
# Ruhrbot Devils
# Team Description Paper for RoboCup 2026
# – Humanoid Soccer League –

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## Team Information

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| **Team name:** | Ruhrbot Devils |
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| **Team website URL:** | http://ruhrbotdevils.de/ |
| **Country of origin:** | Germany |
| **University/company affiliation(s):** | TU Dortmund University |
| **Competition Division:** | Middle - currently 2 x Booster K1 |

## 1 Introduction

The *Ruhrbot Devils* team is the successor of the *Nao Devils* and participates in the newly formed RoboCup Humanoid Soccer League. As *Nao Devils*, we competed in the Standard Platform League since 2009. From 2021, we participated in GORE 2021–2023, RoboCup 2022–2025, and German Open 2024–2025 (detailed results at https://spl.robocup.org/events/), mainly in the 7v7 Champions Cup Division. We consistently achieved second place in the Technical Challenges overall ranking since 2021. We regularly attend workshops such as RoHOW in Hamburg and plan to participate in German Open 2026 in Cologne.


**Fig. 1.** The *Nao Devils* team members at RoboCup 2025 in Salvador, Brazil. From left to right: Dominik Brämer, Diana Kleingarn, Mahdokht Mohammadi, Robert Huber, Lisa Dasmann, Simon Richter, Arne Moos, and Thomas Klute.

## 2 Lessons Learned from the Previous RoboCup Participation

During our SPL participation at RoboCup 2025, we identified key areas influencing our development priorities for the K1 transition.

*Motion Robustness.* NAO robots showed degraded motion performance due to mechanical wear (joint backlash/loosening). Static keyframe motions proved insufficiently robust, and model-based controllers (FLIPM+LQR) did not account for hardware variations and depend on accurate and more computational expensive models.

*Vision and Localization.* Field line detection reliability degraded on faded sprayed lines, impacting localization accuracy especially near the goal. Jersey color classification struggled with similar team colors due to limited discrete color categories.

*Behavioral Decision-Making.* Decision speed proved insufficient in fast-paced 1vs1 situations. At-ball decisions exhibited oscillatory behavior due to noisy sensor data and uncertain world state estimates.

*Audio and Referee Detection.* Whistle direction and distance estimation was difficult due to venue acoustics and reflections. In-game referee gesture detection remained problematic due to cluttered spectator backgrounds and unknown/imprecise referee positioning.

## 3 Major Challenges and Plans for RoboCup 2026

The transition from NAO to Booster K1 represents our central challenge. Below, we outline major development areas with current progress.

*Robot-Agnostic Framework Architecture.* We are integrating the K1 into our NAO-based framework while creating a robot-agnostic architecture for flexible multi-platform deployment. Sensor and camera acquisition is separated into platform-specific wrappers converting data into unified internal representations, enabling identical processing pipelines across hardware. Cross-platform compilation and deployment toolchains support efficient software distribution. First wrapper implementations are completed and under testing.

*Reinforcement Learning for Motion Control.* We transition from model-based control to end-to-end RL policies trained in Isaac Lab and MuJoCo Lab, addressing analytical model limitations with unmodeled dynamics. Building on our published multimodal fault detection work, we integrate joint state monitoring for the Booster K1. For recurring motions (getting up, fall protection), we explore motion capture trajectory retargeting to the K1's kinematic structure. Initial RL walking policies have been successfully trained and transferred to the physical robot with zero-shot sim-to-real transfer, and preliminary experiments with motion capture retargeting have been conducted.

*Vision Pipeline and Depth Estimation.* The K1's GPU enables enhancements to our two-stage perception pipeline. Building on our work on Ultra-Light Vision Transformers for embedded systems, we develop state-of-the-art architectures that execute in real-time on our mobile platform while also ensuring that multiple models run sequentially (depth estimation, hypothesis generation, classification). The patch-based classification is retrained for new robot types, field features, and variable ball appearances. For line detection, which is critical for robust localization even with sprayed lines, we transition from a classical scanline approach to state-of-the-art methods, potentially leveraging semantic segmentation which could also serve hypothesis generation. Given limited labeled data from the new camera and HSL domain, we employ Masked Autoencoder pre-training on unlabeled imagery to bootstrap all newly developed neural network backbones before task-specific fine-tuning. Currently, larger pre-trained models are being explored to enable semi-automatic segmentation dataset generation. Additionally, an automatic camera rectification and custom stereo-camera depth estimation is under development, since the default K1 depth estimation proved insufficient for the robot soccer domain. The wider field of view and stereo camera setup also pose new challenges for active head control and object tracking, particularly maintaining focus on the ball. Adapting our Points-of-Interest-based head movement strategy is planned for the coming months. First pre-training techniques and initial camera rectification as well as depth and hypothesis generation models are under evaluation.

*Behavior and Team Coordination.* HSL's estimated faster gameplay requires behavior framework adaptations. We optimize decision-making speed for at-ball situations using improved utility functions and heat map-based opponent modeling. Team communication strategies should adapt to new game dynamics and constraints. Implementation is planned for the coming months.

*Audio Processing.* Whistle direction and distance estimation is adapted to K1's microphone configuration. However it is currently limited to single-channel access until hardware revision provides multi-channel access.

*Operational Procedures.* Comprehensive handling procedures for games, transportation, and repairs are being documented, including debugging workflows and real-time status monitoring for newer team members.

## 4 Impact of Participation and Research

In the field of education, we offer each year a one-year lasting project group for 12 students in the master of computer science (25 credit points), in which the students are introduced to humanoid robot soccer and have to master a RoboCup-related project with it. We provide students with real-world testing opportunities and at RoboCup promote practical teamwork experience, and direct exposure to the educational and professional benefits of participating in such an event. Afterwards, the students usually remain part of the team until they graduate or write their master's theses with us.

## 5 Other Supporting Information

We have advanced live-streaming of SPL games and together with *Berlin United*, games are live viewable with game overlays and simultaneously archived in high quality. It is planned to generate live statistics utilizing our multi-camera real-world testing infrastructure.

With continuous Technical Committee representation (Stefan Tasse 2011–2012, Matthias Hofmann 2015–2017, Ingmar Schwarz 2018–2019, Arne Moos 2021–2025, Thomas Klute currently), we help drive league development.

### Acknowledgements

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