# Team Description Paper - Team Sweaty

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**Abstract.** This paper presents the ongoing research and development efforts of Team Sweaty from the University of Applied Sciences Offenburg in the domain of autonomous humanoid robotics, with a focus on RoboCup soccer competitions. After years of success with a custom-built humanoid robot, including a world champion title in 2021, the team has transitioned to the Booster T1 platform in response to RoboCup rule changes emphasizing robustness and autonomous gameplay. The project integrates a high-level controller adapted from Team Magma's architecture to manage multi-role behaviors such as striker, defender, and goalkeeper. Parallel efforts target motion refinement via deep reinforcement learning using IsaacLab, enabling precise, biomechanically inspired kicking behaviors. The development pipeline employs simulation environments including MuJoCo and IsaacSim for training, followed by real-world validation in a fully equipped motion lab. The system architecture is based on ROS2 and emphasizes modular design for strategic reasoning and communication. Early results demonstrate successful transfer of trained policies to physical robots, particularly in locomotion and dynamic kicking. Future work includes further sensor integration and mechanical refinements to improve gait agility, balance, and robustness. This research contributes to advanced AI-driven control in humanoid robotics and fosters cross-domain insights into motion intelligence and robot autonomy.

**Keywords:** Humanoid · RoboCup · Sweaty · Simulation · Reinforcement Learning

## 1 Introduction

The University of Applied Sciences Offenburg conducts advanced research in humanoid robotics, exemplified by its participation in the RoboCup through two teams: Team Sweaty and Team Magma. Team Magma specializes in robot's high-level control algorithms and reinforcement learning to develop complex behaviors, where they program simulated humanoid robots to autonomously play soccer.

Team Sweaty focuses on developing autonomous humanoid robots. Sweaty is a humanoid robot developed from scratch with an high degree of vertical integration, initially designed for research in bipedal locomotion. Since the project start in 2014, Sweaty has evolved into a multidisciplinary project, showcasing capabilities such as autonomously bipedal locomotion or in object manipulation, exemplified by playing soccer or chess against human opponents.

In its core competency of soccer, the team Sweaty has participated in the RoboCups 2014, 2016 – 2019, 2021, and 2023. The robot secured the vice world champion title from 2016 in Leipzig, Germany, through 2019 in Sydney, Australia. At the first virtual edition of the RoboCup in 2021, the team achieved the world champion title. In August 2025, the team participated in the first World Humanoid Robot Games in Beijing in the 3 vs. 3 soccer competition and achieved the silver medal on second place.

The recent rule changes in the RoboCup AdultSize League, specifically the prohibition of robot handlers on the field and the shift to 3 vs. 3 matches, are significant challenges for Sweaty's participation. Given Sweaty's height of approx. 1.70 m and its construction using structural carbon fiber parts and spindle motors, the robot is not designed to withstand falls without sustaining critical damage, such as broken spindles or carbon fiber components. Without the presence of handlers to assist, a fall during a match could result in severe damage, rendering Sweaty unable to continue playing. The rule changes led to the team's decision to use from now a standard platform – the Booster T1 robot – for the further participation in the RoboCup.

**Fig. 1.** Humanoid robot Sweaty competing in goal-wall shooting on the RoboCup GermanOpen Competition 2025

## 2   Project Planning

### 2.1   Objectives

Our current primary objective is to develop and deploy a robust, autonomous soccer-playing framework on the Booster T1 humanoid robot platform. This system will encompass advanced locomotion, precise ball-handling, and strategic decision-making capabilities, enabling effective participation in 3 vs. 3 up to 11 vs. 11 matches. To achieve this goal, we have outlined a structured project plan with two key milestones:

**Milestone 1: High-Level Controller Implementation**
In the initial phase, we will deploy our developed high-level control system leaning on and inspired by Team Magma's architecture. This controller is capable of autonomously managing various roles such as striker, goalkeeper, and defender. It facilitates strategic actions including advanced path planing, opponent- and game situation-depending decision making, team communication, evaluating optimal kick distances and directions, and executing passes. In a first step, after the deployment, we will leverage the Booster T1's existing software stack, which provides essential modules for vision, localization, and motion control for the general tests and required adaption. This approach ensures efficient testing and parallel development by utilizing the robot's current capabilities.

**Milestone 2: Reinforcement Learning for Enhanced Locomotion and Kicking**
Building upon the foundational high-level controller, the second phase focuses on enhancing the robot's locomotion and introducing for the kicking abilities. Therefore, we established a custom reinforcement learning environment using NVIDIA's IsaacLab. With this environment, we facilitated the development of a more robust and agile gait, enabling the robot to execute kicks with precise control over distance and direction. Achieving the transfer of robust policies for motion control from the learning environment the the physical Booster T1 robot is crucial for maximizing the potential of our high-level control algorithms and ensuring next level in overall game performance.

Through systematic and parallel advancement across these milestones, our objective is to develop a sophisticated and competitive robotic system that enhances the soccer-playing capabilities of the Booster T1 platform for the RoboCup Humanoid League 2026 in Incheon, Korea.

## 2.2   Testing and Validation

The successful achievement of both milestones will be rigorously tested to ensure seamless integration and the performance of each subsystem, as well as the overall performance in the interplay of all components. We plan to conduct comprehensive testing in our dedicated "Biomechanics and Motion Laboratory", which is equipped with advanced tools to accurately assess the robot's capabilities. Within this laboratory, we have instrumentation to measure ground reaction forces, enabling precise evaluation of the planned motions' performance (gait speed, robustness, etc.) and their transferability from simulation to real-world execution. Additionally, standardized perturbation mechanisms allow us to challenge the Booster T1 robot with controlled disturbances, providing quantitative data on its fall and external impact recovery.

Also in the laboratory facility, we have a full RoboCup AdultSize soccer field along with two Booster T1 robots to conduct extensive testing of game scenarios. This setup facilitates the assessment of various game states, behavioral strategies, and complete match simulations. It also enables real-world performance evaluation of critical software components such as vision systems under varying lighting and environmental conditions, localization accuracy, inter-robot communication, and ball-handling skills including kicking and passing.

Together, the structured testing environment and the RoboCup field tests provide a robust framework to validate the system's readiness for competition and to iteratively refine its capabilities.

## 2.3   Hardware

The humanoid robot Sweaty represents an original and proprietary design that has achieved notable success in the RoboCup Humanoid AdultSize League in recent years. However, due to its large size and broader applicability beyond football, the team started to develop a next-generation robot.

Progress in achieving faster movement speeds and enhanced robustness in smaller robots – especially concerning falls and potential damage – highlighted the need for a more compact robot with low-ratio gearing torque and smaller sensor units.

During the initial design phase, the team collaborated with partners specializing in electric motor locomotion. At the same time, new consumer robots from companies like Unitree, Fourier Robotics, and Booster Robotics emerged. A cost-benefit analysis led to the evaluation of these commercial platforms, with the goal of basing the new Team Sweaty humanoid robot on a proven, off-the-shelf solution.

Changes to the RoboCup rules accelerated this decision-making process. After market research and direct discussions with developers, Team Sweaty selected the Booster T1 platform as the foundation for its RoboCup competition robot. Development with this hardware started in March 2025 when a first machine was available in Offenburg.

So far, the team has gained a strong understanding of the Booster T1 hardware. Experience with the previous Sweaty v3 platform has led to several insights: localization and movement can be improved by integrating a high-performance IMU, ideally placed in the head section. Another improvement under consideration is replacing the RealSense camera with a more powerful ZED camera, which offers a wider field of view, higher resolution, and better integration with custom IMUs.

For the 2026 competition, no further hardware changes are planned. However, in subsequent years, the design of the arms and feet will be optimized to enhance walking and standing-up capabilities. Additionally, pressure sensors will be integrated to improve kicking behavior, balance, and agile motion.

## 2.4   Software

The Sweaty software framework is based on ROS2 (Robot Operating System) and features an interface to a Java-based decision-making component, built on the Magma-3D-Soccer simulation environment. The Sweaty codebase is written in streamlined C/C++ in combination with the ROS2 middleware.

Robot development in simulation was conducted using the Webots simulator, where Team Sweaty won the RoboCup Simulation Championship in 2021.

The current software stack is tailored to the Booster T1 hardware and designed for easy accessibility. The team's extensive experience in high-level football tactics and coordinated play is now being transfered to 3 vs. 3 and 5 vs. 5 match formats.

Rapid prototyping is supported by improving the simulation tools provided by Booster Robotics. Team Sweaty uses the MuJoCo simulator and has developed an enhanced simulation environment, which was presented for use in the 3D Simulation League at RoboCup 2025 in Brasil.

A secondary focus in software development is the application of deep reinforcement learning to refine existing motion patterns and develop new capabilities for the Booster T1 robots. A new training pipeline based on NVIDIA's IsaacLab has been established.

Current research is focused on developing a realistic kicking behavior, supported by high-fidelity ball simulation. The training setup is depicted in Figure 2. Initial kick motions have been successfully
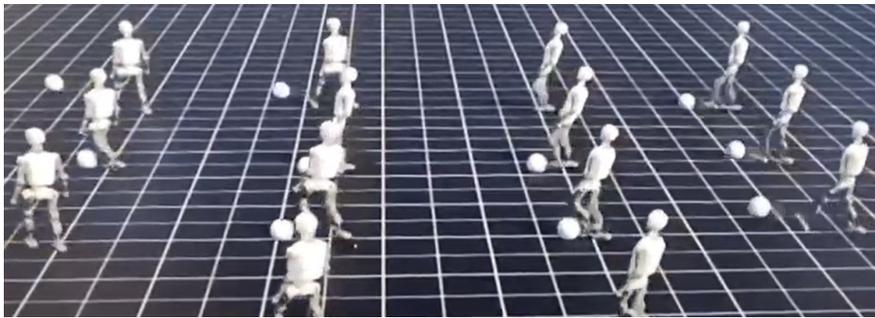


**Fig. 2.** Deep reinforcement learning for ball kicking in IsaacLab

transferred to the physical robot by fine-tuning IsaacSim results in MuJoCo before deployment. Further improvements are being explored using cost functions that incorporate full-body angular momentum.

## 2.5   Conclusion

This team description paper summarizes the current hardware and software developments of Team Sweaty in preparation for the *RoboCup Humanoid League 2026 in Incheon, Korea.*

Having achieved four second-place finishes and one third place in Adultsize humanoid league, and a first-place title in the 2021 RoboCup Simulation League, Team Sweaty brings extensive experience to AdultSize humanoid robot competitions. Rule changes in RoboCup, combined with advancements in AI and commercially available hardware, motivated the team to adopt the Booster Robotics T1 platform. The soccer-playing capabilities of the original Sweaty platform are now being transferred to the new robots, with a strong focus on custom designed high-level play logic and deep reinforcement learning for motion generation.

Substantial improvements have already been realized in match simulations and in the development of a distinct, AI-driven kicking behavior. This behavior draws on research into human biomechanics, motion control, and force modeling, incorporated into custom reward functions for reinforcement learning.

Future work will focus on further enhancing motion capabilities and adding hardware components such as redesigned limbs and new sensors. Research into the optimal combination of machine learning and real-world measurements aims to benefit not only the RoboCup community but also broader applications in robotics and AI.