

HTWK Robots - Team Description Paper

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Abstract. We present recent developments of the HTWK Robots team in RoboCup humanoid soccer. After transitioning to the Booster Robotics K1 and T1 platforms, we established a stable software foundation and achieved competitive results across multiple leagues. Building on this base, our current work focuses on learning-based perception and reinforcement learning for soccer-specific behaviour such as walking, dribbling, and kicking, with the goal of improving performance and autonomy for RoboCup 2026.

Keywords: RoboCup Soccer · humanoid robotics · reinforcement learning · fall resistance · decision speed · robot platform · AI strategy · hardware resilience · team coordination · autonomous robots

1 Lessons Learned and Paths Taken

The HTWK Robots team has a long-standing tradition in humanoid soccer research and competition. Since 2009, the team has been an active and competitive participant in the RoboCup Standard Platform League, consistently contributing to the advancement of humanoid robot soccer.

In the previous year, the team transitioned to the K1 and T1 humanoid robot platforms provided by Booster Robotics. This strategic shift was accompanied by several notable competitive successes, including first place in the KidSize League at RoboCup Salvador, second place in the TeenSize League at the World Humanoid Robot Games, and a second-place finish in the RoboCup Asia-Pacific 5v5 competition in Abu Dhabi.

Throughout the current development cycle, the team focused on establishing a robust and reliable software and system foundation for these platforms. The resulting system demonstrates stable operation under competitive conditions and provides strong evidence that the Booster Robotics K1 and T1 platforms constitute a well-suited and competitive choice for participation in RoboCup humanoid leagues.

2 Publications

In the past year, the team released two software projects and one Bachelor's thesis, reflecting the outcomes of both system development and research activities.

- **Robot Firmware [1]**: The firmware was published in the state used during the RoboCup Asia-Pacific competition in Abu Dhabi. This software manages the complete game operation, including perception integration, and behaviour execution. It represents a further development of the software versions previously deployed in Salvador and Beijing, incorporating improvements based on competition experience.
- **Reinforcement Learning Environment [2]**: The reinforcement learning environment is based on an extended Booster Gym and has been augmented with dedicated training setups for kicking motions and parameterized walking behaviour. In addition to the T1 platform, the environment has been adapted to support training and evaluation for the K1 humanoid robot.
- **Bachelor’s Thesis [3]**: A reinforcement learning policy for kicking was trained to react to varying ball positions. The resulting policy was successfully deployed on a real T1 humanoid robot, demonstrating a complete pipeline for training, transferring, and executing learned kicking behaviour on the physical platform.

3 Focus of the Upcoming Season

While the primary focus of the previous year was the migration of the existing software stack from the NAO platform to the Booster K1 and T1 humanoid robots and the establishment of a stable software foundation, the emphasis of the upcoming competitions shifts towards data-driven and learning-based approaches.

In particular, the team will focus on the application of machine learning methods to improve both perception and behavior generation.

3.1 Visual Perception

We are redesigning the visual perception pipeline using learning-based image analysis methods, replacing the existing YOLO-based demonstration solution provided by Booster Robotics.

To achieve this, we introduce a new two-layer ball detection approach. In the first layer, a detector identifies ball candidates. In the second layer, a classifier selects the most likely candidate. We expect the new system to achieve higher inference speed and improved detection accuracy. As vision serves as a core module for higher-level decision-making, tighter integration with the firmware and improved processing rates are expected. Increased perceptual accuracy will further enable more reliable ball tracking and localisation.

3.2 Motion and Behavior Learning

The team plans to move beyond the default walking and motion primitives provided by the Booster Robotics software stack. While these implementations offer reliable basic locomotion, they limit more dynamic behaviour such as smooth

ball reception, dribbling, and goal-directed motions. To address this, task-specific motion policies will be trained using reinforcement learning, aiming to achieve improved performance in soccer-specific scenarios. Promising results have already been demonstrated in a Bachelor's thesis published by the team, and additional learned behaviour have been successfully trained and validated in simulation. Our developments aim to enhance performance, adaptability, and autonomy under competitive game conditions.

References

1. <https://github.com/NaoHTWK/Firmware-Salvador>
2. <https://github.com/NaoHTWK/htwk-gym>
3. Loos, F.J.: Von der simulation aufs spielfeld: Reinforcement learning für dynamische schussbewegungen im roboterfußball (2025)