HERoEHS, Team Extended Abstract

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Abstract. Team HERoEHS and AeiROBOT present ALICE 4th generation, building on previous successes in mechanical design, walking algorithms, vision recognition, and localization. By integrating a QP Solver-based parallel walking system, linear-actuator mechanisms, and enhanced YOLO-based vision, ALICE4 aims to demonstrate robust, real-time performance at RoboCup 2025. Through refinements such as Divergent Component of Motion based step optimization, a new state estimator, and a hot-swappable 48V power system, we aim to validate the platform's adaptability to real-world environments, moving closer to our shared vision of "A robot for ALL."

Keywords: ALICE4 · RoboCup · Adult Size League · Humanoid Robot

1 Introduction

Team HERoEHS has participated in the RoboCup Humanoid Adult Size League since 2018, steadily advancing ALICE 4th generation through mechanical, control, and vision enhancements. With support from AeiROBOT the latest iteration, ALICE4, aims to integrate more robust walking algorithms, improved vision recognition, and refined localization. In pursuit of the shared vision, "A robot for ALL," we seek to validate ALICE4's capabilities at RoboCup 2025, demonstrating a versatile platform adaptable to real-world tasks and environments.

2 Technical Issues

2.1 Walking Algorithm

Team HERoEHS and AeiROBOT identified the limitations of ZMP-based walking from previous RoboCup competitions. Building on this, they introduced an omnidirectional walking system at RoboCup 2023 and developed QP Solver-based balance optimization and a Parallel Walking system at RoboCup 2024. For RoboCup 2025, the team aims to address two main challenges. First, they plan to enhance robustness and maintain balance by integrating Divergent Component of Motion (DCM)-based step optimization and Whole Body Control (WBC). Second, they intend to implement a real-time walking system to ensure stable movements in dynamic match situations.

To date, the team has successfully completed the QP Solver-based optimization and the development of the Parallel Walking system, enabling the robot to stably approach the ball and perform a kick. The integration of DCM and WBC is underway, along with testing of the real-time walking system. These developments are progressing to ensure high performance at the upcoming RoboCup 2025.

2.2 Mechanical Design

Upgrading to ALICE4 introduced three key mechanical design changes. First, switching from a rotary actuator-based serial mechanism to a linear actuator-based parallel mechanism enhanced robustness by evenly distributing loads, improving rigidity, and reducing costs. Second, replacing high gear ratio actuators with low gear ratio actuators enabled precise torque control through backdriving and current sensing. Finally, increasing the arms' degrees of freedom allows for more complex actions, such as throwing and balancing.

2.3 Vision Recognition

At RoboCup 2024, we utilized YOLOv8s, trained on approximately 90,000 datasets, for object detection. Optimized through TensorRT, YOLOv8s processed images from ZED2i cameras in real time to recognize objects such as balls and goals. Additionally, we introduced a segmentation model to detect field lines, further enhancing localization performance. In 2025, we plan to upgrade our object detection model to YOLOv11 and replace the HSV filter previously used for recognizing the stadium with a segmentation model. These upgrades are expected to significantly improve vision recognition and localization performance, enabling more efficient and precise gameplay at RoboCup 2025.

2.4 Localization

We are developing a vision-based positioning system for soccer robots that uses visual features, field lines, and orientation information. In the previous RoboCup, robots encountered positioning challenges due to limitations in robot state estimation. To address this, we are introducing a newly developed robot state estimator to mitigate the position loss issues experienced in past competitions. We will expand on traditional location tracking methods by introducing a new approach that matches key visual features to a global coordinate system. Our team is currently building a matching algorithm and testing it through computer simulations.

2.5 Electrical Design

The electrical design of ALICE4 features two main improvements. First, custom motor drivers with high-bandwidth current control and high-speed communication interfaces were developed to replace the existing Dynamixel actuators. Second, a hot-swappable 48V power system was introduced to allow continuous operation during charging, and protective circuits were added to enhance safety. These enhancements significantly improve ALICE4's performance and reliability.

3 Future Work & Conclusion

Team HERoEHS and AeiROBOT have already completed development of key technologies such as the QP Solver-based parallel walking system, a mechanical design centered on linear actuators, and YOLO-based vision recognition. Moving forward, they plan to integrate DCM-based step optimization with WBC to achieve more stable walking, and adopt a newly introduced robot state estimation technique for precise localization. Furthermore, the in-house motor drivers and the 48V hot-swappable power system will be further refined to enable uninterrupted operation during competitions.

At RoboCup 2025, these technologies will be comprehensively tested and validated on ALICE4, which is designed for real-world everyday and workplace environments. By doing so, the team aims to establish a more robust foundation for performing tasks in a wide range of settings. Ultimately, this effort serves as a crucial step toward realizing the goal of "A robot for ALL," enabling a single robot to execute a variety of missions.