BigHeroX Team Description 2024

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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! HNU Robot Workshop BigHeroX Team, also known as Chaoneng Lu Team in Chinese. They mainly participate in RoboCup competitions and have recently won the runner up in the 2023 China Robot Competition and RoboCup Robot Man World Cup China RoboCup, as well as the championship in the Skills Challenge.Team members share common interests and enthusiasm to enhance their professional skills and help achieve the goal of defeating the human football team by 2050.This paper gives a brief overview of the status of our soccer robots. In section 2, basic mechanical system of our robots is given. Section 3 presents the introduction of software system. The ongoing effort to improve the robots is described in section 4.

2 Mechanical System

2.1 Driving and Steering Platform

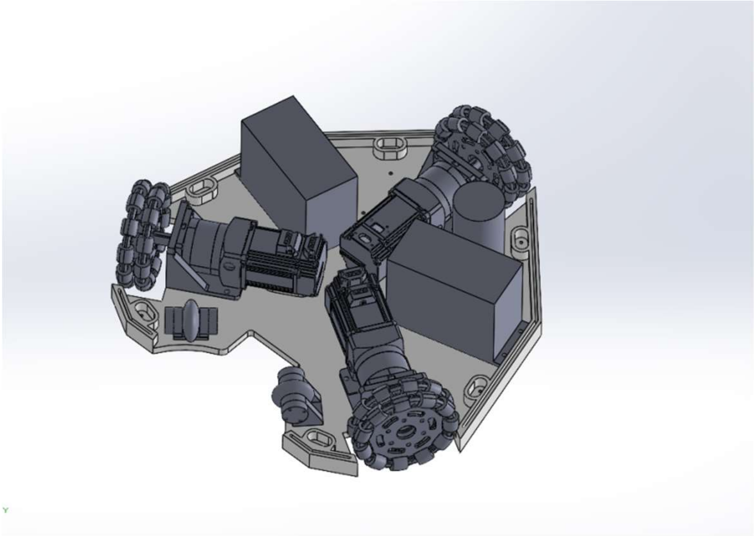


Fig. 1. Driving And Steering Platform

The chassis of the robot adopts an omnidirectional wheel three wheel structure, consisting of one driving wheel and two omnidirectional wheels, allowing the robot to achieve multi-directional motion on a horizontal plane, including translation and rotation, without changing its orientation. It is suitable for movement on sports fields that require flexibility and mobility, and includes the following structures.

1. Driving wheel: responsible for providing the robot with propulsion to achieve forward and backward movement, driven by an electric motor, controlling the speed and direction of the drive wheel.
2. Omni-Wheels: It is a key component that enables the robot to achieve translational and rotational motion without changing orientation. The omnidirectional wheel is composed of multiple small wheels that can rotate perpendicular to the main wheel. By controlling the speed and direction of each small wheel, omnidirectional wheels can achieve multi-directional movement of the robot. Our omnidirectional wheel adopts the McNamp wheel.
3. Mecanum Wheels: The Mecanum Wheels is composed of specially arranged rollers. By controlling the speed and direction of the rollers, the Mecanum Wheels can achieve translational and rotational motion of the robot on the horizontal plane. By reasonably controlling the movement of each wheel, the robot can achieve multi-directional movement.

The advantages of an omnidirectional three wheel structure include:

-Strong mobility: The robot can freely move and turn in narrow spaces.

-High flexibility: The robot can perform translation and rotation movements without changing its orientation.

-Small turning radius: The robot can complete flexible turning operations in a small space.

-Simple control: By reasonably controlling the speed and direction of the wheels, complex motion modes can be achieved.

However, the omnidirectional three wheel structure also faces some challenges, such as high requirements for sensors and control systems, susceptibility to ground friction and torque, and the need for precise attitude control. Therefore, we will strive to improve it in the future.

2.2 Ball Suction Device

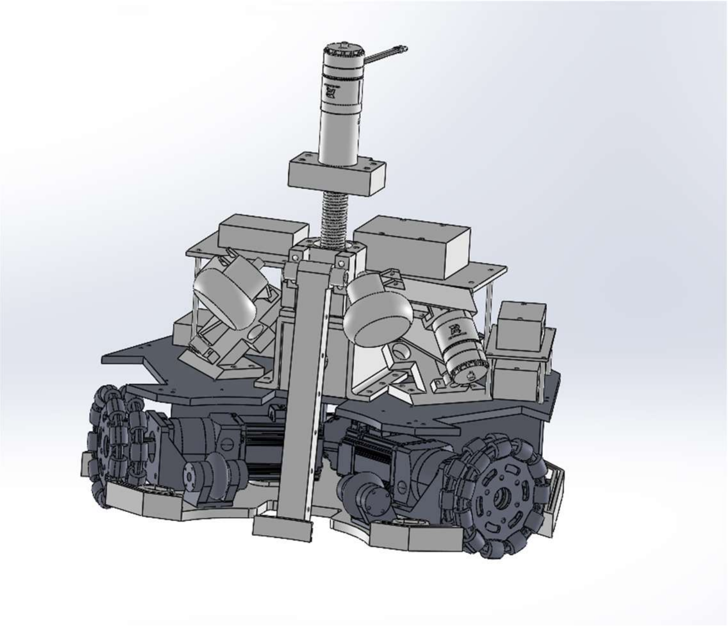


Fig. 2. Ball Suction Device

The device consists of two symmetric components, each including the following parts:

1. Wheels: The wheels are driven by DC motors and are constantly pressed against the soccer ball. By exerting different friction forces on the ball, the wheels can make the ball rotate in the desired direction and speed.
2. DC Motor with Right Angle Reducer: The DC motor is equipped with a right angle reducer to drive the rotation of the wheels. The reducer provides sufficient torque and control capability to ensure effective manipulation of the ball's movement.
3. Linear Displacement Sensor: The linear displacement sensor is installed on the support mechanism to indirectly measure the distance between the robot and the soccer ball. When the ball moves closer to the robot, the support mechanism lifts and stretches the sensor; when the ball moves away, the support mechanism lowers and compresses the sensor.
4. Support Mechanism: The support mechanism is used to support the wheels, DC motors, and linear displacement sensors, ensuring that they can make proper contact with the soccer ball and perform ball control actions. The design of the support mechanism must be sturdy and reliable to ensure the normal operation of the entire system.

Through the collaboration of these components, the ball handling device can achieve precise control of the soccer ball. The closed-loop control system continuously adjusts the speed of the wheels to maintain an appropriate distance and control effect. This design allows the robot soccer player to demonstrate excellent ball control skills in the game, enabling them to participate more effectively and perform various soccer actions.

2.3 Screw Kicking Device

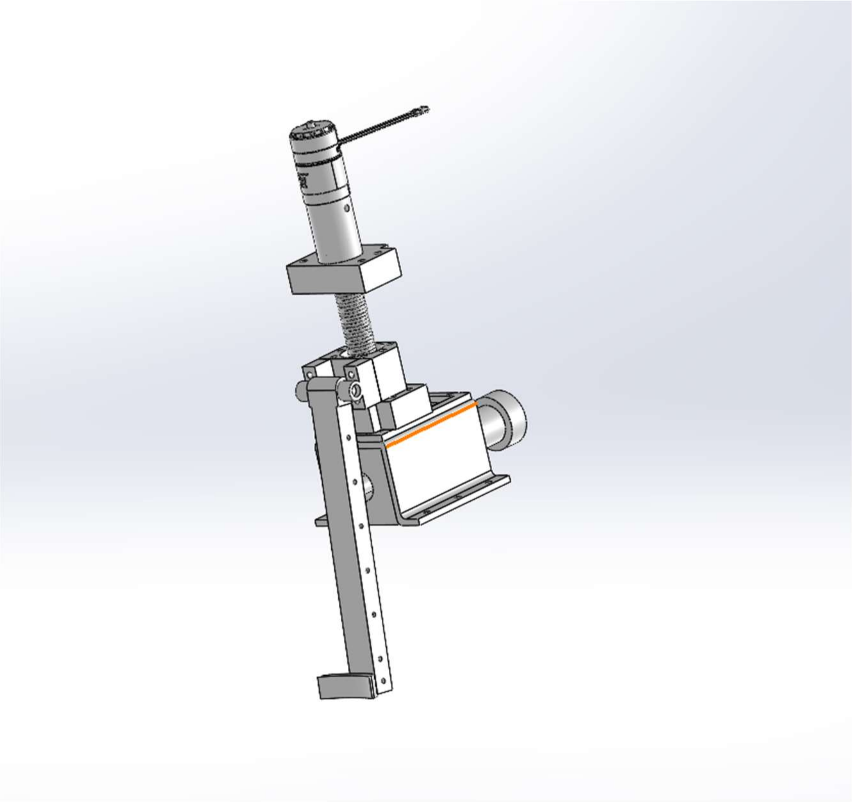


Fig. 3. Screw Kicking Device

The kicking device consists of the following main components:

1. Rod: The rod is the core component of the kicking device, made of high-strength materials. The length and diameter of the rod are designed and adjusted to achieve different strengths and angles of kicking.
2. Motor: The rod is driven by a motor, which rotates to move the rod back and forth, thus performing the kicking action.
3. Ball-contact device: At the end of the rod, there is usually a ball-contact device for contacting and kicking the soccer ball.
4. Control system: The control system of the kicking device controls the rotation of the motor to ensure that the rod kicks the ball with the correct speed and force. The control system is connected to other sensors and decision-making systems of the robot to achieve automated shooting and passing actions.

With such a rod kicking device, robots can accurately and stably shoot and pass the ball.

3 Software System

3. 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.

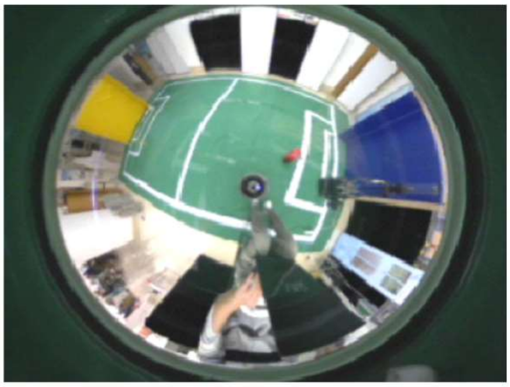


Fig.4 . Before Image Correction

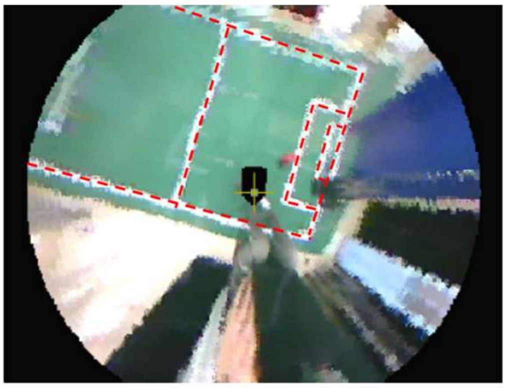


Fig.5 . After Image Correction

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.

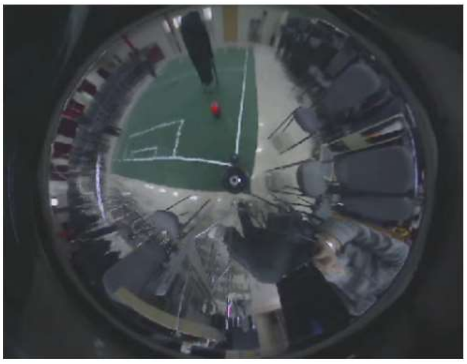


Fig.6. Before Image Binarization

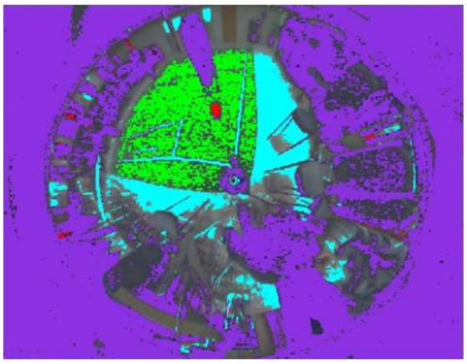


Fig.7. After Image Binarization

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.

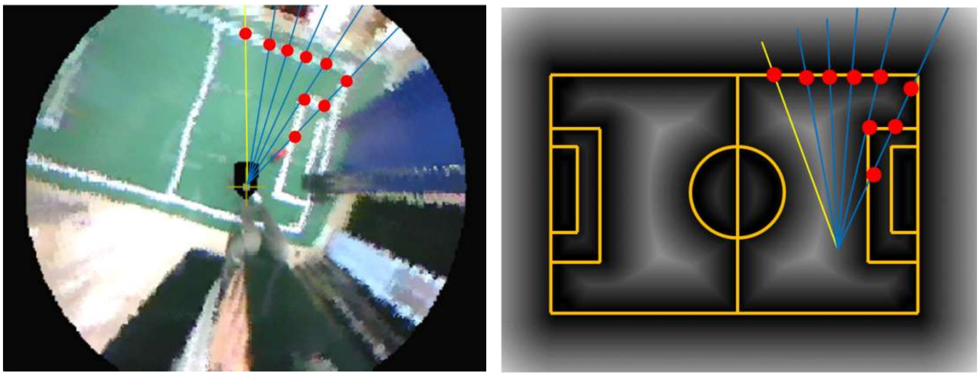


Fig.8. Left：Select A Portion Of The Field Lines For Calculation

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.

3. 2 **Obstacle Avoidance**

Robots use artificial potential field method to avoid obstacles. The specific method is to assume that obstacles exert repulsive force on the robot, while the target point exerts gravitational force on the robot. These two forces are geometrically combined to obtain a combined force that affects the motion trend of the robot. This allows the robot to move away from obstacles and approach the target point, ultimately achieving the effect of obstacle avoidance. The field method is named after this. After continuous potential field processing of the robot's motion process, the robot's motion can be obtained. The motion trajectory is as follows:

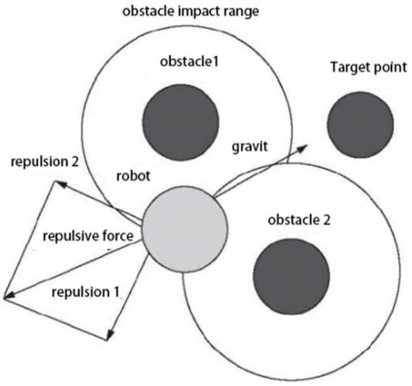


Fig.9. Artificial Potential Field

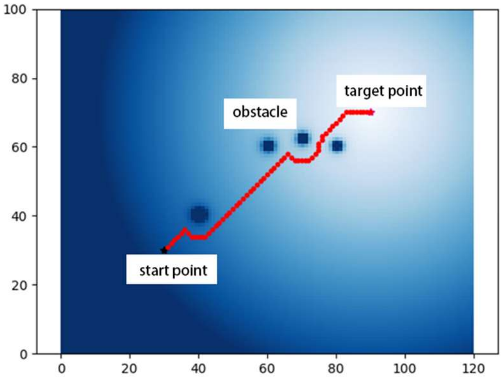


Fig.10. The Final Motion Path Of The Robot

3. 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 break through 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.

3. 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.

4 Research Focus: Multi-robot collaborative technology

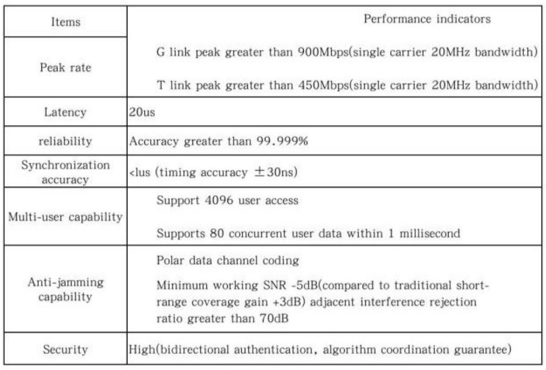
In a multi-robot system, collaboration between robots is crucial. We plan to further develop multi-robot collaborative technology. Enhancing motion planning and control, sensor information fusion, reinforcement learning and adaptive control, fault diagnosis and fault tolerance, and other aspects to improve the collaborative combat capability of robots.

4.1 Developing Collaboration Strategies

Collaboration strategies are crucial. We plan to establish a more comprehensive communication system and consider adopting master-slave, distributed, and other strategies to allocate tasks based on mission requirements and robot capabilities.

4.2 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.



Items	Performance indicators
Peak rate	G link peak greater than 900Mbps(single carrier 20MHz bandwidth) T link peak greater than 450Mbps(single carrier 20MHz bandwidth)
Latency	20us
reliability	Accuracy greater than 99.999%
Synchronization accuracy	<lus (timing accuracy ±30ns)
Multi-user capability	Support 4096 user access Supports 80 concurrent user data within 1 millisecond
Anti-jamming capability	Polar data channel coding Minimum working SNR -5dB(compared to traditional short-range coverage gain +3dB) adjacent interference rejection ratio greater than 70dB
Security	High(bidirectional authentication, algorithm coordination guarantee)

Fig.11. SLB performance evaluation results

4.3 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.

The application of the Random Forest algorithm on player robots is as follows:

1. The robot uploads the detected target set to the coach computer.
2. The coach computer uses the Random Forest algorithm to select the most likely target.
3. The coach computer distributes the information of the most likely target to all robots.
4. The robots use the filtered results as reference values.

4.4 Reinforcement Learning and Adaptive Control

We will apply the Actor-Critic algorithm to player robots, which has many advantages such as online updating to adapt to dynamic environments, handling continuous action spaces, providing value-based feedback signals to improve policy performance, and integrating the advantages of policy gradient methods and value function estimation methods.

The specific implementation method is as follows: The Actor selects actions based on probabilities, and the Critic judges the score of the Actor's actions. The Actor then modifies the probability of selecting actions based on the scores from the Critic.

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