BigHeroX Team Description 2025

Hunan University,

No. 2 Lushan South Road, Yuelu District, Changsha, Hunan Province, 410082, China

http://139.9.79.101 :8080/robocup/

We have two sets of equipment versions, one is the commercial version for the water team, and the other is our self-designed version .

Abstract: Team BigHeroX is a Middle Size robotic soccer team of Hunan University.The paper mainly introduces robot mechanical system and software system, including driving and steering platform,vision system, self-positioning system, and the robot path planning.

Keywords: RoboCup Middle Size, robot

1 Introduction

Team BigHeroX (Super Nenglu Team) is a robotic soccer team of Hunan University,who won the 2023 China Robot Competition and RoboCup China Championship, as well as the runner up. They also won the 2024 RoboCup Middle Size League Ambition Challenge First Place and the 2024 RoboCup Middle Size League Soccer Competition Second Place. HNU Robot Workshop BigHeroX Team, also known as Chaoneng Lu Team in Chinese. Team members share common interests and enthusiasm to enhance their professional skills and help achieve the goal of defeating the human footballteam by 2050.This paper provides a brief overview of the current status of our soccer robots. Section 2 introduces the basic electrical system of the robots, Section 3 presents the fundamental mechanical system, and Section 4 describes our ongoing efforts to improve the robots.

2 Electrical System Design

2.1 Main Controller (PC)

The Main Controller (PC) serves as the core of the entire system, responsible for processing data from various sensors and controlling the robot's movements, including shooting, dribbling, and other actions. Communication between the main controller and each subsystem is facilitated via the CAN bus, ensuring real-time data transmission and processing.

2.2 Attitude System

The attitude system is equipped with an IMU (Inertial Measurement Unit) sensor, which monitors the robot's posture and motion status in real-time. The IMU sensor provides critical data on the robot's acceleration, angular velocity, and direction, enabling the main controller to execute precise motion control and path planning.

2.3. Communication Layout

The communication system is designed around a CAN bus architecture, which ensures efficient and reliable communication between subsystems. The CAN bus is known for its high reliability and anti-interference capabilities, making it ideal for complex robot control systems.

1. CAN Bus: Connects the main controller, chassis controller, temperature sensors, power meters, infrared distance sensors, and other devices.
2. Wireless Communication Module: Facilitates communication with external devices or other robots, supporting real-time data transmission and remote control.

2.4. Chassis Control System

The chassis control system is responsible for managing the robot's motion, utilizing three chassis motion motors and two dribbling motors. Each motor is controlled by an independent controller to ensure flexible and responsive movement.

1. Chassis Motion Motors: Three motors control the robot's forward, backward, left, right, and rotational movements.
2. Dribbling Motors: Two motors control the dribbling action, ensuring the robot can stably dribble the ball forward.

2.5. Sensor System

The sensor system includes temperature sensors, power meters, and infrared distance sensors, which are used to monitor the robot's status and environmental conditions in real-time.

1. Temperature Sensors: Monitor the temperature of the motors and controllers to prevent overheating and potential damage.
2. Power Meters: Monitor the battery's voltage and current in real-time, ensuring the stable operation of the power system.
3. Infrared Distance Sensors: Detect obstacles around the robot, assisting in obstacle avoidance and path planning.

2.6. Shooting System

The shooting system consists of a shooting lever angle motor and an electromagnetic shooting device, enabling precise shooting control.

1. Shooting Lever Angle Motor: Controls the angle of the shooting lever, ensuring the shooting force and direction.
2. Electromagnetic Shooting Device: Achieves rapid shooting through electromagnetic force, ensuring shooting accuracy and power.

2.7. Power Management System

The power management system comprises a Battery Management System (BMS) and multiple DC-DC converters, ensuring stable power supply to each subsystem.

1. Battery (60V): Provides power to the entire system, offering high energy density and long endurance.
2. 2000W DC-DC Converter: Converts 60V to 24V, supplying power to the chassis motors and dribbling motors.
3. 1000W DC-DC Converter: Converts 60V to 24V, supplying power to the shooting system and electromagnetic charging module.
4. 60V to 20V DC-DC Converter: Supplies power to the sensor system, ensuring stable operation of the sensors.

2.8. Capacitor Charge/Discharge Controller

The capacitor charge/discharge controller manages the charging and discharging process of the capacitors in the shooting system, ensuring the instantaneous high current demand during shooting.

2.9. Relay Control

The relay control system manages power distribution and switching, ensuring that each subsystem is powered when needed.

Relay 1: Controls the power switch for the chassis motors.

Relay 2: Controls the power switch for the dribbling motors and shooting system.

Relay 3: Controls the power switch for the sensor system and communication module.

3 Mechanical System

3.1 Driving and Steering Platform

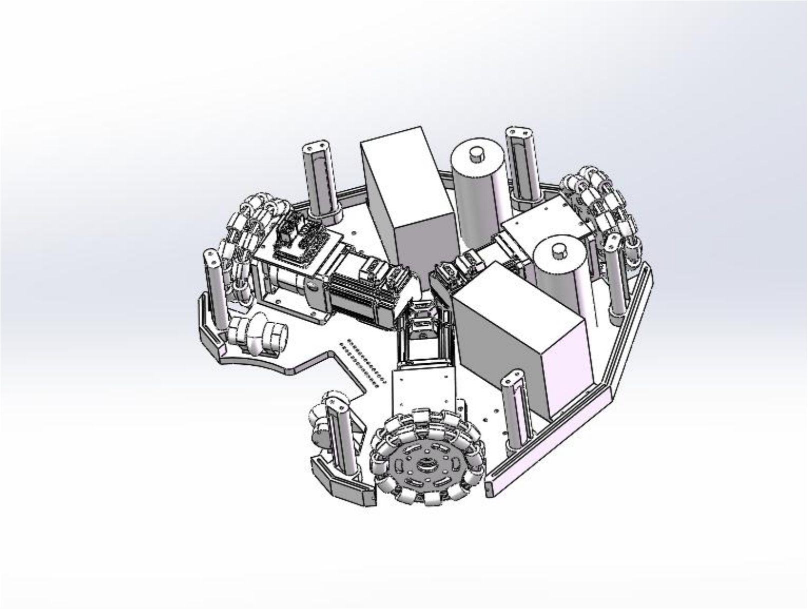

Fig. 1. Driving And Steering Platform

The robot's chassis uses a three-wheel omnidirectional design with one drive wheel and two omnidirectional wheels, enabling multi-directional motion (translation and rotation) without changing orientation. It suits sports fields requiring flexibility and mobility. Key components include:

1. Drive Wheel: Provides propulsion for forward/backward motion via an electric motor.
2. Omni-Wheels: Enable translational/rotational motion without reorientation, using McNamp wheels with small perpendicular rollers.
3. Mecanum Wheels: Use specially arranged rollers for multi-directional movement by controlling roller speed/direction.

Advantages:

1. Strong mobility in tight spaces.
2. High flexibility for translation/rotation.
3. Small turning radius.
4. Simple control for complex motions.

Challenges:

1. High sensor/control system demands.
2. Susceptibility to ground friction/torque.
3. Requires precise attitude control.

Future improvements will address these challenges.

3.2 Ball Suction Device And Screw Kicking Device

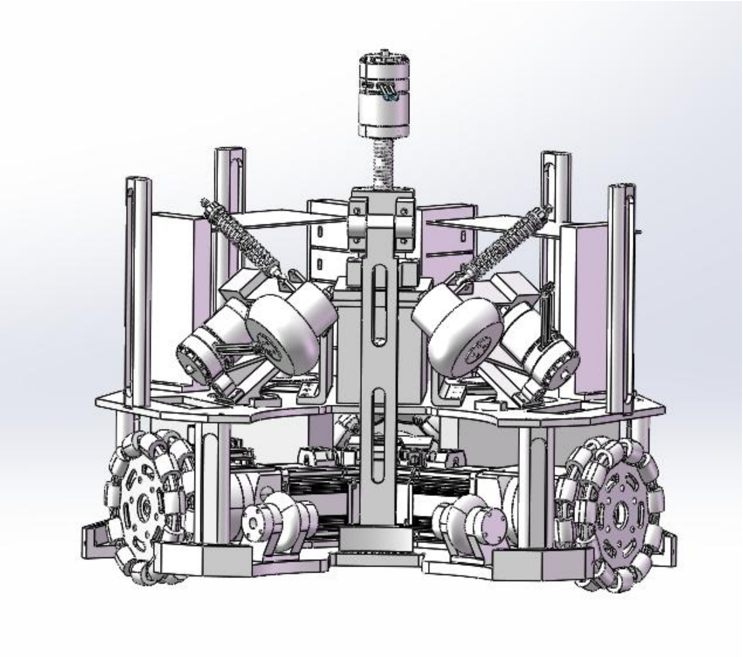

Fig. 2. Ball Suction Device And Screw Kicking Device

The device has two symmetric parts, each with:

1. Wheels: Driven by DC motors, they press against the ball, using friction to control its rotation in desired directions and speeds.
2. DC Motor with Right Angle Reducer: Provides torque to drive the wheels, ensuring precise ball control.
3. Linear Displacement Sensor: Measures the distance between the robot and the ball. The support mechanism adjusts the sensor as the ball moves closer or farther.
4. Support Mechanism: Holds the wheels, motors, and sensors, ensuring proper ball contact and control. It must be sturdy for reliable operation.

These components work together for precise ball control. A closed-loop system adjusts wheel speed to maintain optimal distance and control, enabling effective ball handling during games.

The kicking device includes:

1. Rod: Made of high-strength materials, its length and diameter are adjustable for different kick strengths and angles.
2. Motor: Drives the rod back and forth to perform kicks.
3. Ball-Contact Device: At the rod's end, it contacts and kicks the ball.
4. Control System: Manages motor rotation for accurate kicks, integrating with other sensors for automated shooting and passing.

This design allows robots to shoot and pass the ball accurately and consistently.

4 Software System

4.1 Visual Recognition

The visual recognition algorithm consists of two parts: localization of the robot itself and localization of the target.

We first perform distortion correction, as there may be distortion in the panoramic image, such as perspective distortion or lens distortion. To correct these distortions, we used interpolation discretization to obtain more accurate images.

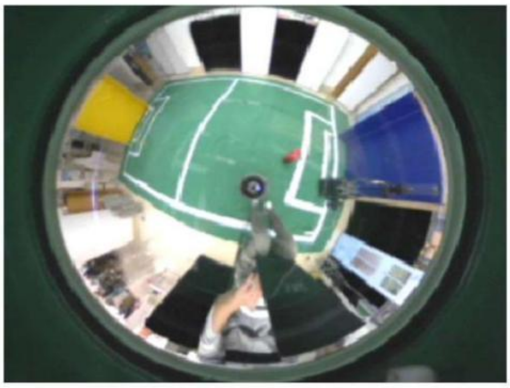

Fig.3 . Before Image Correction

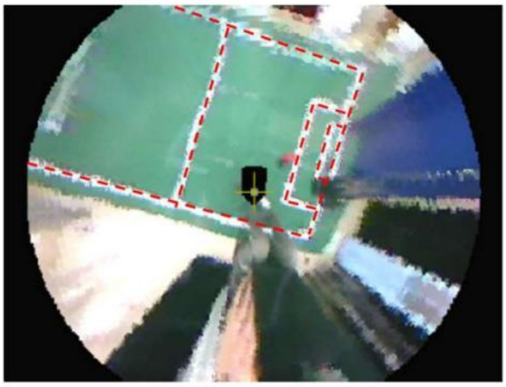

Fig.4 . After Image Correction

Then perform feature sampling. Firstly, perform color space conversion. Convert the collected images from RGB color space to HSV space. Then, the converted image is binarized, and pixels within a specific color range are set as foreground and other pixels as background based on color threshold. The needful site features (such as white lines) are separated from the background.

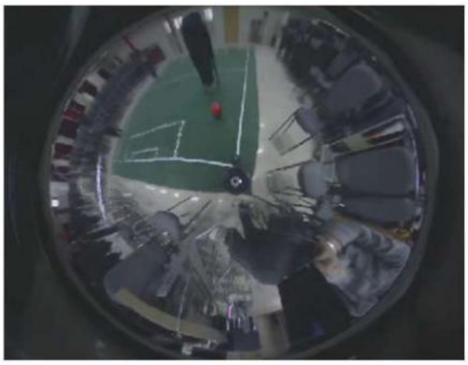

Fig.5 . Before Image Binarization

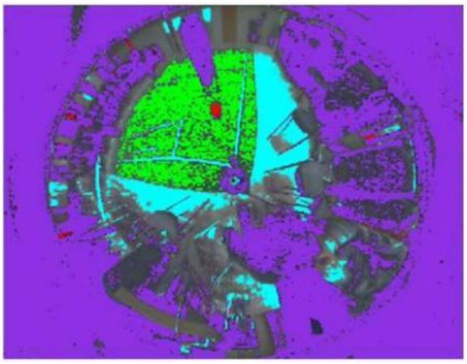

Fig.6 . After Image Binarization

At the same time, in order to improve the efficiency of the algorithm and reduce computational complexity, we adopted a field line down sampling strategy, selecting only a portion of the field lines for calculation, rather than processing all the lines.

To achieve localization of the robot itself, we first perform field line matching. We use a pre prepared field line template to match with the binarized image, and by comparing the field features in the template and image, we can find the matching lines.

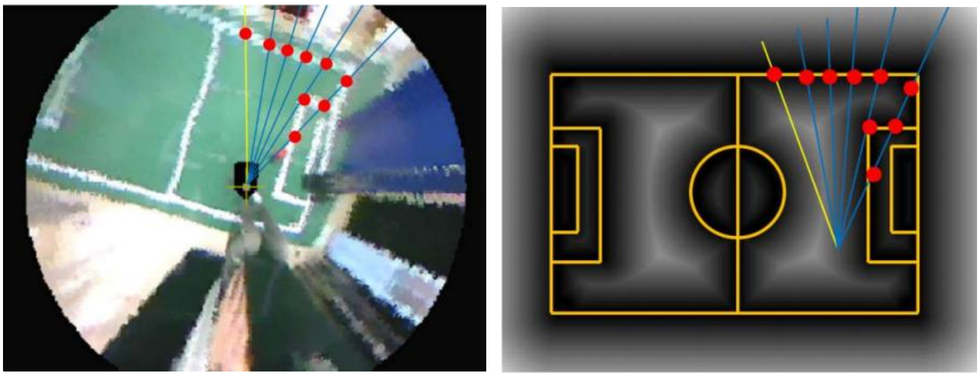

Fig.7. Left：Select A Portion Of The Field Lines For Calculation

Right：Match The Pre Prepared Field Template With The Sampling Points

Then, we use the ICP nearest point iteration algorithm to estimate the position and posture of the robot in the field. By iteratively searching for matching nearest point pairs, aligning the actual observed site features with the predicted site features, the robot's position and attitude estimation can be obtained. In order to improve the accuracy and robustness of positioning, we also used the attitude information obtained from the motor encoder odometer and the IMU attitude sensing unit for fusion. For example, the attitude information obtained by the IMU attitude sensing unit uses attitude fusion algorithms to obtain the rotation angle of the robot.

In order to achieve target localization, we used an eight neighborhood search algorithm to search for target features in the neighborhood around each pixel in the image to determine the position of the target. Simultaneously select and filter candidate targets. First layer filtering: After coordinate restoration, suspected targets located outside the site are excluded. Exclude connected domains with excessively large areas (significantly larger than the target object). Sort the remaining suspected targets by credibility. Second layer filtering: The robot uploads the set of targets it detects to the trainer. The trainer selects the maximum possible target through a target voting mechanism. The trainer distributes the maximum possible target information to all robots. The robot will use the filtered results as reference values.

4.3 Planning

We divide robots into three responsibilities: forward, defense, and goalkeeper. Determine their path planning approach by assigning different roles to robots. Simultaneously build a strategy library. Design coping strategies for all possible states and place them in this strategy library. Then, a finite state machine is constructed to achieve policy switching between different states. The specific strategy is for the forward robot to compete with the opponent's robot for possession of the ball, as long as the rules allow. When gaining possession, pull the opponent's defense by dribbling or passing the ball. Find opportunities to breakthrough the opponent's defense by dribbling or passing. When the opportunity is ripe, complete the shot. Defensive robots can interfere with the opponent's shots, as long as the rules allow. Perform man to man defense on opposing robots who do not have possession but pose a threat to their own team. Collaborate with other defensive players to defend. There are several behavioral patterns, including fixed angle defense, group defense strategy, encirclement strategy, and man to man defense. The goalkeeper robot blocks the opponent's shot.

4.4 Motion Control

Using C++to call the API interface functions provided by the system, send speed commands to the corresponding USB ports on the robot chassis, control the speed of each motor on the robot chassis, and thus achieve control over the overall movement of the robot.

5 Research Focus: Multi-robot collaborative technology

In multi-robot systems, collaboration between robots is crucial. We plan to further develop multi-robot collaboration technologies, enhancing capabilities in task allocation and load balancing, collaborative perception and information fusion, path planning and obstacle avoidance, behavior coordination, and decision-making to improve the collaborative combat capabilities of robots.

5.1 Developing Collaboration Strategies

Collaboration strategies are the core of multi-robot systems. We plan to establish a more comprehensive task allocation system and consider adopting master-slave, distributed, and hybrid strategies to allocate tasks based on mission requirements, robot capabilities, and environmental dynamics.

1. Master-Slave Strategy: A master robot coordinates other slave robots, suitable for scenarios with high task complexity and centralized control requirements.
2. Distributed Strategy: Each robot makes autonomous decisions based on local information, suitable for scenarios requiring high robustness and flexibility.
3. Hybrid Strategy: Combines the advantages of master-slave and distributed strategies, with some tasks coordinated by the master robot and others decided autonomously by the robots.

5.2 Improving Communication Mechanism

We plan to achieve the goal of improvement by utilizing NearLink. Huawei's NearLink technology consists of the NearLink access layer, basic service layer, and basic application layer. The NearLink access layer comprises SLB (basic access) and SLE (low-power access). NearLink technology can bring us lower latency, higher communication quality, stronger anti-interference capabilities, and lower power consumption.

5.3 Motion Planning and Control

In the future, we will apply the Random Forest algorithm to player robots, allowing us to achieve faster training speeds and highly accurate classifiers. By using the Random Forest algorithm, we can handle a large number of input variables and consider the importance of variables when determining categories. This algorithm is very friendly to variable types, capable of handling both discrete and continuous data, and can maintain calculation accuracy even with some missing data.

The specific implementation steps are as follows:

1. Construct sub-datasets by randomly sampling samples from the original data set with replacement.
2. Build sub-decision trees using the sub-datasets, which will form the Random Forest.
3. Input the data set into different sub-decision trees for statistical analysis and aggregation.

References

1. Li Tiejun. Research and Development of Vision System for Medium-sized Group Robots in RoboCup [D]. Shandong University, China, 2006.

2. Cao Yujie. Research on Path Planning Methods for RoboCup Medium-sized Group Soccer Robots [D]. Changsha University of Science and Technology, China, 2017.

3. Lu Shengcai, Hai Dan, Wang Xiangke, et al. Design of Active Ball Control Mechanism for RoboCup Medium-sized Group Soccer Robots[J]. Journal of Mechanical and Electrical Engineering, 2009, 26(11): 13-17+67.

4. Shi Xiaoru. Confrontation Strategies and Cooperative Coordination of Soccer Robots Based on Game Theory [D]. Xi'an University of Science and Technology, China, 2012.

5. Zhao Zengrong, Han Tiwen. Image Recognition Algorithm Based on RoboCup Medium-sized Group Soccer Robots[J]. Journal of Shandong University of Science and Technology (Natural Science Edition), 2007(01): 88-91.