Water 2026 AdultSize Extended Abstract

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Abstract. This paper presents the development journey, technical insights, and future plans of Team Water as we prepare for the RoboCup 2026 Humanoid AdultSize Soccer Competition. Building on our foundation in wheeled robotics, we have rapidly expanded into humanoid robotics and achieved notable results in preliminary competitions. We focus on key technical areas including locomotion optimization, vision-based perception, and multi-robot coordination. By integrating reinforcement learning, sensor fusion, and modular decision-making frameworks, we aim to enhance our robots' agility, stability, and cooperative capabilities. This abstract also shares lessons learned from early competitions and outlines our targeted improvements to excel in the upcoming RoboCup event.

Keywords: Humanoid Robot; RoboCup 2026; Multi-robot Coordination; Locomotion Optimization; Vision Perception

1 Introduction

Team Water's Humanoid Robotics Group was officially established in July 2026 under the School of Mechanical and Electrical Engineering, Beijing Information Science & Technology University. Leveraging the team's years of accumulated expertise in wheeled robotics, we successfully made a leap into the competitive field of humanoid robotics, adhering to the core philosophy of "Promoting Research through Competition, and Promoting Learning through Research."

Comprising interdisciplinary students from the Schools of Mechanical Engineering, Science, and Computer Science, our team operates on a "mentorship" model where experienced members guide new recruits. Under the supervision of faculty advisors, we focus on tackling core technologies critical to humanoid soccer, such as multi-robot coordination, high-precision positioning, and dynamic motion control, to maximize the competitive performance of our T1 humanoid robots.

Within just over a month of formation, we co-founded “Team Blaze” with Team I-Kid and participated in the 2026 World Humanoid Robot Games (WHRG), securing an impressive 4th place in the world’s inaugural 5V5 AI Decision-making Football match. In the same year, we achieved further success by winning the Third Prize in the Humanoid Robot 3V3 category at the RoboCup China Open, the Second Prize at the North China University Student Robot Competition, and the Third Place (Bronze) at the RoBoLeague Robot Soccer League (North China Division, Q1). As a rapidly growing innovation team, we not only demonstrate strong technical capabilities through these outstanding records but also strive to cultivate and deliver composite talents to related fields, emerging as a benchmark team that balances competitive vitality and educational value.

Our participation in RoboCup 2026 marks a key milestone in our development. We aim to leverage this global platform to test our technical advancements, learn from international peers, and push the boundaries of our humanoid robotics research.

2 Lessons Learned and Key Challenges

2.1 Balancing Speed and Stability in Locomotion

Early competitions revealed that our initial gait algorithms, while functional, struggled to balance speed and stability during dynamic game scenarios. Rapid direction changes and sudden stops often led to instability, particularly when the robot was navigating uneven field surfaces. We learned that purely predefined motion sequences lack the adaptability needed for real-time adjustments, highlighting the need to integrate data-driven learning approaches to enhance gait robustness.

2.2 Limitations of Vision-Based Perception in Complex Environments

Our current perception system relies primarily on monocular vision and basic image processing for ball and field line detection. However, we encountered challenges in low-light conditions, partial occlusions by opponents, and fast ball movements, which resulted in delayed or inaccurate detection. This highlighted the critical need for sensor fusion and advanced detection algorithms to ensure reliable perception in dynamic competitive environments.

2.3 Inefficiencies in Multi-Robot Coordination

In team-based matches, we observed inconsistencies in communication between robots, leading to redundant movements and missed passing opportunities. Our initial coordination strategy lacked a flexible role-allocation mechanism, making it difficult to adapt to changing game dynamics. We recognized that effective multi-robot collaboration requires real-time data sharing, dynamic role switching, and predictive decision-making based on teammate and opponent positions.

3 Planned Technical Improvements

3.1 Locomotion Optimization

To enhance walking stability and adaptability, we plan to integrate Reinforcement Learning (RL) with our existing gait framework. We will train RL-based policies in simulated environments to optimize gaits for different scenarios, such as rapid acceleration, sudden deceleration, and obstacle avoidance. Additionally, we will explore Model Predictive Control (MPC) to improve the robot's ability to anticipate and adjust to dynamic changes, ensuring smoother transitions between movements. Hardware-wise, we will upgrade joint motors to enhance torque output and responsiveness, supporting more agile and robust locomotion.

3.2 Vision and Perception Enhancement

We will upgrade our perception system by integrating a ZED 2i Stereo Camera for depth perception, complemented by a 9-axis IMU to improve localization accuracy. To address detection challenges, we will implement a fine-tuned YOLO-v8 model for real-time ball, goalpost, and opponent detection, combined with Particle Filtering algorithms for stable tracking even under occlusions. Furthermore, we will develop a Line Segment Detector to recognize field markings, enhancing the robot's self-localization capabilities on the field. Sensor fusion techniques, including Kalman Filters, will be employed to integrate visual and IMU data, improving perception reliability in complex environments.

3.3 Multi-Robot Coordination and Decision-Making

We will develop a modular decision-making framework based on Behavior Trees (BTs) to replace our initial finite state machine, enabling more flexible and scalable behavior management. For multi-robot communication, we will adopt UDP-based data transmission to ensure real-time sharing of field information, including ball position, teammate locations, and opponent movements. The goalkeeper will act as the central communication host, coordinating defensive actions, while other robots will function as listeners, executing offensive strategies such as chasing, passing, and shooting. We will also integrate A* path planning algorithms to optimize movement trajectories and incorporate opponent position prediction into our decision-making process, enhancing tactical flexibility.

3.4 Hardware Robustness Improvements

To reduce downtime due to falls during competitions, we will enhance the robustness of critical hardware components. This includes reinforcing the robot's feet, shoulders, and neck structures to withstand impacts, as well as adding protective casings for key electrical components such as cameras and processors. We will also explore damage-mitigation motions that the robot can execute when a fall is detected, minimizing hardware damage.

4 Current Status and Future Timeline

Currently, we have completed the initial integration of the T1 robot's hardware platform and basic software framework. The robot is capable of stable walking, basic ball detection, and simple team coordination. We have also established a simulated training environment to test and optimize gait algorithms and decision-making strategies.

Our future development timeline is as follows:

By the end of 2024: Complete RL-based gait training and YOLO-v8 model fine-tuning; implement basic sensor fusion and UDP communication.

Early 2026: Integrate Behavior Tree-based decision-making framework and A* path planning; conduct comprehensive hardware robustness testing.

Mid-2026: Perform real-world validation of all technical improvements through friendly matches and regional competitions; finalize adjustments based on test results.

5 Conclusions

Team Water is enthusiastic about participating in RoboCup 2026 and showcasing our technical advancements in humanoid robotics. Through targeted improvements in locomotion, perception, and coordination, we aim to compete at a high level while contributing valuable insights to the broader robotics community. We look forward to exchanging ideas with international teams and pushing the boundaries of humanoid soccer technology.

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