System Composition and Optimization of Small Soccer Robot

Jinhua Du a,*, Shuang Li b, Hang Wang c, Zhaoming Sun d, Gang Du e

School of Information Engineering, China University of Geosciences, Beijing, 100083, China.

*, a Corresponding author e-mail: dujinhua@cugb.edu.cn, b1004181227@cugb.edu.cn, c1004181221@cugb.edu.cn, d1004181107@cugb.edu.cn, edugang@cugb.edu.cn

Abstract. In view of the present intelligent and practicability of the small soccer robot system is still at the lower level, to improve and optimize the small soccer robot system performance, from the visual model to optimize the design of the decision system physical error control three perspective, based on the visual subsystem, decision-making subsystem and physical subsystems through the research of the three subsystems respectively through the model establishment and design improvement strategy is put forward, and USES the SOM simulation software to verify the simulation experiment and data results show that based on visual decision-making and physical three subsystems of the modified method is helpful to improve the overall performance of soccer robot system and intelligent level.

1. Introduction

In recent years, with the in-depth development of the field of artificial intelligence, the problems of multi-robot collaboration and multi-agent systems have received widespread attention.

The soccer robot system integrates image processing, intelligent decision-making, wireless communication, mechanical control and other disciplines, plus RoboCup and other large-scale football competitions to provide an experimental environment, gradually becoming a good experimental carrier for the research of multi-agent systems at home and abroad [1].

The original soccer robot system is a whole have a certain function, but from the point of view of function decomposition, there are still lack of the realization of the function of the individual subsystems. Combining the theoretical research and actual measuring results, in this paper, the shortcomings of existing small soccer robot system, put forward a more comprehensive improvement ideas and methods, in order to overall promote the intelligent level of small soccer robot system.

2. Research Status at Home and Abroad

In terms of vision, the development of parallel computing machine vision [2] and other technologies has improved the speed and accuracy of visual recognition, making the visual system more adaptable and model and accurate analysis of errors significantly improve the motion accuracy of the robot, making the motion of the robot more accurate and reasonable.
3. Problem Model

3.1. Problems and Established Models of Visual Image Recognition

3.1.1. Several difficulties in image recognition. At present, the small soccer robot vision system adopts global vision, which collects and processes the images of the two halves through two cameras suspended on the field to obtain the position information of the robot and the ball on the field [3]. At present, image recognition mainly faces the following difficulties:

- The lighting conditions of the competition environment are uneven and unstable.
- The target object moves fast and has been processed for image recognition.
- The process requirements are high.
- High accuracy is required for the target object to access information.
- The playing field is large but the recognition target is small.
- The image captured by the camera is severely distorted.

In practical applications, the small robot vision subsystem is complex and large, the process is as follows: first of all, through space at the top of the two cameras to collect the image to get the image coordinates. As the decision-making subsystem must gain ground coordinates, need for camera calibration, through the internal and external parameters of camera calibration model to eliminate the distortion caused by the camera lens, so that the image coordinate system and the corresponding ground plane coordinate system, completed two coordinate conversion between Secondly, the collected colors are classified by establishing the index table of different colors in the color space, and the image is segmented according to the index table to find the position of the target block in the image coordinate system. The target robot was identified according to the corresponding relationship between color code and label, and the coordinate transformation relationship calibrated by the camera was used to obtain the position of the robot in the field coordinate system, as shown in Figure 1.

![Visual subsystem work diagram](image)

Fig. 1 Visual subsystem work diagram

3.1.2. Distortion model. The vision system is the main source of information for the entire small foot system. In order to ensure the accurate and stable operation of the entire system, the accuracy of the vision system needs to be improved. During the processing of the vision system, the quality of the camera calibration result directly affects the positioning accuracy of the vision system, and it is necessary to eliminate image distortion during the camera calibration process.

The mathematical model of radial distortion is established based on the camera image distortion. In computer vision research, the machine vision imaging system can be abstracted as small hole imaging, but the actual imaging is not strictly small hole imaging, which will cause distortion and cause image distortion. Common types of distortion there are radial distortion, tangential distortion and eccentric distortion, radial distortion is the main factor affecting the calibration accuracy [4]. Therefore, the model established here only considers radial distortion.
The radial distortion model of the camera is expressed in mathematical formula as follows:

\[
x_u = x_d (1 + k_1 r^2 + k_2 r^4 + \ldots + k_6 r^6)
\]

\[
y_u = y_d (1 + k_1 r^2 + k_2 r^4 + \ldots + k_6 r^6)
\]

Among them are the actual image coordinates of the image point, the coordinates of the image point after distortion correction, the camera distortion parameter, the distortion radius, and the greater the radial distortion at the edge of the image. For ordinary cameras, only the first-order radial distortion \([5]\) is considered, namely:

\[
x_u = x_d (1 + k_1 r^2)
\]

\[
y_u = y_d (1 + k_1 r^2)
\]

When the main point of the camera is located in the center of the image, if only the offset of the main point of the camera is considered, the mathematical model is

\[
x_u = x_d + k_1 r^2(x_d - x_0)
\]

\[
y_u = y_d + k_1 r^2(y_d - y_0)
\]

Where: \(r\) is the distortion radius, and

\[
r = \sqrt{(x_d - x_0)^2 + (y_d - y_0)^2}
\]

3.2. Problems in Multi-machine Scheduling and Coordination Tactics and the Established Model

The main task of the decision-making system is to make offensive and defensive judgments based on the situation on the playing field, assign roles and tasks to each of its robots, and coordinate the cooperation between different robots. Since the information input of the decision-making subsystem comes from processed visual information, the decision-making subsystem can also be regarded as a mapping, which maps a set of digital information to a game state to realize the judgment and processing of the game situation. A good decision-making system should have the following three characteristics: adaptability, real-time and effectiveness, that is, it can respond effectively to the complex and changeable situation on the field within a specified time.

In the original decision-making system, the role of each robot is pre-allocated. In a game, the role and task of the robot are fixed. This static role assignment mechanism limits the flexibility of robots to a large extent, and is not conducive to multi-robot collaboration. In addition, the original decision-making system lacked offensive and defensive judgment and offensive and defensive conversion mechanisms, and could not cope with the complex and changeable game situation on the field.

In this paper, a more dynamic decision-making system is adopted, in accordance with the design idea of hierarchical control \([6]\), and the mathematical model of finite state machine \([7]\) is merged to realize decision-making through decision functions. It consists of a tactical layer, a skill layer and a basic action layer, and it constructs a centralized control system, which uses a global controller to uniformly control multiple robots \([8, 9]\). Among them, the performance and reliability of the entire decision-making system largely depend on the performance and reliability of the decision function, as shown in Figure 2.

![Soccer robot system model](image_url)
3.3. Problems in the Realization of Kinematics and the Established Model

3.3.1. The problem of instability of shooting range. As shown in Table 1, the landing distance under the same hitting force is not stable, and the relationship between hitting force and range is not linear.

| Shooting force F/N | Distance S₁(cm) | Distance S₂(cm) | Distance S₃(cm) | Distance S₄(cm) | Distance S₅(cm) | Distance S₆(cm) | Distance S₇(cm) |
|-------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 10                | 16.6           | 14.3           | 13             | 11.4           | 13             | 12             | 13             |
| 20                | 48             | 48             | 48             | 50             | 43             | 45             | 44             |
| 30                | 125            | 116            | 108            | 110            | 112            | 111            | 118            |
| 40                | 176            | 173            | 168            | 161            | 188            | 180            | 178            |
| 50                | 220            | 221            | 210            | 194            | 184            | 182            | 190            |
| 60                | 205            | 210            | 225            | 193            | 186            | 191            | 208            |
| 70                | 188            | 205            | 213            | 213            | 223            | 232            | 230            |
| 80                | 236            | 206            | 204            | 212            | 188            | 193            | 210            |
| 90                | 190            | 210            | 216            | 208            | 200            | 216            | 230            |
| 100               | 218            | 213            | 209            | 238            | 236            | 214            | 202            |
| 110               | 225            | 226            | 217            | 206            | 205            | 228            | 195            |
| 120               | 211            | 239            | 220            | 210            | 223            | 198            | 215            |
| 127               | 206            | 202            | 221            | 200            | 204            | 201            | 214            |

The basic principle of the soccer robot hitting the ball is to control the strength of the magnetic field by controlling the magnitude of the current released in the capacitor, and then generate different forces through the magnetic conductive material in the magnetic field. On the one hand, the range of the robot is unstable because the magnetic field generated by the energized coil is difficult to be linearly distributed [10], on the other hand, when the current in the capacitor is unstable, the strength of the picking ball is also different [11].

3.3.2. The distance and angle error caused by the posture of the ball. The depth at which the ball cuts into the hitting opening affects the hitting distance. When the distance of the ball cutting into the shot opening is d₁, d₂, d₃, the force of the batting stick acts on the ball at different positions. It may be assumed that the distance of the ball cutting into the shot opening conforms to d₁>d₂>d₃, and α is the elevation angle of the shot. The force of the ball is shown in the figure 3 below:

![Fig. 3 The distance and angle of the ball](image)
The direction of the force is different, and the range of the ball is also different. This problem can be analyzed by establishing a dynamic model.

In addition, the deviation of the ball from the hitting opening affects the angle of the ball's advancement. When the ball deviates from the center of the stick to the left or right (as shown in Figure 6): part of the force will be transformed into the rotation of the ball, and the other part of the force will act on the ball in the original direction. This phenomenon can be circumvented by setting the precision in the code implementation process, and this article will not discuss it, as shown in Figure 4.

![Fig. 4 Deviating from the original direction](image)

3.3.3. Flat shot force control problem. Horizontal shots can be used in both shooting and passing situations: when shooting, the strength of the shot can be directly set to the maximum value; when passing, you need to control the strength of the passing. Too much force will cause the ball to go too fast, which will cause the ball to be too fast. There was a bounce situation after colliding with the ball-catching robot.

4. Algorithm Design

4.1. Visual Recognition Algorithm

4.1.1. The principle of distortion correction. A straight line in space is mapped to a straight line in the perspective projection, but due to camera distortion, the image points of the same line will be in a curve distribution. As shown in Fig. 7, if a radial distortion value is added to the non-distorted image point, the point will have different radial distortion according to different values [12], as shown in Figure 5.

![Fig. 5 Soccer robot system model](image)

Distortion correction based on image processing is basically to achieve two steps: first, camera calibration; Secondly, the distortion coefficient is solved, and the obtained results are used to correct the distortion.
4.1.2. Camera calibration. The imaging process of shooting a space object with a camera is as follows: first, the object in the world coordinate system is transformed into the camera coordinate system by rigid body transformation according to the external parameters of the camera, and then the camera is transformed into the image coordinate system by projection transformation.

Coordinate points are represented in the world coordinate system, and coordinate points are represented in the camera coordinate system. The transformation of the world coordinate system to the camera coordinate system is a rigid body transformation that changes only the spatial position and orientation of the object, not the shape, and is represented by the rotation matrix \( R \) and the translation variable \( t \).

\[
\begin{bmatrix}
    x_c \\
    y_c \\
    z_c \\
\end{bmatrix} = R \begin{bmatrix}
    x_w \\
    y_w \\
    z_w \\
\end{bmatrix} + t
\]

From the camera coordinate system to the image coordinate system, through perspective projection, the coordinate origin is the intersection of the camera’s optical axis and the image coordinate system.

![Camera Coordinate System And Image Coordinate System](image_url)

Fig. 6 Camera Coordinate System And Image Coordinate System

According to the principle of similar triangles

\[
\begin{align*}
    x &= f \frac{x_c}{z_c} \\
    y &= f \frac{y_c}{z_c}
\end{align*}
\]

(6)

In homogeneous coordinates, it's denoted by

\[
\begin{bmatrix}
    x \\
    y \\
    z_c \\
    1
\end{bmatrix} = \begin{bmatrix}
    f & 0 & 0 & 0 \\
    0 & f & 0 & 0 \\
    0 & 0 & 1 & 0 \\
    0 & 0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
    x_c \\
    y_c \\
    z_c \\
    1
\end{bmatrix}
\]

From the image coordinate system to the pixel coordinate system, the pixel coordinate system is in pixels, the coordinate origin is in the upper left corner.
The image coordinates to the pixel coordinate system do not rotate, and the knowledge coordinate origin and units are different.

\[
\begin{align*}
    u &= \frac{x}{dx} + u_0 \\
    v &= \frac{y}{dy} + v_0
\end{align*}
\]  

(8)

In homogeneous coordinates, it's denoted by

\[
\begin{bmatrix}
    u \\
    v \\
    1
\end{bmatrix} =
\begin{bmatrix}
    1 & 0 & u_0 \\
    0 & 1 & v_0 \\
    0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
    x \\
    y \\
    1
\end{bmatrix}
\]  

(9)

The four coordinate systems are transformed into a comprehensive transformation

\[
\begin{bmatrix}
    u \\
    v \\
    1
\end{bmatrix} =
\begin{bmatrix}
    f & 0 & 0 & 0 \\
    0 & f & 0 & 0 \\
    0 & 0 & 1 & 0
\end{bmatrix}
\begin{bmatrix}
    R & t \\
    0' & 1 \\
    Z & 1
\end{bmatrix}
\]  

(10)

4.2. Multi-machine Scheduling Algorithm

Based on the shortcomings of the original decision-making system, this article introduces the improvement plan of the decision-making system from four aspects: offensive and defensive judgment, offensive role assignment [13] [14], passing coordination and defensive strategy design.

4.2.1. Offensive and defensive judgment and offensive role assignment. The main function of offensive and defensive judgment is to decide whether to attack or defend the next stage according to the current situation of the game. It determines the main tone of our main robot movement in the future. On this basis, the role allocation function obtains the best allocation plan through corresponding calculations, and at the same time mobilizes the defense robot to execute the corresponding defense strategy.

Combining the model and experience of live football games, we divided the field into 7 areas as shown in Figure 8. When the ball falls in different areas, our robots will take different countermeasures. Here again, different decision functions can be set according to the universality and pertinence, such as the universal function for determining the left and right half of the field and the targeted function for
determining the 7 regions. This article only describes the implementation of the decision-making system in a certain game situation based on the universal function.

![Site area division](image)

**Fig. 8 Site area division**

The decision-making system first judges the half-court where the ball is located, and then judges the minimum distance between our robot and the ball and the minimum distance between the opponent's robot and the ball. Based on this, the roles and tasks are assigned. The decision-making process is as follows Figure 9.

![Decision-making process](image)

**Fig. 9 The decision-making process in a game situation**

Each scene corresponds to an offensive and defensive tone. Under the corresponding tone, each robot cooperates, passes the ball and shoots to achieve a goal.
4.2.2. Pass match. The passing cooperation between football robots is the top priority of the game. Good passing cooperation can greatly improve the ball control rate of the game and provide opportunity support for shooting goals. The original passing strategy is rigid and rigid. It is from a fixed role to a fixed role, and the passing point is relatively fixed, which is not suitable for a game where the situation changes in real time; and from a long-term point of view, this strategy is not highly scalable and is not suitable later dynamic expansion.

The improved passing strategy is dynamic passing, and the pass receiver is selected according to the distance between the ball and each robot and the current role of each robot. This strategy has been well implemented in the football robot team of Zhejiang University [15]. The improvement strategy of this article refers to some of its ideas.

4.2.3. Defensive strategy design. For the design of robot defense strategy, each robot can be divided into an area to allow them to defend in different areas, or they can be dynamically scheduled to achieve defense according to actual needs. The defense task of the robot is mainly to predict the trajectory of the ball, and move to a specific point in advance to block the ball movement and block the robot's dribbling movement. In addition, in actual games, you can consider allowing multiple robots to form a "wall" in front of the penalty area to cooperate with the goalkeeper to defend. This defensive strategy has strong practicality and has a better defensive effect.

In general, the core of the decision-making system is to coordinate the actions between multiple robots. In the system, each robot has an independent goal, and the overall goal of the robot team is the same. It fully demonstrates individual intelligence and collective intelligence, and unified decision-making is the ultimate goal of a multi-agent system.

4.3. Error Optimization Algorithm

4.3.1. Optimization of the problem of unstable range of the pick-up shot. Assuming that the instant collision time of the ball is $\Delta t$, which is approximately 0.01s, the force of the ball is $F$, the mass of the football is $m$, and the initial velocity of the football after hitting is $v$. According to the momentum theorem:

$$F\Delta t = mv$$  \hspace{1cm} (11)

After decomposing the speed, the horizontal and vertical speeds are:

$$\begin{align*}
  v_x &= v \cos \alpha \\
  v_y &= v \sin \alpha
\end{align*}$$  \hspace{1cm} (12)

Here is only a qualitative analysis, without considering the influence of air resistance, Bernoulli's principle [16], etc., the time of the ball moving in the air is $t$, so the motion equations of the object in the horizontal and vertical directions are obtained:

$$\begin{align*}
  x &= tv_x \\
  y &= H + vt - \frac{1}{2}gt^2
\end{align*}$$  \hspace{1cm} (13)

Here $H$ is the initial height, and the approximate expression of the horizontal range $S$ can be obtained:

$$S = \frac{v[\sin 2\alpha + (\sin^2 2\alpha + \frac{8gH}{v_x^2 \cos^2 \alpha})^{\frac{1}{2}}]}{2g} + \frac{v^2 \sin 2\alpha}{g}$$  \hspace{1cm} (14)

In order to consider the distance of the ball into the shot hole and the error of the electrical level, a correction term and its coefficient are introduced to further obtain the expression of range and $S$ hitting force $F$:

$$F = \frac{m}{\Delta t} \sqrt{\frac{8gH}{\sin 2\alpha}} + O(S)$$  \hspace{1cm} (15)

Among them, $O(S)$ is the correction item, and the actual data is brought in and the following results are obtained using multiple fitting methods [17]. As shown in Table 2.
Table 2. Styles Statistics Table of Fitting Condition of Multiple Correction Items

| O(S)                                         | \( R^2 \) |
|----------------------------------------------|-----------|
| - 0.2596x - 64.50                           | 0.3027    |
| - 24.75ln(x) + 14.96                        | 0.4467    |
| \( 3 \times 10^{-5} x^3 + 5 \times 10^{-7} x^4 - 2 \times 10^{-4} x^3 \) | 0.8175    |
| + 0.0271x^2 - 2.1445x - 18.066               |           |
| \( 7 \times 10^{-7} x^4 - 2 \times 10^{-4} x^3 + 0.0297x^2 - 2.2293x - 17.326 \) | 0.8175    |
| \( 6 \times 10^{-5} x^3 - 0.0142x^2 - 0.0161x - 44.257 \) | 0.7919    |

Among them is \( R^2 \) the goodness of fit. The closer it is to 1, the better the fitting effect. Choose the correction item with the best fitting effect, and finally get the expression of the hitting force \( F \) with respect to the ideal range \( S \):

\[
F(S) = \frac{m}{\Delta t} \sqrt{\frac{Sg}{\sin 2\alpha}} + 7 \times 10^{-7} S^4 - 2 \times 10^{-4} S^3 \\
+ 0.0297S^2 - 2.2293S - 17.326
\]  

(16)

Due to the impact of various temporary factors on the robot system during the game, it is difficult to stabilize the hitting distance of the robot's mouthpiece. In order to improve the accuracy, the correction item can be dynamically adjusted: by continuously retaining the new hitting data as the fitting data, the current correction item is recalculated [18].

4.3.2. Optimizing the problem of flat shots. After experiments, when the football is passed to the football robot with the ball suction switch turned on at a speed not higher than 0.5m/s, the football robot can suck the ball. The dynamic friction coefficient of football field carpet \( \mu \) is close to 0.10 [19].

After the ball is shot horizontally by the robot, it is affected by friction and air resistance on the football field. If the air resistance is approximately zero, there are:

\[
f = umg
\]  

(17)

In order to make the football reach the critical speed of catching the ball at the speed of the robot, the dynamic equation is set:

\[
\left( \frac{F\Delta t}{m} + v_0 \right) \left( \frac{F\Delta t}{m} - v_0 \right) = S
\]  

(18)

Solve the function expression of the hitting force and the target range:

\[
F = \frac{m}{\Delta t} \sqrt{2ugS + v_0^2}
\]  

(19)

5. Simulation

5.1. Experiment Preparation

5.1.1. Experimental platform and experimental data source. In order to verify the optimization of the small football robot system, the SOM-V3.3 platform provided by Suzhou Nanjiang Lebo Robot Co., Ltd. is used for simulation. The hardware environment configuration is: Intel core i5-8300, 2.3GHZ, quad-core, 8G memory. Using SSL_Vision vision software, numerical calculations are carried out with the help of MATLAB.

5.1.2. Parameter settings. The actual field size connected to the experimental platform is 10400mm*7400mm, the robot is a regular cylinder with a diameter of 85mm, and the ball is a standard body with a diameter of 43mm. On the SSL_Vision vision software, the experiment uses a USB3.0 camera with a focal length of \( f = 35 \)mm. The highest resolution: 2592*1944, sensor size: 25.4*63.5mm.
5.2. Experiment 1: Visual Recognition

From the radial distortion model (5), after the first order radial distortion coefficient is obtained, the position coordinates after distortion correction can be obtained, and an objective function is set, which represents the distance between all position coordinates of the image before and after the distortion correction.

\[
d = \sum \left[ (x_u - x_v)^2 + (y_u - y_v)^2 \right]
\]  

(20)

When \(d\) is smaller, it indicates that the distance between the points before and after correction is the smallest, and the correction effect of the first order radial distortion coefficient \(k_1\) corresponding to the value of \(d\) is better.

The algorithm process of solving the first-order distortion parameters by using the dichotomy distortion correction: First, the initial value of \(k_1\) is given as the upper bound \(a\), and generally there is a minimum lower bound order of magnitude \(b = 10^{-8}\) for \(k_1\). According to the algorithm idea of dichotomy, the steps of calculating \(k_1\) are as follows:

- Calculate \(X_u\) from \(\frac{a+b}{2}\);
- \(X_u\) objective function obtained by formula (a)

\[
d = \sum \left[ (x_u - x_v)^2 + (y_u - y_v)^2 \right]
\]

- Plot the obtained \(d\) value into a fitting curve
- Calculate \(k_1\) according to the distance of the \(d\) value from the fitted straight line:
- If \(d\) is farther from the fitted straight line, decrease the value of \(k_1\)

\[
b = k_1, a = a, k_1 = \frac{a+b}{2};
\]

- Near, increase the value of \(k_1\)

\[
b = b, a = k_1, k_1 = \frac{a+b}{2};
\]

- The \(k_1\) corresponding to the smallest or smallest \(d\) value of the final distance fitting straight line distance is the evaluated value.

According to the obtained first-order radial distortion coefficient, the image is corrected. The distortion correction algorithm runs the distortion correction algorithm on MATLAB to obtain the images before and after the football field distortion correction. As shown in Fig.10, the correction effect is good.

![Fig. 10 Before and after correction](image-url)
5.3. Experiment 2: Multi-machine Scheduling

Based on the improvement plan of multi-machine coordination proposed in this paper, the decision-making system is improved. As shown in Table 3: The actual game results show that the improved decision-making system's decision-making ability is significantly enhanced, and the ability to respond to complex and changeable game situations is enhanced, and combined with the improved skill level, better game results can be achieved.

| Years   | Competition Team                     | Result | Net Score |
|---------|---------------------------------------|--------|-----------|
| 2019    | ZJUNlict (improvement): MRL           | 2:0    | 2         |
| 2019    | RoboDragons: MRL                     | 0:1    | -1        |
| 2018    | ZJUNlict (improvement): CMus          | 4:0    | 4         |
| 2018    | ZJUNlict: CMus                       | 1:2    | -1        |

5.4. Experiment 3: Error Optimization

5.4.1. The problem of unstable shooting range. According to the optimization algorithm provided above, the unstable situation of the shooting degree is improved in the actual simulation experiment. Compared with the unimproved data, the situation is shown in Figure 11:

![Fig. 11 Comparison of landing distance after picking the ball model](image)

Obviously, the improved ball picking model has a better simulation effect on the actual test. During the game, the system can dynamically modify the strength of the ball according to this model, thereby improving the accuracy of the ball [20].

5.4.2. The power control problem of the flat shot pass problem. After the introduction of (19) into the model, the collision and bounce of the ball with the robot are greatly reduced, and the soccer robot can effectively receive the ball from teammates. The experimental data is shown in the following figure 12:
6. Conclusion

This article comprehensively proposes a series of system optimization schemes based on the existing research of soccer robots:

- The part of the visual system improves the traditional calibration method of camera internal parameters by establishing a distortion correction model and using algebraic ideas to find the local optimal solution, and improves the computational efficiency.

- The decision-making system part improves the soccer robot's ability to respond to the complex and changeable situation on the field by designing the decision-making function, and thereby improves the overall performance of the decision-making system.

- In the physical simulation part, through the establishment of physical models and analysis of data, a mathematical model for dynamically setting the force of the soccer robot to shoot and flat shoot is established, which innovatively reduces the original hitting error.

The small football robot system is composed of five major subsystems, each of which is closely connected. Starting from the vision subsystem, decision-making subsystem, and physics subsystem, this paper proposes a system optimization plan. However, it does not consider the optimization of the venue subsystem and the wireless communication subsystem, nor does it optimize the coordination between the various subsystems. Starting from two aspects, the performance of the small football robot system is improved by comprehensively improving the system structure.

Acknowledgments

Finally, I would like to thank China university of geosciences (Beijing) technology research and application of project (No. 354711002) and China university of geosciences (Beijing) education innovation fund project (No. 202011415049) support, thank to Professor Yan Hongping for her careful guidance on the optimization process of visual subsystem and thank to the nanjianglebo robot company who provides us hardware and technical support.

References

[1] Hong Bingrong, Han Xuedong, Meng Wei. Research on Robot Football Match[J]. Robot, 2001, 25 (4) :2004-2006.

[2] Chu H,Hu W.Discussion on target recognition and Tracking location of visual robot based on soccer rules.[J] Journal of Baoshan University.2020(02):50-55.

[3] Shu J.Research and design of human vision system for small football robots[D].Hubei University of Technology, Computer Application Technology.2009(5).
[4] Lu Yue, Liu Xuejun, Wang Meizhen, Zhen Yan. Digital-based calculation of camera radial distortion parameters[J]. Geographic Information Science, 2011, 06, pages 18-22.

[5] Xue Bai, Duan Suolin, Zou Ling. Camera parameter calibration considering first-order radial distortion[J] Journal of Changzhou University, 2012, 02, pp. 49-53.

[6] Zhao Fengda, Kong Lingfu, Li Xianshan. Design of Robot Soccer Decision System Based on Hierarchical Structure Model[J]. Journal of Harbin Institute of Technology, 2005, 37 (7) :933-935.

[7] Gaina, Wang Jun, Wang Zhi, et al. Design of a humanoid soccer robot decision system based on a finite state machine [J]. Tool Technology, 2019,53(8):101-104.

[8] Chen Xin, Wu Min, Che Xun. Design and analysis of soccer robot decision-making subsystem[J]. Computing Technology and Automation, 2001, 20 (3) :48-52.

[9] Wang Jicheng, Li Ranran, Xu Tianwei. Research on the Motion Control System of Intelligent Soccer Robot[J]. Green Science and Technology, 2018(22):176-180.

[10] Liu W, Gao Y. Modeling Method of Nonlinear Output Force of Electromagnetic Actuator.[J] Journal of Electrical Machinery and Control. 2020 09 Page 115-125.

[11] Robotics; Investigators from Qufu Normal University Zero in on Robotics (Fuzzy Obstacle Avoidance Optimization of Soccer Robot Based On an Improved Genetic Algorithm) [J]. Journal of Engineering, 2020.

[12] Wang Huiyong. A correction method for radial geometric distortion of imaging measurement image[J] Applied Optics. 2010(01): 55-59.

[13] Li Peng, Li Yongxin, Du Huasheng, et al. Role assignment design of small robots based on play strategy[J]. Automation and Instrumentation, 2006 (3) :16-18.

[14] Ding Chengbo, Cai Jiabin, Liu Wen. Research on an improved method of multi-robot role transformation[J]. Modular Machine Tool and Automatic Processing Technology, 2017(07):9-13.

[15] Chen Z, Zhang H , Guo D , et al. Champion Team Paper: Dynamic Passing-Shooting Algorithm Based on CUDA of The RoboCup SSL 2019 Champion[M]. 2019.

[16] Gardim Fernando G., Giacalone Giuliano, Luzum Matthew, Ollitrault Jean Yves. Effects of initial state fluctuations on the mean transverse momentum[J]. Nuclear Physics A, 2021, 1005.

[17] Mu Zhenghui, Chen Huadong, Li Xu, Huo Ruikun, Li Xiaoge, Xu Lei. Simulation experiment research on distance optimization algorithm[J]. Journal of Transducer Technology, 2020, 33(04):524-528.

[18] Li Guojun, Chen Dongjie, Dong Qifen, Lu Tiantian. Adaptive learning control of nonlinear system with correction term[J]. Information and Control, 2020, 49(03):343-350+364.

[19] Liu Yuping. Application of Computer Aided Analysis Technology in the Calculation of Damping Friction Force——Comment on "Principles of Tribology"[J]. Acta Tribology, 2020, 40(05):688.

[20] Cao Shenglin. Design of soccer robot based on single chip microcomputer[J]. Southern Agricultural Machinery, 2020, 51(06):123.