on a context oriented formulation of behaviors that consider a increased knowledge base in order to have a better fit on situation that might occur during an SPL match. Furthermore, thanks to the coordination introduced last year, each behavior implementation strongly depends on the task that the single robot has to accomplish on the field (e.g. support, score, defend, etc.) and the role assignment changes dynamically depending on the situation. Due to the localization issues we experiment during Hefei Robocup, the new behaviors are also localization-sensitive, in order to manage situation of difficult positioning on the field. All these information, plus a more complete , are part of the new, extended, knoledge base used in behaviors.

## 2.3 Auto Camera Settings

The initial manual camera calibration constitutes a very restrictive limit for any robotic applications. The NAO vision system is not very robust to illumination variations and the two auto-white balance and auto-exposure options can drastically influence the performance. These led to consider the environment lighting conditions as one of the most influencing factor during a match. Every, unexpected, change in the camera settings requires a non-trivial recovery of the stable conditions. Hence, in order to participate in the Outdoor Challenge, we develop a module to automatically provide the camera setting values. When enabled the dynamic procedure allow the framework to continuously adapt to environmental changes, still attesting around 25 frame per seconds. This adaptive camera setting update procedure is initialized with values calculated on contextual information. For instance, in the white balance settings, our approach uses the green world assumption (i.e. the field color) to set the initial values.

## 2.4 Black and White Ball

**Ball Detector** The introduction of the real ball in the SPL RoboCup competitions made necessary to study new methods to perform the perception of the ball. In order to detect the white and black coloured ball we exploit the geometrical information enclosed in it. Particularly, we apply two different detection procedure based on the distance of the ball with respect to the robot. If the robot is close to the ball then we look for patterns, i.e. we look for alternance of black and white. On the other hand, if the robot is far from the ball, is really difficult to exploit such informations due to the high noise present in the image. Thus, we look for a simple white (and black) circle placed on green.

**Dynamic studies for advanced kick motions** In order to let the robot properly handle the new ball, we reshaped all the motions of the robot to make them complaint with the new ball. This goal has been achieved by study the NAO body distribution mass in order to properly move the center of mass of the robot and to perform better motions on the field.

## 2.5 NAO Detection with Deep Learning

During the last months we develop a NAO Detection by using Deep Learning. In the RoboCup Symposium, we will present this novel approach for object detection and classification based on Convolutional Neural Networks (CNN).

The approach is designed to be used by NAO robots and is made of two stages: Image region segmentation for reducing the search space and Deep Learning for validation. This method can be easily extended to deal with different objects and to be adopted in other RoboCup leagues. Quantitative experiments have been conducted on a data set of annotated images captured in real conditions from NAO robots in action. The used data set is made available for the community [2].

## 2.6 Networking

SPQR Team often experiment issues with the communication between robots by using a point-to-point network protocol for exchanging packets, due to non robustness to packets loss.
Last year we created a more robust protocol that can adapt to the quality of the wireless network available. This protocol tries to guarantee reliability while being able to discard untrustable packets and we want to make it as general as possible, so to be able to use it in different multi-robot environments.

## 2.7 Coordination module

One of the main focus of the SPQR is the development and the improvement of a new coordination system, the so-called Context-Coordination system [4] . The key contribution of our approach consists in exploiting the rules governing the scenario and the combination of the robot actions and perceptions to enhance both single and collective behaviors. This method aims at contextualizing the environment in order to easily change over time the roles assigned to each robot and guide the entire team toward its goal. The contextualization module helps in avoiding inappropriate behaviors or actions that could be considered pointless in particular situations. More specifically, our architecture includes two submodules: the context and the coordination system. The former influences the sets of roles and tasks according to the current context, and the latter, relying on utility estimations, keeps mapping the playing robots into the context-aware roles in order to improve efficiency.
Moreover, we are generalizing our definition of contextuality in other applications. For instance, we are exploiting the context-coordination developed within the RoboCup scenario in multi-robot coordinated search and target localization. The main idea is to deploy a coordinated team of robot to localize multiple targets (e.g. lost objects, control malfunction infrastructures, victim assessments) and to leverage the execution of the current robot tasks by exploiting any kind of information that can help the robots to specialize their search and to improve their performance.

[2] www.diag.uniroma1.it/ labrococo/?q=node/6

### 2.8 Distributed Data Fusion

Distributed data fusion is the process that merges together multiple data and different perception of the same real-world provided from different agents. Eventually, the process will end up with a more accurate definition of the real-world model which will be used by the whole team of robot. This is exactly what we are trying to do, we developed a system capable to disambiguate the robot pose using the ball perception taken from all active robots by employing a state-of-the-art particle filter tracker [5]. This year, our intention is to improve and make our algorithm more stable involving in the disambiguation model also the position in the field of the teammates, i.e. robots sharing the same jersey color. In a regular match, it could happen that the pose of a robot is inverted or flipped. The algorithm, retrieving information from other robots, is able to correct the pose of the inverted player and redirect it toward the opponent goal.

## 3 Software Architecture

During the development of many RoboCup teams (ranging from middle-size, to legged, rescue and @Home robots) we have gained a significant experience and developed a set of reusable modules. In the RoboCup2013 symposium our laboratory presented a substantially new project with the final aim to electronically refer an entire game among Nao robots. GNAO (Ground Truth Acquisition System for Nao Soccer Robots) [3] is an open source software for monitoring humanoid soccer robot behaviours aims at providing a simple and fast calibration set up, a foreground mask for each captured frame, a 3D information about each player on the field as well as the position of the ball, a multi-camera data fusion scheme and a set of the tracks representing the objects of interest. GNAO is conceived for registering ground truth data that can be used for evaluating and testing methods such as robot coordination and localization. The hardware architecture of the system is designed for using multiple low-cost visual sensors (four Kinects). The software includes a foreground computation module and a detection unit for both players and ball. A graphical user interface has been developed in order to facilitate the creation of a shared multi-camera plan view, in which the observations of players and ball are re-projected to perform the tracking task. This approach is robust to the presence of people on the field (e.g. referees), illumination changes, shadows, and unexpected noise in the background geometry (e.g. audience around the field).

## References

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[4] Francesco Riccio, Emanuele Borzi, Guglielmo Gemignani, and Daniele Nardi. Context-based coordination for a multi-robot soccer team. *RoboCup Symposium*, 2015.