Team Description Paper

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1 Team Information

Team Name	HULKs
Team Leader	Lars Knäpper
Team Contact Email	hulks@tuhh.de
Team Website	https://www.hulks.de and https://github.com/hulks/
Country of Origin	Germany
University Affiliation	Hamburg University of Technology

2 Code Usage

No code of other teams is used in the HULKs codebase. For inference of our neural networks, we depend on the CompiledNN library of B-Human. Our walking engine is inspired by rUNSWift concepts. Some of our standup motions are based on files from the NAO Devils. Berlin United concepts served as inspiration for our energy saving processes. Our MuJoCo NAO simulation model is based on a model by Arne Hasselbring from B-Human.

3 Own Contributions

In this section, we highlight the primary developments and tools we have introduced to enhance our robotics workflow. From advanced deployer tooling, better recordings to a new behavior simulator and reinforcement learning approaches, we cover a broad scope of innovations. We actively support other teams by remaining open source and championing open research, ensuring everyone can benefit from and expand upon our progress.

3.1 Deployer Tooling

In addition to smaller enhancements in our existing tools, we are improving our deployment process before games. To reduce stress in these tense situations, we develope new tools to simplify the process of setting game specific settings and to help with communication between in our team. Moreover we get a reliable way to track our robot substitutions and code and parameter changes during the game.

3.2 MCAP recordings

Building on our ability to record our framework during games we developed last year, we now implemented an export option to the `mcap` file format[1] This allows us to persist data since the files are self-describing. Despite using this data for machine learning and statistics collection, we are now also able to distribute the recordings to other teams. Team Bit-Bots from the Mid-Size League is already using this data to train neural networks.

3.3 Model-Predictive Step Planning

As part of a research project, we explored the use of Model Predictive Control (MPC) for step planning on our robots. The research project showed promising results, and the technique is currently being implemented for the real robot. This approach plans a sequence of steps which optimizes some cost function, rather than only planning one step ahead. Furthermore, the steps planned by this approach can take more advantage of the kinematics of the NAO.

3.4 Bevyhavior Simulator

Since RoboCup 2024 we completely rewrote our behavior simulator. It is now based on the game engine Bevy[2] and uses native Rust code instead of Lua for scripting scenarios. This enables much faster development and simulations.

3.5 Reinforcement Learning in Simulation

To improve our robustness of motion tasks, this year we started implementing reinforcement learning algorithms for motion control. We build upon a MuJoCo[3] NAO simulation model by Arne Hasselbring from B-Human. Our code and training scripts can be found on GitHub. To transfer these algorithms to the NAO hardware, we still have to narrow the reality gap. We are researching this in an ongoing project thesis.

[1] https://github.com/foxglove/mcap
[2] https://bevyengine.org/
[3] https://mujoco.org/

3.6 Framework Paper

Last year at the RoboCup 2024 Symposium we presented a paper on our framework: *Advancing Humanoid Robotics with Rust: An Open Framework for Runtime Efficiency*. In it we describe the architecture and theory behind our robotics software. Special emphasis was put on low runtime overhead, determinism, and temporally ordered message passing between multi-threaded data processing graphs.

3.7 Automatic Field Color Segmentation with Support Vector Machines

To identify the soccer field in camera images, we use a threshold based approach in the HSV color space. Tuning this algorithm is an error-prone and time-consuming task. There are many multi-dimensional parameters to tune, there's always the risk of over-fitting to a specific situation and domain knowledge and experience is required to achieve good results. To reduce the effort linked to manual tuning, this year we are developing a machine learning approach using support vector machines. This allows us to only take a few photos of the field and then sparsely label the images using annotation tools. The data is used to train a support vector machine which is directly inferred on the NAO.

3.8 Detection of Visual Referee Signals

Last year's introduction of the visual referee signals have been expanded. Starting from this season, a visual referee signal will be used to indicate the kicking team during set plays. To accommodate for these rule changes, we updated our pose detection neural network to the state-of-the-art YOLOv11 pose. Along with this, the processing of these detections was expanded to the new signal. New behavior was implemented to support pose detection as well as handle not knowing the kicking team during set plays of free kicks.

3.9 Collaboration with other teams

One of our core principles is to promote open research and collaboration. We thus always try to support other teams, whether new to our league or already experienced.

3.10 Documentation

We're constantly working on providing an up-to date documentation of our code and algorithms on our website. Our main contribution here is to provide algorithms and general ideas, without extensive code to understand and read through.

4 Past History

Competition	Tournament State	Opponent	Score
RoboCup 2024	3rd Place	RoboEireann	0:3
RoboCup 2024	Semi-Finals	HTWK Robots	0:2
RoboCup 2024	Quarter-Finals	SPQR Team	3:0
RoboCup 2024	Round 7	RoboEireann	0:3
RoboCup 2024	Round 6	rUNSWift	7:0
RoboCup 2024	Round 5	HTWK Robots	1:4
RoboCup 2024	Round 4	B-Human	0:8
RoboCup 2024	Round 3	NomadZ	6:0
RoboCup 2024	Round 2	SPQR	1:2
RoboCup 2024	Round 1	Nao Devils	7:0
GermanOpen 2024	3rd Place	Nao Devils	0:0 [0:2]
GermanOpen 2024	Semifinals	HTWK Robots	0:3
GermanOpen 2024	Round 6	Dutch Nao Team	8:0
GermanOpen 2024	Round 5	Naova	2:0
GermanOpen 2024	Round 4	B-Human	0:6
GermanOpen 2024	Round 2	Berlin United	2:0
GermanOpen 2024	Round 1	Bembelbots	2:0
RoboCup 2023	3rd Place	rUNSWift	1:1 [0:2]
RoboCup 2023	Semi-Finals	HTWK Robots	0:4
RoboCup 2023	Quarter-Finals	NomadZ	8:0
RoboCup 2023	Round 6	Berlin United	1:0
RoboCup 2023	Round 5	B-Human	0:9
RoboCup 2023	Round 3	Bembelbots	2:0
RoboCup 2023	Round 2	rUNSWift	3:0
RoboCup 2023	Round 1	Nao Devils	1:1
GORE 2023	Quarter-Finals	R-ZWEI KICKERS	2:8
GORE 2023	Round 6	NomadZ	4:0
GORE 2023	Round 5	Naova	5:0

Competition	Tournament State	Opponent	Score
GORE 2023	Round 4	B-Human	0:7
GORE 2023	Round 2	Dutch Nao Team	5:0
GORE 2023	Round 1	Bembelbots	2:0
RoboCup 2022	Quarter Final	Nao Devils	2:3
RoboCup 2022	Round 5	Nao Devils	2:1
RoboCup 2022	Round 4	B-Human	0:6
RoboCup 2022	Round 2	NomadZ	9:0
RoboCup 2022	Round 1	SABANA Herons	4:0
GORE 2022	Quarter Final	B-Human	0:10
GORE 2022	Round 6	Bembelbots	0:6
GORE 2022	Round 5	RoboEireann	1:9
GORE 2022	Round 4	SPQR	0:3
GORE 2022	Round 3	R-ZWEI KICKERS	0:4
GORE 2022	Round 2	Nao Devils	0:10
GORE 2022	Round 1	rUNSWift	0:6
GORE 2021	Round 3	Bembelbots	1:0
GORE 2021	Round 2	B-Human	0:10
GORE 2021	Round 1	Berlin United	4:1

5 Impact

The HULKs always have been active in organizing events for both our league and the Humanoid League. This includes eleven Robotic Hamburg Open Workshops (RoHOWs) and two German Open Replacement Events. We look forward to our next RoHOW at the end of November 2025, to which you cordially will be invited. As the first team to develop our software fully open source, we are pioneering the free sharing of code and data to promote collaborative research in the SPL. By participating in organizational, technical and executive committees, we are shaping the future of the SPL and humanoid robotics research. Our tools for creating self-packaged OPN files enabled teams to deploy their robots remotely, overcoming the limitations caused by the Corona virus outbreak. Our framework, freely available under the GNU GPLv3, allows new teams to easily join our league using a framework that is not written in C++.