Team Description Paper Hamburg Bit-Bots 2026

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Preface

This extended abstract gives a short overview of our team's participation in past RoboCup competitions. Our most recent international RoboCup participation was in Eindhoven, The Netherlands, in 2024. This holds as our most successful international competition yet, and our lessons learned will mainly be focused on this. We participated with our kid-sized *Wolfgang OP* robots [3] and felt we were reaching the physical limitations of this platform. Therefore, we were working on a new robot platform based on team Rhoban's Sigmaban platform [1] with identical brushed servos.

While still working on the Sigmaban-based platform, we brought the *Wolfgang* robots to the RoboCup German Open 2025. This event showed us the capabilities of modern, reasonably priced brushless robot platforms. As a result, we stopped all development and improvements of the Sigmaban-based platform. Since that time, we have gotten access to the adult-sized *DroidUp X02* [1] and the kid-sized *HIGHTORQUE Mini Pi Plus*[2] robot platforms.

Our team did not participate at RoboCup 2025 in Salvador, Brazil, because of the ongoing procurement process. Still, two members visited for the RoboCup Symposium and followed the developments of other teams.

1 Lessons Learned in Previous RoboCup Competitions

Previous RoboCup iterations offered lots of learning lessons, resulting in our team's best results during RoboCup 2024 and GermanOpen 2025.

The most impactful lesson is to invest sufficient time into hardware maintenance, even when nothing seems out of order. This might sound obvious, especially when using robots with aging structural components and servos, but constant inspections and overhauls are needed for the robots to perform at their potential.

Software development can benefit from the same lesson: RoboCup 2023 demonstrated the general functionality of our software components, although there were still many areas that could be improved. Constant fine-tuning and deep integration of software components without major changes have turned out to be very valuable for the overall soccer performance.

[1] https://www.droidup.com/
[2] https://store.hightorque.cn/products/bipedal-robot-mini-pi-plus

Another lesson is the importance of proper game preparation. In addition to having tested software and functional hardware, this entails: (1) assigning team members to fixed roles (deployment, monitoring, robot-handler, note-keeper, repair, and recording) in order to eliminate communication delays and ambiguity of responsibilities; and (2) making investments in skills and tools that enable rapid, one-person software deployment, which frees up resources.

Lastly, the advantages of creating and enhancing a live monitoring system greatly outweigh the expenses incurred. Monitoring might seem like a non-critical component for soccer competitions. Contrarily, live monitoring of measurements and the resulting decisions of autonomous robots eliminates guesswork in case of problems, thereby accelerating troubleshooting and developing solutions.

2 Major Challenges the Team is Trying to Solve for RoboCup 2026

The introduction of any new robot platform will inevitably bring a major need for software development, adaptations, and unforeseen integration problems. In anticipation of these challenges, we are already testing new motion capabilities for the *Mini Pi Plus* platform in simulation utilizing state-of-the-art reinforcement learning methods.

The merge of multiple former RoboCup soccer leagues into a single RoboCup Humanoid Soccer League results in a new rulebook. To comply with these rules will require major changes to our players' behavior.

As a student team, we frequently face the difficulties of losing team members because of graduation or shifting priorities. Recent changes in our department-wide communication and events, however, have shown preliminary success in gathering a sufficient number of interested and skilled new team members.

3 Plans for the Major Changes the Team Expects to Have Implemented for RoboCup 2026

We expect to perform the integration of the new *Mini Pi Plus* platform with our current software in the following months in preparation for the RoboCup 2026. This involves infrastructure setup and real-world testing.

To address the challenges for our vision detection system, we are currently working on extending the impactful (see Section 4.1) *TORSO-21* dataset [2] with more recent and diverse images, and are replacing our convolutional neural network-based detection *YOEO* approach [7] with the transformer-based state-of-the-art *RF-DETR* [5].

Preliminary rules demand the detection of referees' whistle signals. A detection system and the integration with our current software architecture are in the works.

As mentioned above, we are already working on motion capabilities for the *Mini Pi Plus* platform using zero-shot-transfer reinforcement learning methods.

With that, we switched from the *Webots* 3D physics simulation to *MuJoCo*. The motion capabilities include the low-level skills of walking, kicking, getting up, and dribbling. These skills need to be carefully integrated with our current software and behavior. We have also started research on emergent multi-agent high-level behavior learned and optimized in simulation.

4 Impact of the Team's Participation and Research in RoboCup

4.1 Impact on the Humanoid Soccer League

Our team has published several scientific works related to the Humanoid League over the past years. Recent publications can be found in Section 5.

Sharing and encouraging reusability of source code is a core principle of ours. The great majority of our source code is open source and developed publicly. We encourage the exchange of knowledge and ideas by participating in workshops like the *Robotic Hamburg Open Workshop* (*RoHOW*)[3] and online discussions. Additionally, we encourage the exchange of source code by providing modularized, documented, and reusable software packages. This is done through the organization *ROS Sports*[4] where we donated and still maintain several *ROS* packages for standard software interfacing (message definitions) and reusable algorithms. Our main code base heavily relies on the industry-standard *ROS 2* framework[5] and uses modern tooling like *Pixi*[6], enabling quick and easy installation and publication.

At the RoboCup Symposium in 2021, we published the extensive vision dataset *TORSO-21* (*Typical Objects in RoboCup Soccer*) [2]. Numerous RoboCup teams and outside researchers have since used this dataset to train their methods on and compare them to a baseline *YOLO* object detection evaluation.

4.2 Impact on the University and Community

Our team runs multiple practical courses in the computer science bachelor's curriculum at the university. Our students learn about the RoboCup and humanoid robotics here, and they also work on solving some of our unresolved problems along with our guidance. Regularly, students become team members, and we can integrate their solutions into our main architecture.

[3] https://rohow.de/2025/en/
[4] https://ros-sports.readthedocs.io/en/latest/background.html
[5] https://ros.org
[6] https://pixi.prefix.dev

5 Releases and Publications

Our software[7] and *Wolfgang OP* hardware[8] are open-source and available on GitHub.

Recent bachelor's theses from team members or regular students related to the RoboCup:

Wiegmann worked on extrinsic calibration of the robot's camera in relation to the robot's base and IMU [9]. Small mounting offsets appear for every individual robot, leading to distortions in the localization position of perceived game objects. Frequent recalibrations are necessary due to impact forces and the subsequent mounting drift. This work evaluates the feasibility of automatic extrinsic calibration using field line features, thereby improving precision and lowering human effort during competitions.

Wedmann did research on the tangibility of humanoid robot systems for non-experts [8]. A real-time educational live visualization on a personal mobile phone screen illustrates and explains details of our robot system (see Figure 1). This work has now been extended to be shown on a desktop screen, and we intend to show this to the audience at upcoming events and competitions, including RoboCup 2026.

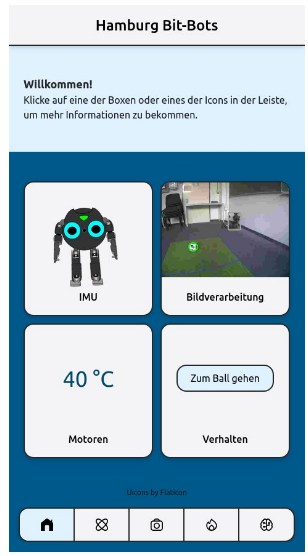

Fig. 1: Educational live visualization: Dashboard [8].

Additionally, we published the following scientific papers during the past year and are currently working on new publications.

With *SoccerDiffusion* [6], we trained an end-to-end action diffusion policy from recordings of previous RoboCup competitions with the *Wolfgang OP* platform. However, we cannot use this approach on the planned *Mini Pi Plus* platform at RoboCup 2026, since we do not yet have any game recordings.

We enhanced our previous vision architecture *YOEO* [7] by including the real base footprint point of detected robots in the output predictions of *YOLO-BF* [4]. This improves the precision of localizing other players compared to naively using the center-bottom point of a detected robot's bounding box. We will be using this approach or a similar architectural enhancement to *RF-DETR* [5] at the next RoboCup competition.

[7] https://github.com/bit-bots/bitbots_main
[8] https://github.com/bit-bots/bitbots_hardware

References

[1] Julien Allali et al. “Rhoban Football Club: RoboCup Humanoid Kid-Size 2023 Champion Team Paper”. In: *RoboCup 2023: Robot World Cup XXVI*. Ed. by Cédric Buche et al. Springer Nature Switzerland, 2024, pp. 325–336.

[2] Marc Bestmann et al. “TORSO-21 Dataset: Typical Objects in RoboCup Soccer 2021”. In: *RoboCup 2021: Robot World Cup XXIV*. 2021.

[3] Marc Bestmann et al. “Wolfgang-OP: A Robust Humanoid Robot Platform for Research and Competitions”. In: *IEEE Humanoids 2021*. July 2021.

[4] Jasper Güldenstein et al. “YOLO-BF: Enhancing Robot Detection and Localization using Base Footprint Point Detection”. In: *RoboCup Symposium*. July 2025.

[5] Isaac Robinson et al. *RF-DETR: Neural Architecture Search for Real-Time Detection Transformers*. 2025. arXiv: 2511.09554 `[cs.CV]`. URL: https://arxiv.org/abs/2511.09554.

[6] Florian Vahl et al. “SoccerDiffusion: Toward Learning End-to-End Humanoid Robot Soccer from Gameplay Recordings”. In: *RoboCup Symposium*. July 2025.

[7] Florian Vahl et al. “YOEO -You Only Encode Once: A CNN for Embedded Object Detection and Semantic Segmentation”. In: *IEEE International Conference on Robotics and Biomimetics (ROBIO)*. Dec. 2021.

[8] Lea Wedmann. “Mobile Visualization for Better Understanding of Robotics for Non-Experts”. MA thesis. Universität Hamburg, 2025.

[9] Pär Wiegmann. “Automatic Extrinsic Calibration in the RoboCup Humanoid League using Field Lines”. MA thesis. Universität Hamburg, 2025.