

Retraction

Retracted: Real-Time Evaluation Algorithm of Human Body Movement in Football Training Robot

Mathematical Problems in Engineering

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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- [1] N. Hu, S. Lin, and J. Cai, "Real-Time Evaluation Algorithm of Human Body Movement in Football Training Robot," *Mathematical Problems in Engineering*, vol. 2021, Article ID 9932737, 9 pages, 2021.

Research Article

Real-Time Evaluation Algorithm of Human Body Movement in Football Training Robot

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As one of the most challenging topics in the field of artificial intelligence, soccer robots are currently an important platform for humanoid robotics research. Its fields cover a wide range of fields, including robotics, artificial intelligence, and automatic control. Kinematics analysis and action planning are the key technologies in the research of humanoid soccer robots and are the basis for realizing basic actions such as walking. This article mainly introduces the real-time evaluation algorithm of human motion in the football training robot. The football robot action evaluation algorithm proposed here designs the angle and wheel speed of the football robot movement through the evaluation of the angular velocity and linear velocity of the center of mass of the robot. The overall system of the imitation human football robot is studied, including the mechanical system design. The design of the leg structure, the decision-making system based on the finite state machine, the robot vision system, and the image segmentation technology are introduced. The experimental results in this article show that the action of the football training robot model is very stable, the static rotation movement time is about 220 ms, and the fixed-point movement error is less than 1 cm, which fully meets the accuracy requirements of the large-space football robot.

1. Introduction

Humanoid soccer robot is an important platform for humanoid robot technology research and an effective way to promote the transformation and industrialization of scientific and technological achievements. Currently, RoboCup and FIRA have developed humanoid robot football games. This project provides a good research platform for humanoid robot technology and multirobot collaboration technology. The humanoid robot football game has good real-time and dynamic characteristics. This not only requires the robot to have a stable and fast walking ability but also requires the robot to complete various complex actions and be able to accurately and real-time identify multiple static and dynamic target environments. In addition, the robot can perform task planning, route planning, and action planning based on the recognition and placement results, which may lead to confrontation with another group through cooperation with team robots.

As the highest form of soccer robots, humanoid soccer robots with multiple moving positions have very important research significance. First of all, it is a key factor in determining the performance of a soccer robot and determines whether the soccer robot can continue to play. Secondly, due to the characteristics of soccer, extremely high requirements are placed on the motion, control, and intelligence of such robots. Therefore, as a concentrated expression of the theory and technology of intelligent robots, this is one of the most representative and obvious manifestations of whether a country has a world-class level in this respect; finally, the development of robots can also drive many related industries and crossovers. The development and progress of technology: if robots can play football like humans, then robots can replace humans in any dangerous, difficult, or even inaccessible place.

Xiong used an artificial intelligence control algorithm to optimize the parameters of the artificial intelligence control algorithm, simulated the control signal output of each

steering part of the wheeled football robot in the experiment, and controlled the steering action of the wheeled football. The experiment verifies the robot using an artificial intelligence control algorithm. However, due to the complexity of the simulation process, the results are not very accurate [1]. Azadeh proposed an integrated algorithm based on fuzzy simulation, fuzzy linear programming (FLP), and fuzzy data envelopment analysis (FDEA) to deal with the layout design of workshop facilities in special circumstances with unclear environmental and health indicators. First, the software package to generate feasible layout alternatives is used, and then quantitative performance indicators were calculated. LP evaluates weights to make pairwise comparisons (through language terms) when evaluating certain qualitative performance indicators. Then, fuzzy simulation is used to model different layout alternatives with uncertain parameters. Next, the impact of environmental and health indicators from the standard questionnaire was retrieved. However, due to the fact that there are too many uncontrollable factors in the parameter evaluation, the results have a large error [2]. Khan explored the usefulness of conditional random fields in the challenging task of head pose estimation through the idea of semantic face segmentation. A multitype face segmentation algorithm based on the conditional random field is implemented, and a model is built for each discrete pose. When a new test image is used as the input of the face segmentation framework, the trained model will predict the probability of each face part. However, establishing the posture model is very difficult, leading to the completion of the experiment beyond the expected time [3].

The first part of this article introduces the concept, origin, and development history of soccer and soccer robots and outlines the purpose and significance of soccer robot research. The second part uses the robot action algorithm to introduce the two basic actions of the robot. In addition, the robot pose evaluation algorithm is used to control and evaluate the robot's pose from the linear velocity and the angular velocity. The third part describes the working mode of the soccer robot and constructs the soccer robot system. In the fourth part, the basic actions, technical actions, combined actions, and tactical actions of the soccer robot are explained in detail, and several typical actions of the microsoccer robot are tested and analyzed. Finally, the soccer robot action evaluation algorithm is analyzed. The fifth part summarizes the action evaluation algorithm of the football training robot and points out the shortcomings of this article and the expectations for future research.

2. Football Training Robot Action Evaluation Algorithm

2.1. Robot Pose Evaluation Algorithm. The posture of the robot refers to the position and direction of the robot in the plane. As a vector, it can control the robot by adjusting the linear velocity and angular velocity of the center of mass of the robot to achieve the effect of adapting to different postures [4].

The pose Q of the robot can be expressed as

$$Q = f(x, y, \theta). \quad (1)$$

The robot in the robot soccer system has two driving wheels, and the pose of the robot in the Cartesian coordinate system can be easily calculated. In addition, the relationships between the linear velocity of the two wheels of the robot and the center of mass and the angular velocity of the center of mass are also demonstrated [5].

Suppose the linear velocity of the left and right wheels of the robot are defined as v_a and v_b , respectively. Then, the linear velocity v_c of the center of mass of the robot is expressed as follows:

$$v_c = \frac{v_a + v_b}{v_c}. \quad (2)$$

If the wheelbase of the two wheels of the robot is R , the angular velocity w_c of the center of mass of the robot is expressed as follows:

$$w_c = \frac{v_a - v_b}{v_c}. \quad (3)$$

2.1.1. Wheel Speed Evaluation. The linear speed of the two wheels of the robot is referred to as the wheel speed of the robot, and their size depends on the speed information of the host [6]. The host computer issues specific wheel speed commands to the robot in a certain format according to the task of the decision, the robot interprets the command as the output of the pulse width modulator, and the motor driver drives the motor according to the output of the PWM [7].

2.1.2. Angle Evaluation. The angle control of the robot can be understood if the rotation gain K_q of the center of mass is the wheel speed of the robot during rotation as follows:

$$\begin{aligned} v_a &= -K_q \cdot \theta_{-e}, \\ v_b &= K_q \cdot \theta_{-e}. \end{aligned} \quad (4)$$

The distance and rotation angle between the robot and the target point are expressed as r_{-e} and θ_{-e} , respectively. Then,

$$\begin{aligned} r_{-e} &= \sqrt{rx^2 + ry^2}, \\ \theta_{-e} &= \theta_{-d} - \theta_{-r}. \end{aligned} \quad (5)$$

If the wheel acceleration of the robot and the angular acceleration of the center of mass are expressed as K_{pd} and K_{pa} , respectively, the robot's pose control is

$$\begin{aligned} v_A &= K_{pd} \cdot r_e - K_{pa} \cdot \theta_e, \\ v_B &= K_{pd} \cdot r_e + K_{pa} \cdot \theta_e. \end{aligned} \quad (6)$$

2.2. Football Robot Action Algorithm. In robot motion, rotation and stable point motion are the two most basic motions. It is mainly divided into the following three steps: the first is the removal of space, that is, the transformation of

the coordinate system; the second is the determination of the movement mode, that is, how to move forward or backward; the third is to determine the wheel speed [8].

- (1) Space movement is mainly realized through the conversion of the coordination platform system and the coordination trolley system [9]. The formula is as follows:

$$\begin{aligned} X &= x \cos(\theta) + y \sin(\theta), \\ Y &= -x \sin(\theta) + y \cos(\theta). \end{aligned} \quad (7)$$

Among them, x, y is the coordinate system of each stage, that is, the coordinate system with the lower-left corner of the field as the coordinate origin. X, Y is a coordinate system with the center of the robot as the origin, and the positive direction of the robot is the coordinate system of the OX axis. The angle between the robot and OX is represented by θ [10].

- (2) The motion mode is divided into rotation judgment and fixed-point direction judgment.

In the rotation determination mode, $\theta < 180^\circ$ means rotating to the right and $\theta \geq 180^\circ$ means rotating to the left, that is, fuzzy rotation and rotation to the target angle in the fastest way [11]. After the test, the average time for this method to rotate at any angle is 240 ms.

According to the different movement modes of the target point in the four quadrants of the target coordinate system, when the rotation is complete, the fixed-point motion is usually a curved motion. This is true linear motion.

- (3) Finally, determine the wheel speed [12]. According to the dynamic principle, the following formula can be obtained:

$$\begin{aligned} V_{dF} &= \omega L, \\ V_L &= \frac{V - V_{dF}}{2}, \\ V_R &= V_L + V_{dF}, \end{aligned} \quad (8)$$

where V is the speed parameter passed by the upper strategy function; V_L, V_R, ω, L have the same meaning as in the algorithm analysis; V_{dF} cylinder is the speed difference between the left and right wheels [13].

According to the model defined in the algorithm analysis, the wheel speed is not difficult to achieve. However, we must consider the initial cycle of the truck and the ever-changing safety distance and use them to determine the final wheel speed [14]. When the speed of the car robot changes, it makes the trolley more expensive to move. Stability is better.

The combination of actions based on the above two main action algorithms can form a robot monitoring algorithm and a receiving algorithm. These two algorithms are not

critical actions and must be combined with predicting the speed and position of the football [15].

2.3. Application of Fuzzy System in the Field of Soccer Robots. Any method of controlling a dynamic system requires knowledge about the controlled system—"model." For the robot system, in addition to the model of the robot itself, it also includes the model of the environment where the robot is located. The robot model can be easily obtained, but the real-time environment model cannot be easily established [16]. While the technology in the field of robotics is booming, many problems remain to be solved:

- (1) Information fusion, including the consistency of sensor information fusion and knowledge extraction, is all affected by different types of uncertain factors [17].
- (2) In the case of limited prior knowledge, such as the obstacle avoidance behavior activated by the robot when facing unpredictable obstacles, robust behavior control is established.
- (3) Coordination of synchronous behavior or competitive behavior, that is, which behavior should be activated in different situations and how to execute the commands of different behaviors, remains an issue to be solved [18].
- (4) Integration of different levels of knowledge, such as knowledge-based planning, includes the problems of uncertainty, unpredictability, and unpredictable measurement. Therefore, the application of fuzzy logic is possible [19].

2.3.1. Fuzzy Control Technology. Fuzzy control belongs to intelligent control. As a kind of intelligent control, fuzzy control is a very active field in automation technology. The basic idea of fuzzy control is to use machines to simulate human control of the system. It is a method of system control using approximate inference opaque controllers according to the fuzzy type of the controlled object [20]. The fuzzy model uses fuzzy language and rules to describe the dynamic characteristics and performance indicators of the system. It does not need to know the mathematical model of the controlled object or process, and it is easy to check uncertain objects and processes. It is a strongly nonlinear object. It has strong resistance to changing the characteristic parameters of the controlled object. Moreover, the interference has the advantages of strong suppression. And, all the decisions of the robot system are ultimately transformed into the realization of the underlying control. Therefore, the robustness, stability, and rapidity of the control are all key issues. In many works in the literature, fuzzy control technology is used to improve the "combat power" of robots based on the characteristics of robot soccer.

2.3.2. Uncertain Expression of Fuzzy Logic. In recent years, intelligent information systems have attracted more and

more attention. Many models of this system are based on first-order predicate logic, which are usually called data reasoning systems. In an uncertain environment, the information provided by the database is often used as input information for decision-making and problem solving [21]. In practical applications, approximate reasoning is usually used to deal with uncertain transactions or inaccurate data. Therefore, the intelligent information system needs to effectively deal with the uncertainty when used in decision-making. This requires the system to be able to simulate human approximate reasoning methods.

The decision-making of the robot soccer system is derived from the analysis of information from different sources. This information is disturbed to varying degrees or has inherent uncertainties. Therefore, an intelligent information system is needed to extract knowledge from this special information database in order to make reasonable decisions and command the operation of the robot soccer system. Fuzzy logic provides a fuzzy mechanism based on nondeterministic data and approximate reasoning using nondeterministic inference rules [22, 23].

2.3.3. Blur Image Processing. In the soccer robot system, the vision subsystem is the main information source of the decision-making system. The accuracy of image collection and the speed of image recognition directly affect the final result of the game. When processing and recognizing images, we must fully consider the characteristics of the image itself and human visual characteristics. The image display process is a mapping process from diversity to unity. The three-dimensional scene is only expressed in the form of levels, which determines that the image itself has many uncertainties; that is, uncertainty and human vision change from black to white. Unclear gray levels are difficult to distinguish accurately. Therefore, vague set theory can be used as a model and method to effectively describe image features and human visual features and can be applied to analyze human crisis, perception, and recognition behaviors [24]. In recent years, in the research of image processing and recognition technology, many students have devoted themselves to introducing fuzzy set theory into image processing and recognition technology and have achieved remarkable results. Experiments show that the processing and recognition technology based on vague set theory are better than traditional methods in some cases, especially when the image is very noisy [24].

3. Football Training Robot Action Evaluation Algorithm Experiment

3.1. Robot Material Selection. Considering the dual requirements of strength and weight reduction, aluminum alloy is mainly used as the body material of the robot, and some parts with low strength requirements, such as the arms and front and rear chest cavity, use carbon fiber materials. Considering the factors of control, torque, and volume, Dynamixel RX-28 high-performance servomotor produced by ROBOTIS of Korea [25] is selected.

RX-28 motor integrates reducer, driver and communication interface, compact structure, and small size and offers strong power output. It has standardized mechanical and electrical interfaces to facilitate system expansion. It adopts a closed-loop position and speed servo control. The encoder can realize real-time feedback monitoring of the action process, with high control accuracy and an angular displacement resolution of 0.3° [26]. With strong customizability, users can customize the attributes of the motor by modifying the system parameters stored in its EPROM area. For example, when multiple motors in the system are connected in series via cables, in order to enable the controller to uniquely identify the motors, each motor can modify the data in the corresponding position in the EPROM area to set its own unique ID number and only need to specify the ID of the receiving motor in the command packet to ensure the correct transmission of the command. Other motor parameters that can be customized include baud rate, rotation angle limit, maximum output torque, and maximum internal operating temperature [27].

3.2. Working Mode of the Robot Soccer System. The robot soccer system basically includes robots, vision systems, computers, and communication systems. The choice of hardware, execution agents, sensors, and software control strategy algorithms is closely related to the overall working mode.

According to the location of the decision-making part, the working mode is divided into the following two types: vision-based robotic soccer system and robot-based robotic soccer system [28].

According to the robot's intelligence, it can be divided into a vision-based remote control nonintelligent robot soccer system, referred to as a remote control robot and a vision-based intelligent robot soccer system [29].

In fact, we got three working modes:

- (1) Nonintelligent robot soccer system based on visual remote control

Generally speaking, each robot in the system has a driver, a communication unit, and a control panel. It can control its movement direction and speed according to the data received from the central computer. Visual data processing, strategic decision, and robot position control are all done on the central computer, just like a remote control car [30].

- (2) Intelligent robot soccer system based on vision

In this system, the robot has functions such as speed control, position control, and automatic obstacle avoidance. The central computer processes countermeasure decisions through optical data and then issues instructions to the robot, and the robot responds to the instructions. In order to avoid automatic obstacles and perform position detection, the robot itself is equipped with sensors.

- (3) Robot-based robot soccer department

In the system, the robot has many autonomous behaviors, and all calculations, including decision-making, are done by the robot itself. The host only processes the visual data and transmits the relevant position and other information to the robot, including one's own party, the other party, and the ball. In fact, the role of the host in processing visual data is equivalent to a sensor [31].

3.3. Football Robot System Structure. From a structural point of view, the centralized control microsoccer robot system can be divided into two parts: the upper computer and the lower computer. Most of the software work of the system is concentrated in the upper computer. The overall structure of the upper computer program system is divided into 6 modules: master control, virtual stadium, vision, strategy, communication, and simulation. The task of the master control is responsible for the process of system initialization, creation of data exchange memory area between modules, task scheduling, time allocation, and system unloading; the virtual arena draws objects on the designated screen position based on the visual feedback data, and in the virtual venue, a memory area is opened for data exchange with the vision or simulator; the simulation module calculates the pose of each object on the field at the next moment according to the command sent by the strategy to the vehicle body and mainly deals with the calculation of the object's trajectory and collision processing; the module completes the pre-processing and real-time identification of information; the decision-making module converts the strategic thinking of the decision-maker into an insinuation relationship from the state space to the action space. The lower computer refers to the walking mechanism of the robot car system, which concentrates most of the hardware workload and is responsible for the control and processing of the robot car. From the perspective of the geographical location of the hardware, the MiroSot football robot system includes four major subsystems: vision subsystem, communication subsystem, trolley subsystem, and decision-making subsystem. The system includes hardware devices: host, vision interface, communication interface, CCD camera, image capture card, communication transceiver, single-chip computer system, drive device, and energy system. The overall framework of the system is shown in Figure 1:

4. Analysis of Action Evaluation Algorithm for Football Training Robot

4.1. Analysis of Football Training Robot Effect. The analysis will be simulated and verified by Matlab. We will compare the kicks after training with the manually adjusted parameters before training, and the experimental results will fully reflect the effectiveness of enhanced learning. For the results of walking optimization, we will compare the effects of the manually adjusted parameters and the optimized parameters and analyze the comparison between the comprehensive parameters of the hierarchical learning and the parameters of each training task. It can be seen how

hierarchical learning can effectively avoid the overfitting characteristics of reinforcement learning and ensure the flexibility, speed, and stability of walking to the greatest extent. Note that we have turned off server noise and visual restrictions when training to play football or walking so that the simulation results of the agent are not affected by the server to produce unnecessary data noise. In the experiment, in order to detect the performance of the robot in the real game, all the experimental structures are the average values of multiple experiments under the noise environment.

Both long shots and kicks used 100 samples per generation, 200 iterations of training, and the penalty value gradually converged. Table 1 shows the comparison of the kicking effect after training and before training.

Figure 2 shows the comparison of the position error and orientation error of the robot before and after the kick. The blue curve represents the position and orientation error before optimization, and the red curve represents the position and orientation error after optimization using the method in this chapter. It can be seen from the figure that after the optimization, the position of the robot basically does not change, and the orientation angle also changes slightly, which shows the effectiveness of this method.

4.2. Analysis of Action Real-Time Evaluation Algorithm

4.2.1. Time Performance Analysis. For the environment where the soccer robot is located, the ICP (iterative closest point) algorithm and the algorithm in this article are used to compare the estimated time of the robot's pose. Randomly select 20 consecutive frames of data from the data frames tested by the test instrument, and the time unit is recorded in seconds. The result is shown in Figure 3.

From the data analysis in the figure, it can be seen that the average time for the ICP algorithm to realize the robot pose estimation is 0.079 s; the average time for the pose estimation proposed in this paper is 0.004 s, which is much shorter than the ICP algorithm in comparison. The difference in the smoothness of the time curves between the two is related to the matching method. If the corresponding point is selected correctly in the ICP algorithm, the matching time will be very short. If the corresponding point is selected incorrectly, the matching time will be very long; the algorithm in this paper only selects obstacles. The central point coordinate feature of the object participates in the calculation, which reduces the amount of data for environmental matching, and the obstacle repetition rate is high, making the pose estimation time relatively short and relatively stable.

4.2.2. Accuracy Performance Analysis. For the environment where the soccer robot is located, the ICP algorithm and the algorithm in this paper are used to compare the accuracy of the estimated values of the robot's pose (x , y , a). Randomly select 10 consecutive frames of data from the data frames tested by the testing instrument, and the results are shown in Figure 4:

From the data in the figure, it can be seen that the maximum deviation of the Y displacement estimation result of the algorithm in this article and the ICP algorithm is 0.3 m,

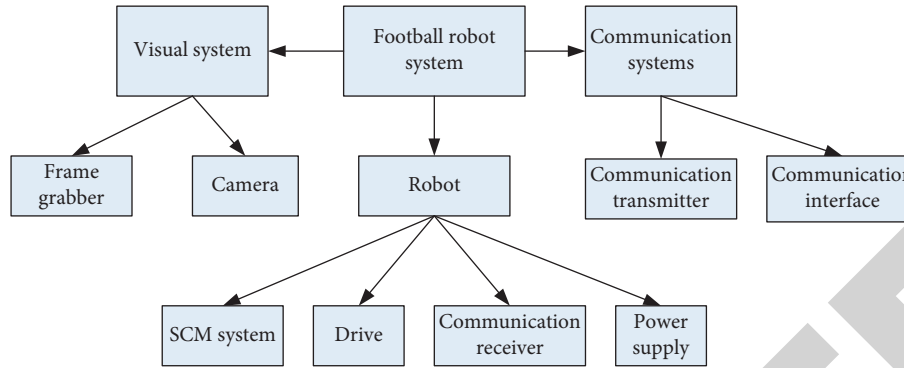


FIGURE 1: Soccer robot system composition.

TABLE 1: Comparison of soccer robot kicking results.

Kick	Average penalty	Average distance (m)	Time (seconds)
Far kick (before training)	-3.6	8.7	2.5
Far kick (after training)	-3.2	14.5	2.5
Quick kick (before training)	2.5	5.5	1.5
Quick kick (after training)	4.8	8.1	0.8

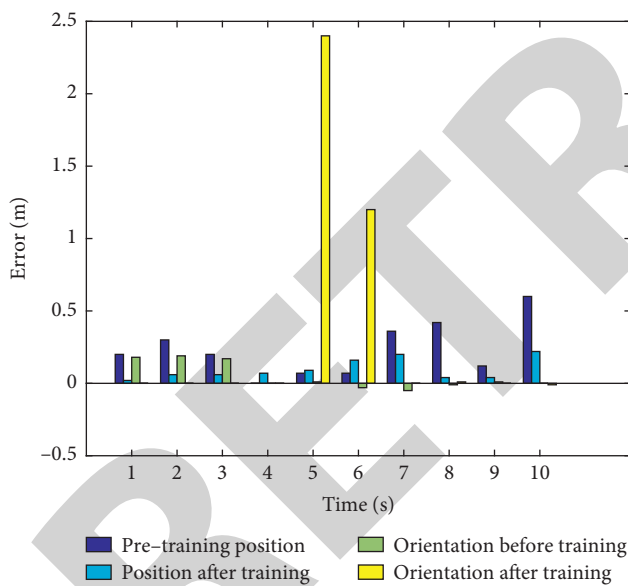


FIGURE 2: Comparison of position and orientation errors.

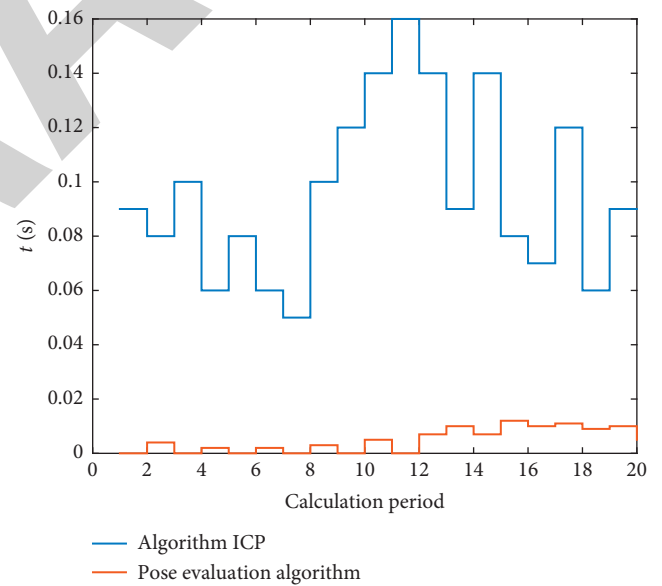


FIGURE 3: Comparison of action pose estimation time.

and the X displacement estimation value appears to be obvious deviation at 6 frames. This is mainly due to the calculation step of the ICP algorithm, $1/15$, resulting in a larger cumulative error. The maximum deviation of an estimated value between the ICP algorithm and the algorithm in this paper is 0.05 rad. The results show that the accuracy of the proposed algorithm is very close to that of the ICP algorithm.

4.3. Analysis of Action Algorithm of Football Training Robot. The SCRAM algorithm is used to optimize the player's position of Nanyou Apollo2D. The state when the offensive

and defensive transition occurs is used as the root node of the Monte Carlo tree model, and the simulation experiment is carried out in combination with the defense strategy under the MCTS algorithm. First of all, in order to eliminate the interference of other factors as much as possible, the experiment selects a known action convergence area and position as the root node of the experiment to reduce the influence of different action choices on the results; second, on this basis, the training method is used to obtain the return value of the evaluation function as the evaluation value of the role assignment under the SCRAM algorithm to evaluate the three algorithms. The experimental results are shown in Figure 5:

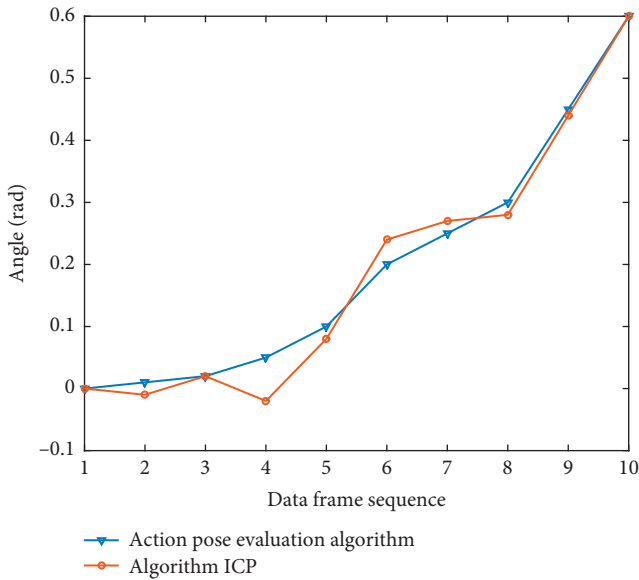


FIGURE 4: Accuracy comparison of an angle component.

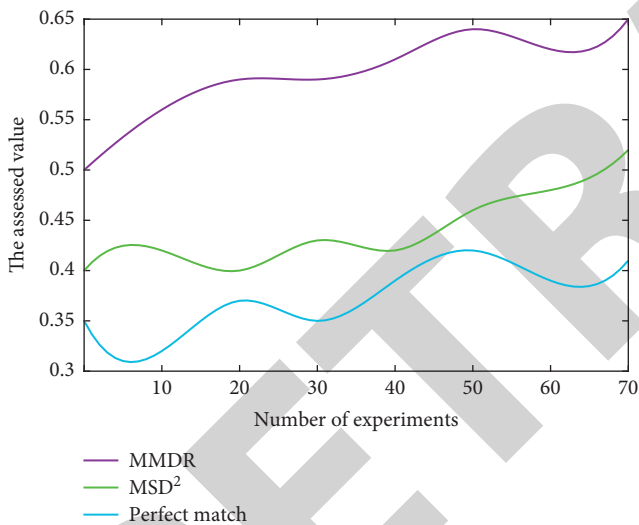


FIGURE 5: The average evaluation value of the algorithm under the fast counterattack.

The abscissa of the chart is the number of experiments, and the ordinate is the average return value during the experiment. We can find that in the actual training process, the performance of the MSD² algorithm, which is the fastest in place, is not satisfactory. Because in this algorithm, in order to ensure the speed, the motion of the agent cannot meet the dynamic consistency, which leads to a certain unreasonable situation in the path allocation. At this time, the player's position may cause certain errors, resulting in a low final return value. The accuracy requirements of the perfect matching algorithm enable the agent to keep running according to the optimal path during the process of returning to the defense. The time problem of a perfect matching in normal defensive tasks can be allowed.

Another defensive case that needs to be specifically put forward is the situation where the opposing player steals the ball to counterattack quickly. Through the game, it was found that when the enemy player steals the ball and quickly scores into our half, our defenders often experience heavy physical exertion and slow return to defense. This is because in this case, the players need to quickly return to our side to defend in order to solve the problem of the enemy's many offensive players and our own defensive players as soon as possible. Therefore, the above evaluation value will no longer apply to this situation. After conducting multiple simulation experiments on this special situation, the result is that in the case of a fast counter-attack, the MSD² algorithm has good adaptability because of its speed advantages.

5. Conclusions

In this article, only kinematics analysis is performed, and dynamics analysis is not performed. The research on robot walking in a stable manner needs to be further deepened. This article has carried out a simple gait planning for a biped robot moving at low speed. The biped robot needs to increase the walking speed of the robot in order to achieve anthropomorphic walking. This puts forward higher requirements for gait planning. At present, the academic community needs further research to confirm whether the proposed gait planning method can meet the requirements of high-speed walking, and the dynamic walking method proposed in this article needs to be further improved.

The development trend of the soccer robot system is a completely autonomous multiagent system. Each robot in the system has many functions and autonomous behaviors. It can observe the situation on the field according to its own eyes, make strategic choices through the strategy library, automatically avoid according to sensor data, and communicate with other robots through the communication system. In other words, all calculations, decisions, and control are done by the robot itself.

Aiming at the pose estimation problem of mobile robots, this article proposes a robot pose estimation algorithm based on the analysis of the advantages and disadvantages of current commonly used estimation methods, combined with the characteristics of the data tested by the tester. Experimental results show that the algorithm can efficiently and accurately realize the pose estimation of mobile robots. However, this algorithm still has a serious problem. When there are obstacles in the environment that cause the lidar to measure the width at different angles, the center coordinate position of the obstacle may change greatly, leading to the position of the algorithm in this article. The pose estimation result is not accurate.

Data Availability

The data underlying the results presented in the study are available within the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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