

# KHUBER: Team Description and System Overview for RoboCup 2026 Humanoid Soccer League (Small Robot Division)

Hooseok Lee, Hyunhae Park, Euisun Jung, Soohan Lim, Yerang Gwak, and Jinseok Lee\*

Department of Biomedical Engineering, Kyung Hee University, Yongin, Republic of Korea  
gntjr1@khu.ac.kr, qkrguswo2946@khu.ac.kr, dominicjjung@khu.ac.kr, luke00804@khu.ac.kr, letter0930@khu.ac.kr, gonasago@khu.ac.kr

**Abstract.** This paper presents the Team Description Paper of Kyung Hee University Biomedical Engineering Robotics (KHUBER), a first-time participating team in the RoboCup 2026 Humanoid Soccer League (Small Robot Division). The KHUBER humanoid robot is a custom-developed platform designed to support research on learning-based humanoid locomotion and robust hardware–software co-design. The team focuses on modular hardware architecture, real-time embedded motor control, and reinforcement learning-based walking generation validated through physics simulation and real-world deployment. This paper outlines the scientific aspects of the robot system, including hardware design, sensing and actuation, control architecture, and learning-based locomotion framework. The planned developments toward RoboCup 2026 are described together with the current implementation status. The objective of KHUBER is to contribute reproducible robotic hardware and software components and to explore practical reinforcement learning methodologies for humanoid soccer environments.

**Keywords:** Humanoid robotics · RoboCup · Reinforcement learning · Legged locomotion · Embedded control

## 1 Introduction

Kyung Hee University Biomedical Engineering Robotics (KHUBER) is a newly formed humanoid robotics team at Kyung Hee University aiming to participate in the RoboCup 2026 Humanoid Soccer League (Small Robot Division) for the first time. The team was established with the objective of developing a fully custom humanoid robot platform that enables close integration between mechanical design, embedded motor control, and learning-based motion generation.

Unlike platforms that rely on predefined gait engines or purely model-based control, KHUBER focuses on reinforcement learning (RL) approaches for humanoid walking. The team emphasizes sim-to-real transfer, modular hardware

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\* Corresponding author

abstraction, and transparent system design to facilitate reproducible research outcomes. This paper presents the current system design and research direction, highlighting the scientific contributions planned for RoboCup 2026.

## 2 Humanoid Robot System Overview

### 2.1 Mechanical Design and Dimensions

The KHUBER humanoid robot is a Small Robot Division platform with a compact and lightweight structure. The robot has approximate dimensions of 600 mm in height, 280 mm in width, and 125 mm in depth. Structural components are primarily fabricated using 3D-printed PLA, enabling rapid prototyping and iterative design updates.

The robot features 18 degrees of freedom, focusing on lower-body articulation to support stable bipedal locomotion while maintaining sufficient upper-body degrees of freedom for balance and future manipulation tasks.

### 2.2 Actuation and Power System

All joints are actuated using Dynamixel MX-64AR smart servo actuators connected via RS-485 communication. The actuators provide integrated position sensing, velocity control, and current feedback, enabling low-level torque-aware control strategies.

The robot is powered by a lithium-ion battery pack composed of Molicel INR-21700-P42A cells in a 3S2P configuration, providing a nominal voltage of 11.1 V. This configuration was selected to balance energy density, current capability, and system weight for dynamic walking experiments.

### 2.3 Sensing

The robot is equipped with a stereo vision system based on the Intel RealSense D405 camera, enabling perception research for humanoid soccer scenarios. Inertial sensing is provided by a 6-axis IMU based on the STMicroelectronics LSM6DSV16X, delivering high-rate accelerometer and gyroscope measurements. Foot-ground interaction is measured using force-sensitive resistor (FSR) pressure sensors (RA9P), which are integrated into the soles to detect contact timing and load distribution.

## 3 Control Architecture

### 3.1 Embedded Motor Control

Low-level motor control is currently performed via the ROBOTIS U2D2 interface, which is responsible for actuator command transmission and the acquisition of motor state data, including joint position, velocity, and current. In contrast,

an ARM Cortex-M4-based custom STM32 control board is dedicated to sensor data acquisition, such as inertial and foot contact measurements. The custom controller focuses on real-time sensor sampling and timing management and communicates with the main computer via USB CDC.

In the current system, motor control and sensor data acquisition are implemented through separate hardware pathways to improve system stability and facilitate debugging. The control firmware is designed around deterministic timing constraints to ensure consistent sensor data delivery and to provide a reliable foundation for higher-level learning-based control.

In future iterations, motor control and sensor data acquisition will be integrated into the custom STM32-based control board to reduce communication latency and improve overall system responsiveness. This integration aims to enable faster and more efficient low-level control, further enhancing the real-time performance of learning-based controllers.

### 3.2 High-Level Computing

High-level control and learning algorithms run on an NVIDIA Jetson Orin NX (16 GB), which serves as the main onboard computer. The system architecture separates real-time motor execution from computationally intensive perception and policy inference tasks. This separation allows safe deployment of learning-based controllers without compromising hardware integrity.

## 4 Planned Developments Toward RoboCup 2026

The following developments are planned before RoboCup 2026:

- Full deployment of reinforcement learning-based walking on hardware.
- Integration of perception-driven behaviors for ball detection and navigation.
- Robustification of foot contact sensing and state estimation.
- Public release of hardware design files and control software components.

At the time of application, the mechanical platform, embedded control system, and simulation environment are operational. Learning-based locomotion is currently transitioning from simulation to real-world testing.

## 5 Expected Contributions

KHUBER aims to contribute to the RoboCup Humanoid League by:

- Demonstrating a reproducible learning-based humanoid locomotion pipeline.
- Providing open-source hardware and software components for educational and research use.
- Investigating practical sim-to-real transfer strategies for humanoid robots.

The team also expects the project to strengthen humanoid robotics research and hands-on education within the university and the broader robotics community.

## 6 Conclusion

This paper presented the KHUBER humanoid robot system and research direction as a first-time participant in the RoboCup Humanoid Soccer League. By combining modular hardware design, real-time embedded control, and reinforcement learning-based locomotion, KHUBER aims to explore scalable and reproducible approaches to humanoid soccer robotics. The team looks forward to contributing to the RoboCup community through open research and continued development toward RoboCup 2026.