

# Research and Design of Ball Sports Training Robots

Junshu Chen, Yuran Ye, Jinghong Yao, Mingli Lin, Gui Lin, Jie Xu, Xinkai Li \*

Guilin University of Electronic Technology, Guilin, Guangxi, 541004, China

\* Corresponding author: Xinkai Li

---

**Abstract:** The ball sports training robot belongs to the field of robotics. It can autonomously identify the balls on the field, plan the path, move to the ball's position through an omnidirectional movement chassis, perform the automatic ball retrieval task, and then conduct secondary identification to determine the position of the trainee. It can autonomously adjust the direction and angle of the omnidirectional pan-tilt unit, change the rotational speed of the active roller, thereby adjusting the serving trajectory, and automatically serve the ball. There is no need for manual ball retrieval and serving. It can effectively replace manual practice, with high training efficiency and strong applicability.

**Keywords:** Training Robot; Automatic Recognition; Omnidirectional Motion Chassis; Automatic Ball Retrieval; Omnidirectional Pan-Tilt; Automatic Ball Serving.

---

## 1. Introduction

With the rise of mass sports, the popularity of large ball sports such as basketball, football, and volleyball has continued to increase. Compared to the high cost of human coaching and the short training time, people are more inclined to use machine coaching such as ball-throwing machines; currently, the common coaching machines on the market are mostly ball-throwing machines for various ball types, such as basketball throwers, football throwers, and volleyball throwers. These ball-throwing machines can continuously launch the target balls to the designated positions, and the throwing time and trajectory can be adjusted manually, and they have strong stability and will not have excessive deviation due to long-term operation. However, the biggest drawback of these ball-throwing machines is that they are mostly fixed-type ball-throwing machines, which are not flexible enough, have poor adaptability, cannot frequently change training venues, and will not automatically change the throwing trajectory according to the position of the athlete, but can only launch balls according to the pre-set trajectory. They are suitable for fixed-point training. In addition, these ball-throwing machines only have the function of throwing balls and cannot autonomously retrieve the balls; although most of the ball-throwing machines have certain ball storage capabilities, they also need manual collection of the balls on the ground to replenish the ball source, and the intelligence level needs to be improved. Currently, there is an urgent need for a ball-throwing machine that can achieve autonomous movement, can flexibly adjust the throwing direction and angle, and has a ball-retrieval function to improve the coaching efficiency and reduce manual labor. This article mainly introduces a training robot that can achieve fully automatic ball throwing and ball retrieval and can move freely, with the ability to flexibly adjust the throwing direction and angle, and has a ball-retrieval function to improve the coaching efficiency and reduce manual labor. Compared with traditional ball-throwing machines, this equipment can minimize manual labor to the greatest extent, achieve intelligence and flexibility, reduce costs and increase profits.

## 2. Research Background

Currently, the domestic robot-assisted practice products mainly focus on two types: one is the fixed ball-throwing device, which uses preset programs to achieve single-angle passing but lacks dynamic interaction capabilities and is difficult to meet the needs of tactical training; the other is the new type of intelligent robot that emphasizes interaction capabilities with athletes, autonomously changing the ball-throwing trajectory through algorithm analysis, but has only a single function and can only perform hitting practice, without the functions of picking up the ball or throwing, and this type of robot is relatively rare. Currently, only table tennis, tennis and badminton have corresponding intelligent robot-assisted practice robots. While the ball-assisted practice robot technology in foreign countries has developed rapidly and has formed a relatively mature industrial ecosystem. In terms of technology, robot-assisted practice robots for ball sports, such as the Japanese Omron FORPHEUS, adopt visual tracking and adaptive learning algorithms, which can adjust the ball-throwing strategies in real time according to the trainee's level; tennis robots like Topspin Pro in the United States integrate computer vision and biomechanical analysis to provide professional-level training plans. These devices are generally equipped with core components such as high-speed cameras and precise servo systems, and have a high technical threshold. In contrast, China has currently developed relatively fast in the field of intelligent ball-assisted practice robots, with significant technological breakthroughs, but there is still a certain gap compared to developed countries. Further development of the intelligence, comprehensive functions and interaction capabilities of ball-assisted practice robots is still needed.

## 3. Mechanical Design Development and Innovation

### (1) Overall Design Structure

The ball sports training assistant robot belongs to the field of robotics. It is mainly composed of a omnidirectional pan-tilt device, a laser radar ranging and positioning module, a vision system [3], a ball-receiving and ball-throwing device

[2], and an omnidirectional motion chassis. The omnidirectional pan-tilt structure enables 360° rotation and a certain degree of elevation, which is the key for the assistant robot to flexibly adjust the ball-throwing trajectory. The laser radar ranging and positioning module, the vision system are components of the multi-system positioning device in this project, helping the assistant robot identify the position of the target ball and the target person. The ball-receiving and ball-throwing device consists of a ball-holding frame, a vacuum pump-matched adjustable suction nozzle, and an active roller. It is responsible for the picking up and launching of the target ball. The omnidirectional motion chassis is composed of four McNamara wheels and a metal chassis [1]. The overall structure is shown in Figure 1. The omnidirectional pan-tilt device and the laser radar ranging and positioning module are directly installed on the omnidirectional motion chassis. The pan-tilt and the ball-receiving and ball-throwing device are fixed, and there is a fixed port at the front end of the ball-receiving and ball-throwing device for installing the vision system.

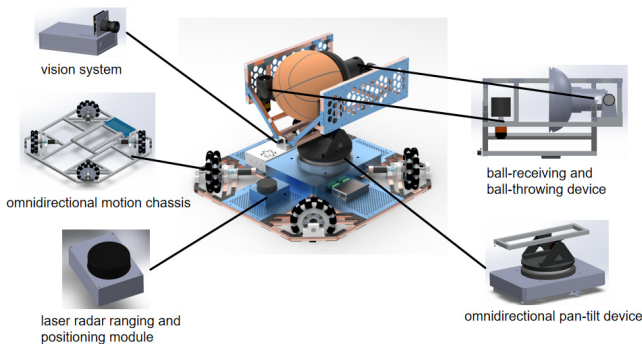


Figure 1. Structure Diagram of the Ball Training Robot

The working process of the ball sports training robot is shown in Figure 2. Firstly, the visual system observes the surrounding environment and identifies the position of the ball [3]. Once the ball is identified, the laser radar begins to detect the distance from the ball and transmits the data to the control system. The control system autonomously plans the path for picking up the ball [5] and controls the omnidirectional motion chassis to execute the path, so that the practice robot can reach the range where the ball can be picked up and align its back towards the ball [4]. At this time, the omnidirectional pan-tilt device is tilted at a certain angle, and the adjustable suction nozzle can rotate under the action of the motor to align with the ball. Then, the vacuum pump starts to evacuate the air in the suction nozzle to create negative pressure, and the ball is adsorbed. Subsequently, the motor rotates again to reset the adjustable suction nozzle to the ball holder [4]. After completing the ball-picking operation, the visual system re-identifies the surrounding environment to determine the position of the performer [3], and the laser radar begins to detect the distance from the performer. After that, it uses the positioning module to determine its own position and establish a coordinate system. The control system autonomously analyzes and plans the parabolic trajectory of the ball [5], controls the adjustment of the omnidirectional pan-tilt device to adjust the direction and angle of the ball-throwing, and then adjusts the rotational speed of the active roller. After the adjustment is completed, the vacuum pump releases the pressure, allowing the ball to fall out of the adjustable suction nozzle and roll along the ball holder to the position of the active roller, where it comes into contact and gains power to launch [4]. The maximum throwing height can reach 5.5 meters, and it can throw 9 balls per minute.

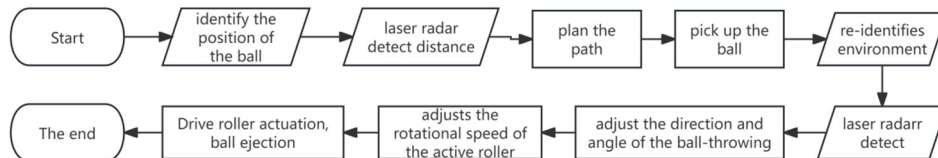


Figure 2. Workflow Diagram of Ball-Type Training Robot

## (2) Technological Innovation

### 1) Omnidirectional motion chassis

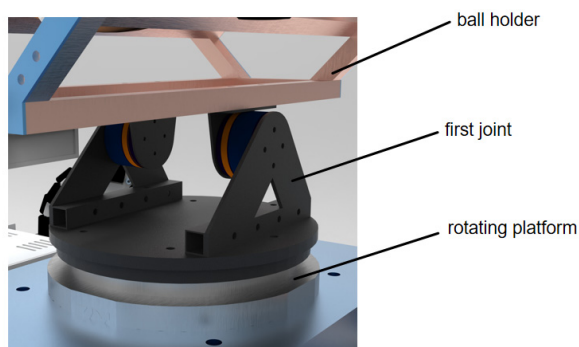
The omnidirectional motion chassis consists of the chassis frame, McNamur wheel set, and the drive motor [1]. The chassis frame serves as the main body of the robot, with four drive motors connected to four McNaum wheels, which are placed at a 45° angle relative to the horizontal and are positioned on the chassis frame. The drive motors jointly control the rotational speed and steering of the four wheels, enabling the robot to freely move in any direction, including forward, backward, diagonal, and 360° rotation on the spot, thereby enhancing the flexibility of the robot. At the same time, the McNaum wheel set, in conjunction with the low center of gravity frame design, can improve the stability and adaptability during high-speed steering and small-radius obstacle avoidance.

The use of the McNaum wheel set allows the robot to freely move, enabling it to autonomously choose the serving position like a real coach, thereby adjusting the athlete's movement state, making each serve not limited to a fixed position, and making the training more diverse. At the same

time, it eliminates the dependence of traditional equipment on the venue, truly achieving the improvement of venue adaptability and the flexibility of the main body. Moreover, compared to the conventional motion chassis with a large turning radius and no translational ability, the omnidirectional motion chassis can achieve rapid turning and the ability to freely translate.

### 2) Omnidirectional Pan-tilt Device

The omnidirectional pan-tilt device consists of a vertically rotating platform, a first joint, and a ball holder. The platform is installed on the moving base and can be rotated by a motor; the first joint can rotate up and down, and its lower end is fixed to the platform, while the upper end is connected to the ball holder, allowing the ball holder to rotate up and down with the first joint, and then the entire device rotates together with the pan-tilt platform, featuring two degrees of freedom, achieving the effect of freely adjusting the direction and angle of the serve, thereby enhancing the flexibility of the serve. As shown in Figure 3.



**Figure 3.** Structure Diagram of Omnidirectional Pan-tilt Device

Compared with traditional ball-throwing machines, the use of the omnidirectional pan-tilt system eliminates the need to fix the robot at a specific position for throwing, allowing the training to throw the ball from any position at the receiving area or elsewhere. Moreover, it can adjust the throwing angle at any time to achieve diverse throwing trajectories, such as simulating the long pass in the middle of a basketball court, or replicating the high-arc and large-angled throw required for a corner kick in football.

### 3) Ball-receiving and ball-throwing device

The ball-receiving [2] and ball-throwing device consists of a negative pressure ball-retrieval mechanism, a friction-wheel type serving mechanism, and a ball-holding frame. Both are fixed to the ball-holding frame and the frame serves as the guiding channel. When the ball-retrieval device releases the ball, the ball can move from the ball-retrieval mechanism to the serving mechanism, performing a continuous ball-retrieval and serving action.

The negative pressure ball-retrieval mechanism is composed of a vacuum pump and an adjustable suction nozzle [2]. The vacuum pump can generate strong negative pressure, even when dealing with large mass balls such as basketballs, and can provide sufficient suction force. The adjustable suction nozzle is soft in texture and has extensibility, capable of adapting to balls of different sizes and materials. Its flexible edge and pressure sensor can prevent the ball from getting stuck or damaged. There is an open area on the suction nozzle that partially covers the surface of the ball, connected to the negative pressure source through a pipeline, for stable adsorption of the ball.

The active roller type serving device drives the ball to be launched through the high-speed rotation of the active rollers. Two motors are arranged in opposite directions to drive the active rollers, with parallel rotation axes and opposite rotation directions. Friction force is used to impart an initial velocity to the ball, allowing the adjustment of the rotational speed of the two rollers to control the rotation and initial velocity of

the ball. The difference in rotational speed can also be used to project side-rotating balls.

## 4. Conclusion

The ball sports training robot is ingeniously designed. The omnidirectional movement chassis can move flexibly according to the position of the ball. The omnidirectional pan-tilt device achieves adjustable directions and angles of the serve through the collaboration of the turntable and the pitch joint. The integrated negative pressure ball-attaching device uses a vacuum pump and adjustable suction nozzles to stably attach different balls. The active roller serving device realizes multiple speeds and types of serving by means of the high-speed rotation of the active roller. The four parts cooperate and work together to achieve the training functions of flexible ball picking and serving. At the same time, the entire practice process is automatically completed, which can be flexibly adjusted according to the different training needs of the athletes, greatly improving the practice efficiency, releasing manpower, enhancing the training effect, and thereby increasing economic benefits. Therefore, such a machine is still of great design significance and promotion potential.

## Acknowledgments

Fund Project: National-level College Students' Innovation and Entrepreneurship Training Project "Application and Promotion of Large-Scale Ball Sports Training Robot" (Project Number: 202510595105X).

## References

- [1] Ao, W., Zhang, L., Zhang, H., et al. (2023). Structure design and event-triggered control of a modular omnidirectional mobile chassis of life support robotics. *Fractal and Fractional*, 7(2), 121. <https://doi.org/10.3390/fractalfract7020121>.
- [2] Mei, Z., Li, Y., Zhu, R., et al. (2025). Intelligent fruit localization and grasping method based on YOLO VX model and 3D vision. *Agriculture*, 15(14), 1508. <https://doi.org/10.3390/agriculture15141508>.
- [3] Peng, Y., Wang, Z., Zhang, Y., et al. (2026). RobKiNet: Robotic Kinematics Informed Neural Network for Optimal Robot Configuration Prediction. *Robotics and Autonomous Systems*, 105541. <https://doi.org/10.1016/j.robot.2026.105541>.
- [4] Li, J., Li, M., & Li, H. (2026). Adaptive Exploration Proximal Policy Optimization for Efficient Robotic Continuous Control. *Symmetry*, 18(5), 717. <https://doi.org/10.3390/sym18050717>.
- [5] Huang, J., Luo, J., Wang, G., et al. (2026). A fast path planning method based on obstacle vertex information. *Ocean Engineering*, 361, 126172. <https://doi.org/10.1016/j.oceaneng.2026.126172>.