BigHeroX Team Description

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Abstract. BigHeroX, transitioning from the RoboCup Middle Size League, will make its debut in the Humanoid League at RoboCup 2026 using the Z4 robot platform provided by Zoomlion Zvalley. This paper presents the team's current technical developments in visual perception, motion control, communication, and decision-making. Key components include deep learning-based visual perception, MPC-WBC-based bipedal locomotion, low-latency wireless team communication, and a robust dynamic stack-based decision framework. These developments aim to improve system robustness, real-time responsiveness, and team coordination in high-dynamic humanoid soccer scenarios.

Keywords: RoboCup Humanoid League, bipedal robot, visual perception, motion control, multi-robot communication, behavior decision

1 Introduction

BigHeroX is the robotic soccer team of Hunan University, with extensive experience in the RoboCup Middle Size League, including winning the 2023 China Open championship and achieving top rankings in the 2024 RoboCup Middle Size competitions. In 2026, the team will participate in the RoboCup Humanoid League for the first time, addressing new challenges such as bipedal locomotion, dynamic balance, close-range interaction, and physical contact in unstructured environments.

The team adopts the Z4 humanoid robot platform provided by Zoomlion Zvalley, equipped with Intel i7 for onboard computation. Our software stack builds upon and significantly extends the Hamburg Bit-Bots framework (HNU-BigHeroX branch), with focused adaptations for humanoid-specific perception robustness, locomotion stability, and multi-robot coordination. As a transition-year participation, our primary objective is to establish a reliable and rule-compliant humanoid soccer system while progressively improving performance and autonomy.

2 Technical Developments

The transition from wheeled robots to bipedal humanoids exposed limitations in balance control, close-range precision, perception robustness under lighting variation, and communication reliability. We addressed these challenges through targeted subsystem-level improvements.

2.1 Visual Perception

Dynamic object perception is based on a YOLOv8 deep learning model accelerated with OpenVINO on Intel i7 achieving real-time performance on high-resolution image streams. The system focuses on detecting the ball, robots, and goalposts under varying lighting conditions.

Static field features, particularly white field lines, are extracted using traditional OpenCV-based methods, including Canny edge detection and probabilistic Hough transforms. These features provide stable geometric landmarks for localization.

Coordinate transformation is performed using inverse perspective mapping (IPM). Camera extrinsic parameters relative to the ground plane are obtained in real time through TF2-based kinematic modeling, combined with camera intrinsic calibration to construct homography matrices. Detected ground contact points, such as the bottom of the ball or field line intersections, are projected onto the planar field to enable Cartesian-space planning.

Active vision is managed by a finite state machine. When the ball is visible, PID-based head control maintains target centering. Upon target loss beyond a time threshold, predefined scanning behaviors are triggered, incorporating the last observation and teammate communication to maximize information acquisition.

Localization is implemented using a Monte Carlo particle filter that fuses visual landmarks, IMU data, and odometry. GameController information is used to resolve field symmetry when applicable. Overall, the perception system is designed to provide reliable input for close-range interaction and dynamic play.

2.2 Motion and Control

Bipedal locomotion is generated using a linear inverted pendulum model combined with model predictive control (MPC) for center-of-mass trajectory planning. Whole-body control (WBC) is employed to coordinate joint motion, enabling simultaneous walking, balance recovery, and obstacle avoidance.

Online gait adaptation utilizes IMU and foot pressure feedback to accommodate variations in ground conditions. Parameter adaptation is primarily achieved through Bayesian optimization, with preliminary exploration of lightweight reinforcement learning approaches under controlled conditions.

Key actions such as kicking and getting up are executed using a conditional real-time trajectory generator. Motion parameters are adjusted based on the robot's posture, ball position, and estimated ground contact state. Control loops operate above 200 Hz under ROS 2 real-time DDS. In cases of unreliable perception, the system automatically falls back to conservative motion strategies to maintain stability.

These mechanisms improve disturbance rejection and execution reliability during rapid maneuvers and close-range interactions.

2.3 Communication

Team communication is implemented using a low-latency wireless networking module with differentiated message prioritization. Control and tactical messages are assigned higher priority than routine status data to ensure timely coordination.

A distributed topology management mechanism supports real-time node discovery and role-based bandwidth allocation. Communication robustness is enhanced through channel quality monitoring, adaptive transmission strategies, and interference mitigation mechanisms. In the event of temporary disconnections, incremental state synchronization is used to recover shared team information.

The communication system is designed to achieve end-to-end latencies on the order of tens of milliseconds with low packet loss under typical competition conditions, enabling coordinated passing, defensive positioning, and role switching.

2.4 Decision System

The core framework is the Dynamic Stack Decider. Close-range (<1 m) scenarios bypass global navigation with direct visual PID servoing to correct localization drift. A confidence decay filter on ball detection prevents oscillation from transient occlusions. Collaboration logic tracks teammate last-seen timestamps; communication loss exceeding 2 s triggers an aggressive single-robot mode to secure ball possession and avoid deadlock. These refinements ensure fluid attack-defense transitions under imperfect perception or connectivity.

3 Conclusion

BigHeroX has integrated Middle Size League expertise into a cohesive humanoid architecture emphasizing deep learning perception, MPC-WBC locomotion, low-latency communication, and robust decision-making. The resulting system offers improved dynamic stability, precise close-range execution, and effective multi-robot coordination, ready for competitive evaluation at RoboCup 2026.

References

1. BigHeroX Team Description 2025. Hunan University, 2025.