HSL Joint Team SPQR
Team Description Paper 2026

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1 Team Information

- **Team name:** SPQR Team
  A joint team composed by Sapienza University of Rome (Italy) and International University of Rome - UNINT (Italy)
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SPQR is a growing research team based at the Department of Computer, Control, and Management Engineering "Antonio Ruberti" at Sapienza University of Rome (Italy). SPQR Team 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 (2006), Virtual-rescue (2006) and Standard Platform League - SPL (2008-2025). SPQR hosts another Robocup group based in Italy, namely UNINTeam. SPQR team members have served the RoboCup organization in several ways:

- Prof. Daniele Nardi served as Exec, Trustee, and President of RoboCup Federation from 2012 to 2014 and was RoboCup Symposium co-chair in 2004.
- Prof. Luca Iocchi is Exec member of RoboCup@Home, and was Vice-president and RoboCup Symposium co-chair in 2008.
- Prof. Domenico D. Bloisi is the Italian Regional Committee spokesperson.

SPQR team members published a total of 26 papers in RoboCup Symposia (including best paper awards in 2006, 2015 [2], 2021 [6], 2023 [10], and 2025 [26]), in addition to other RoboCup-related publications in International Journals and Conferences in AI and Robotics (including IROS RoboCup Best Paper Award in 2016 [3]).

Currently, SPQR Team owns one Booster T1 robot viable for competition.

2 Code Usage

From 2026, SPQR is developing its own framework and simulator. This decision has been taken after RoboCup 2025, in order to fully exploit the capabilities of the new humanoid robot platforms while minimizing external dependencies.

From 2013 to 2025, SPQR Team used the *B-Human Team* framework as base for developing its code. The authors acknowledge the members of the B-Human team for their great contribution and work in the SPL league. In particular, from 2023 to 2025, SPQR has adopted the B-Human 2021 framework, modified in the following areas: *perception, coordination, and decision making.*

3 Own Contributions

3.1 SPQR Framework

We designed our framework with a distributed architecture organized into three core components: Modules, Nodes, and Topics.

Modules are synchronous processing units where state update rules are programmed explicitly. They can receive inputs from both other modules and topics (with no difference in usage), and publish outputs to topics either entirely or partially.

Nodes are asynchronous logic units that run in independent threads. Each node is uniquely defined by its set of *input topics*, *output topics*, and *internal modules*. Within a node, all modules execute synchronously to ensure components are updated with the most recent state. Nodes communicate with each other asynchronously through topics.

Topics are asynchronous messages that enable information sharing across nodes. They define only the message structure (attributes/fields) and support serialization, deep cloning, and comparison through reflective programming. The entire framework structure is defined declaratively in a single YAML configuration file and automatically instantiated at runtime, eliminating boilerplate code and enabling developers to focus solely on implementing module logic.

Behaviors are managed through the library BehaviorTree.CPP, a hierarchical reactive control architecture that provides modularity, composability, and real-time execution capabilities. It allows to separate the structure from the logic of the behaviors: the former is managed through an xml-based tree definition, which define the decision-making structure (i.e. how behaviors are organized); the latter define the action nodes of the tree, and represent the actual capabilities of the robot (i.e. what the robot can do). They are written in C++ code. The behavior tree of a robot executes in a separate thread with its own update frequency, and the action nodes have the possibility to

read topics to access fundamental information for the correct execution of an action.

3.2 SPQR Simulator

We developed a simulator specifically optimized for the RoboCup Humanoid Soccer League, using MuJoCo [24] as the physics engine with a complete C++ implementation. The simulator implements a distributed architecture where the physics simulation runs in the main process, while each robot's control software executes in an isolated Docker container. This design ensures isolation between robots, supports heterogeneous robot types and frameworks within the same simulation, and minimizes the sim-to-real gap by allowing the same code that runs on physical robots to execute in simulation. To maintain framework independence, we implemented socket-based communication with each Docker container, enabling direct interaction with robots in a general manner. To support this architecture, we developed SimBridge, a bridge node that acts as a translator between framework-specific commands and the simulator's communication protocol.

3.3 Research Roadmap

SPQR Team is interested in detaching the robot perception system from the RoboCup field peculiarities and in increasing the world representation of the robots. To this end, we started with a ball preceptor that does not rely on ball and field colors and we recently detached the perception from the action of the robot creating a semantic layer capable of inferring the inner capabilities of the perceived elements[10]. To increase the state representation of the robot, we included crowd noise and indication from a human coach as a means to extend the inner representation of the agents.

Robot Behavior Conditioning With Crowd Noise. In [6] we exploit the collective intelligence of the audience of a robot soccer match to improve the performance of the robot players. In particular, audio features extracted from the crowd noise are used in a Reinforcement Learning process to modify the game strategy. The effectiveness of the proposed approach is demonstrated by experiments on recorded crowd noise samples from several past RoboCup SPL matches.

Semantic Conditioning for Playing Everywhere. In the path of having robust behaviors on robots capable to generalize when the game environment change, in [10], we propose a temporal logic based approach that allows robots' behaviors and goals to adapt to the semantics of the environment. The proposed approach enables the robot to operate in unstructured environments, just as it happens when humans go from soccer played on an official field to soccer played on a street.

RL-based multi-robot coordination. Behaviors can be really difficult to program based on rules, due to the unpredictability intrinsic to soccer. Our goal is try to capture this unpredictability by leveraging a multi-agent RL-based approach to learn behaviors. The idea is to adopt a hierarchical algorithm where we define coarser representations of the continuous environment, in order to use rule-based solutions on the abstract level, to adequately inform and guide the lower levels and learn optimal actions depending on the local observations given in input to the robot.

4 Impact

Impact in SPL/RoboCup Community. The Ro.Co.Co. (Cognitive Cooperating Robots)[1] laboratory has been participating in the RoboCup since the beginning of the SPL. The aim is to transfer our research in machine learning, behavior formalization and coordination in the RoboCup competition and to contribute to the development of a more reliable soccer team in the pursuing of the goals of the league. In 2017, we proposed a supervised method for detecting the realistic black and white ball in images captured by a NAO robot. In 2019, with the adoption of the new robotic platform, i.e. the V6 NAO robot, Starkit team from Russia has been involved in the competition by using the Code Base released by SPQR. In 2022, we presented MARIO[8] a fully-automatic system specifically designed for analyzing NAO soccer robot matches. MARIO ranked first, ex-aequo with the B-Human Team's system, in the Open Research Challenge at RoboCup 2022. We recently updated the capabilities of *MARIO*. The latest version is publicly released at `https://github.com/michelebri/MARIO2.0`.

Impact in University/Community. Our university strongly supports our participation in RoboCup competitions, which serve as an excellent testbed for validating research outcomes.

Over the past year, we have applied our expertise in computer vision and reinforcement learning to enhance control of the robots, not only for soccer but also for alternative applications such as human-robot interaction. We actively promote AI and robotics research through multiple media channels to disseminate our results. We maintain a YouTube channel[2], LinkedIn page[3], and Instagram profile[4] featuring RoboCup-related content.

Our outreach extends to appearances on major Italian television programs (*TG1*, *TG2*, *TGR*, *TG Sport*, *I Fatti Vostri*, *Laudato sii'*, *Quante Storie*) and participation in prominent national exhibitions (IAB Forum, Wired Next Fest, Blue Fest, Unirete, RomeCup, Maker Faire).

We are committed to promoting scientific knowledge through the dissemination of technology culture, using RoboCup to show progress. We achieve this mainly through events like the Maker Faire. This European event connects businesses, academia, and tech enthusiasts, facilitating discussions on technological advancements and practical demonstrations. This gives us the opportunity to share the latest RoboCup Soccer advancements with thousands of people by organizing friendly matches with other teams. We started this tradition back in 2019 when we invited for the first time two SPL teams (i.e., HTWK and NomadZ). We continued this trend in editions from 2021 to 2025, inviting teams such as HULKs, Nao Devils, B-Human, and HTWK Robots to play in person or remotely, depending on their availability. Recognizing the event's appeal on social media, we actively share updates to amplify the reach of RoboCup SPL videos. Notably, a video we posted on our Instagram page garnered an impressive 100,000 views in 2024.

[1] `http://www.dis.uniroma1.it/~labrococo`
[2] `https://www.youtube.com/@SPQRTeamItaly`
[3] `https://www.linkedin.com/company/spqr-team/`
[4] `https://www.instagram.com/spqrteam/`

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