ISSN 2618-1576 Vol. 6, Issue 3: 80-85, DOI: 10.25236/FSR.2024.060310

Review on Robotic Application in the Field of Sports

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Abstract: *With the updating of computer processing capabilities and the deep learning network models, artificial intelligence technology based on computer software and hardware has developed rapidly. As a physical carrier of artificial intelligence technology, robots, as a comprehensive technology that integrates multiple disciplines, have also rapidly developed and applied in multiple fields. Meanwhile, sports science studies are no longer limited to the study of sports and training, gradually introducing engineering techniques. This improves the traditional sports moving towards smart sports and increases the fun of physical education. By consulting literature and materials, this paper reviews the application of robots in the field of sports and lists some common robot cases. In addition, the robot technology of different sports projects is analysed and the relative positive significance for each sports project is explained. Finally, a summary and suggestions for the future trends were provided.*

Keywords: *Interdiscipline; Information technology; Intelligence science; Robotic application; Sport*

1. Introduction

A recognized fact is that life lies in healthy exercise. Sports carry the dream of national prosperity and national rejuvenation, and the self-reliance and self-improvement of technology is an important strategic support for national development. Currently, the integration, collaboration, and innovation of sports and technology are accelerating, and digital and intelligent means have become an important part of promoting national fitness and high-quality development of the sports industry. The effective combination of artificial intelligence and sports can promote more possibilities [1]. Chinese association for artificial intelligence (CAAI) has a branch organization which is robot culture and art professional committee. It has become one of the largest academic organizations in China that combines robotics, artificial intelligence, and cultural arts research. The research areas of the special committee mainly include the application of robots in industries such as education, sports, art, entertainment, and services, as well as service robot related directions such as multi-agent robot collaboration and robot emotional interaction [2].

Robots are carriers of embodied intelligence which represents the latest technology [3]. Introduction robots into sports increase the entertainment value [4]. Consequently, we conduct research on literatures in recent years and list some robot applications for ball sports. Additionally, other sport robots are described and analyzed. The researches refer to ball hitting using robot arm, ball detection and recognition, ball trajectory estimation, athlete detection and behavior prediction, sport injury prevention and so on.

2. Various Technologies of Robotics in Sports

2.1. Table Tennis Robots in Sports

The robotic table tennis is a research hotspot because of the introduction of imaging processing technique and robot control theory. These tasks need accurate control of the fast moved robot arm and precise state estimation of the flying ball. Tebble et.al. [5] designed a robot which used an industrial KUKA Agilus R900 and four cameras to play table tennis with human beings. Figure 1(a) shows the 6 DOF robot system which combines color and background threshold to predict the ball's trajectory using curve fitting and extended Kalman filter. The experimental results indicate that 87% hitting rate is achieved based on the fifty consequential strokes. Büchler et.al. [6] proposed to employ reinforcement learning to learn the control skills from data, in addition, they used hybrid sim and real training procedure to avoid training with real balls. A practically tested scene is shown in figure 1(b), a ballgun launches

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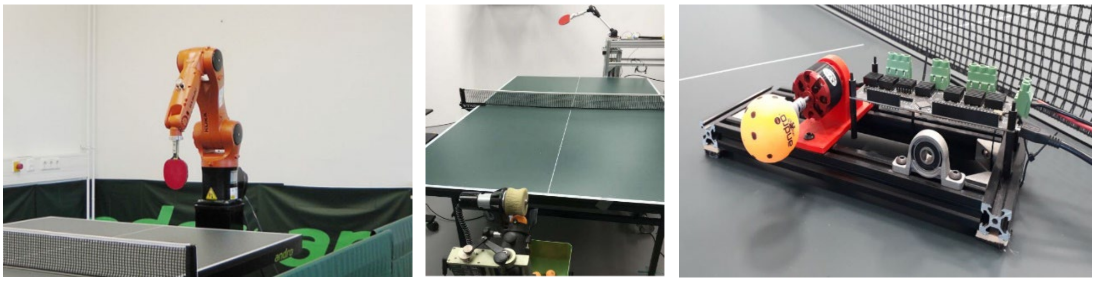
balls directed to the 4 DoF robot arm.



(a) (b) (c)

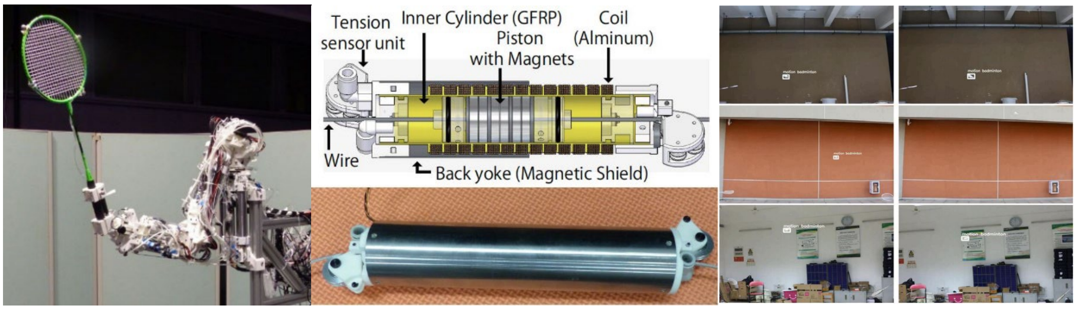
Figure 1: Table tennis robots in sports.

Traditional table tennis robots ignore the spin of the ball that limits the capabilities of the robots. Gossard et.al. [7] proposed a method which is SpinDOE to estimate the ball spin. They used a CNN dot detector to generate a dot heatmap, then utilized the blob detection to estimate the dot's position. The dot's ID was generated by using Bayesian geometric hashing. The quaternion of the ball orientation was achieved through Kabsch algorithm. Figure 1(c) shows the ball spinner which is a designed equipment to generate the training data. In order to accurately represent the flying state of a table tennis ball, Wang et.al. proposed a generalized aerodynamic model with variable aerodynamic coefficients [8]. Sun et.al. [9] proposed to compute the ball-racket rebounds in the vertical and horizontal directions. They used Kelvin-Voigt model to analyze the collision dynamics to indicate that the contact time is not relative to the incoming ball's velocity. In addition, the restitution coefficient varies based on the incident velocity. Thus, the accuracy of the ball's linear and angular velocities will be improved.

2.2. Badminton Robotics in Sports

Another dynamic ball sport that needs high accuracy is badminton. Due to the lightweight of the shuttle and racket, the agility of badminton sport is essential. Many badminton robots are designed to play games with human athletes. Mori et.al. [10] designed the pneumatic-electric hybrid actuators to simulate high speed humanoid robot arm which is shown in figure 2(a). The mechanism and prototype of the pneumatic-electric hybrid actuators is shown in figure 2(b). This research focuses on the flexibility and rapid response of the robotic arm part.

The shuttlecock detection is also an important task for a badminton robot that refers to the accuracy and computational efficiency. When the visual system detects the shuttlecock, a trajectory is fitted and the ball is hit to the opponent by the moving robot. Cao et.al. [11] proposed a detection approach based on the deep learning network which is YOLO series model. They firstly capture images by using a ZED binocular camera, then extract 2D featured points using shuttlecock detector which is a trained neural network model. Finally, the 3D trajectory of the shuttlecock is estimated utilizing trajectory reconstruction method. The detected results in different contexts are shown in figure 3(c).



(a) (b) (c)

Figure 2: Badminton robots in sports.

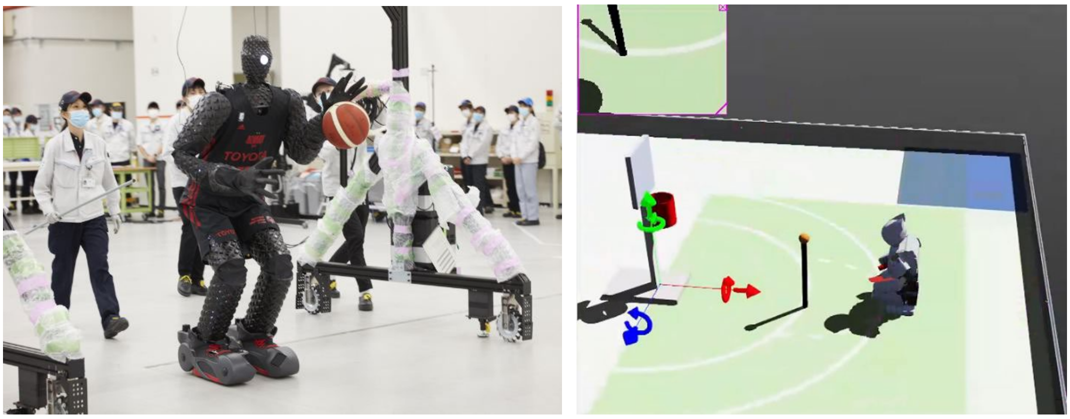
To prevent player injuries, Xie et.al. [12] designed an intelligent badminton training robot which employes machine learning approach to recognize the movement of the athletes. They improve the hidden Markov model to achieve a high recognition ratio and enhance the performance of the pitching motion. Ye et.al. [13] proposed a shuttlecock aerodynamic model to simulate the gravity and air resistance, then combined the convolution neural network with ordinal processing method to recognize the shuttlecock. They also improved the single shot multibox detector model (SSD) and achieved a higher

ISSN 2618-1576 Vol. 6, Issue 3: 80-85, DOI: 10.25236/FSR.2024.060310

accuracy than original SSD and the faster region convolutional model (Faster-RCNN).

2.3. Basketball Robots in Sports

As one of the most popular sports in the world, basketball sport has sufficient fun and sportiness. Some high-tech companies are also participating in related research, for example, the basketball robot developed by Toyota Motor Company has a high successful shooting rate [14,15]. The basketball robot named Cue is shown in figure 3(a) and has a humanoid appearance. Zhang et.al. [16] proposed to use a unified architecture to learn shooting strategies. Firstly, a multi-modal perception system using multi-head attention is used for a whole perception of the basketball scenario. Then, a deep Q-network based reinforcement learning approach is used to learn shoot strategies. Finally, an end-to-end architecture integrates these parts and make decision processes.



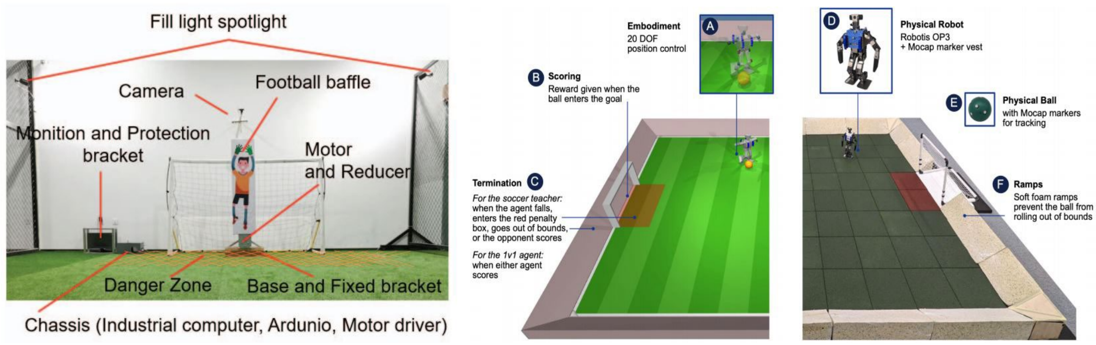
(a) *(b)*

Figure 3: Basketball robots in sports.

A double deep Q-learning network framework is proposed to train the humanoid robot to master shoot skills in basketball sport [17]. The simulated environment and task are shown in figure 3(b) where the robot achieves images from the around and then decides the motion direction. Rochim et.al. [18] proposed to use parabolic motion trajectory. They utilize Arduino microcontroller to control the movement of basketball throwing motion. Shi et.al [19] proposed to employ multi-sensor data fusion for fuzzy dynamic obstacle avoidance. Through data transmission and image processing, the basketball robot can recognize the target and avoid collisions.

2.4. Football Robots in Sports

Football is one of the most popular ball games in the world, with over 3.5 billion fans worldwide. This exciting ball game has gained a large following due to its thrilling gameplay and fast-paced movements. Tian et.al. [20] designed a football goalkeeper robot as shown in figure 4(a). The robot utilizes an RGB-D camera to capture images that each pixel has depth information along with the color value. The football is detected and located by using a deep learning model which is modified based on Yolov3-tiny network [21]. A fuzzy logic control method is utilized to predict the hitting points and an improved PID method is employed to prevent the entering crossbar motion.



(a) *(b)*

Figure 4: Football robots in sports.

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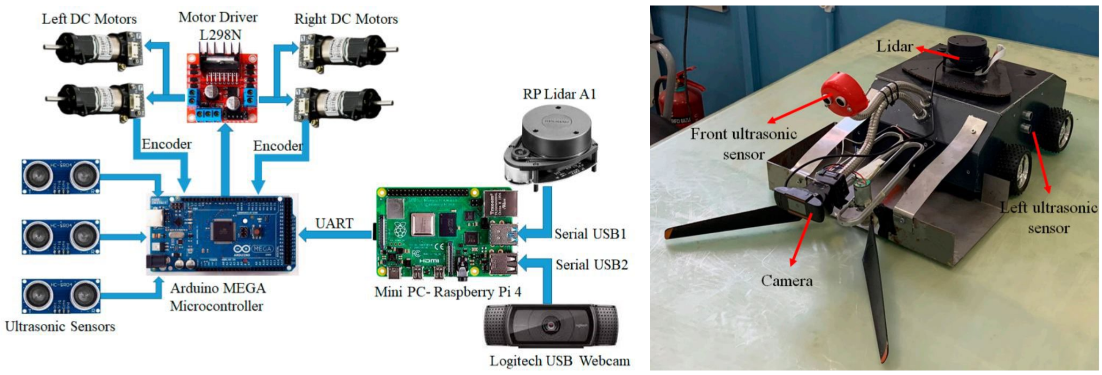
Liu et.al. found that the learning-based methods are useful for complex movement, multi-agent coordination and long-term planning [22]. They trained physically simulated agents to play football in virtual environment. Zhou et.al. proposed to use deep learning approaches to help strength training for football players. In addition, the visual detection of field line for football robots is also an interesting application [23]. Haarnoja et.al. utilized deep reinforcement learning model to help a bipedal robot to learn agile soccer skills [24]. The members are mainly come from Google DeepMind team and some famous universities. Figure 4(b) shows the simulated and real soccer environment for the soccer robot which has 20 actuated joints. The skills are trained in playing a one-to-one football game in simulated environment and then transferred to real field.

2.5. Other Robots in Ball Categories Sports

Wang et.al. used a self-attention scheme to process information from different sensors and the technology is used to control a volleyball robot precisely [25]. Latifinavid et.al. designed a tennis ball collection robot which can detect the balls on the ground and then move to collect them using fuzzy logic algorithm [26]. Figure 5(a) shows the hardware modules of the mobile robot and figure 5(b) is the physical prototype. In fact, there are other ball categories robots which are being researched and designed.



(a) *(b)*

Figure 5: Tennis ball detection and collection robot.

3. Other Applications of Robots in the Field of Sports

In the 2022 Winter Olympics, we saw that robots can serve, protect, and help people excel in many aspects of their lives [27]. With the rapid development of artificial intelligence, the new technologies are used in the virtual and real soccer robots. Actually, the robot world cup (RoboCup) was started as early as the year 1997. From 2018, an AI World Cup has been founded and figure 6(a) shows an AI Soccer game which is displayed in a simulation [28]. When the soccer robots are matching with each other, an AI commentator observes the match and gives real-time commentary. In the meanwhile, an AI reporter gives a summary article. In addition, the robot news reporter used in sports news or events is not a novelty anymore [29].

(a) *(b)*

Figure 6: Other robots in sports.

In the robot-aided sports rehabilitation training filed, there are also many researches and applications. Tsai et.al. designed a lower limb rehabilitation system by using a pneumatic artificial muscle structure

ISSN 2618-1576 Vol. 6, Issue 3: 80-85, DOI: 10.25236/FSR.2024.060310

which had hip joint and knee joint [30]. The 2-DOF bionic structure is shown in figure 6(b). As an Olympic sport, fencing which uses a bladed weapon is popular for young people. To model a fencing robot used for training, Harfoush et.al. used Kinect camera to capture the motions of fencing athlete and ANN to make the robot arm intelligent [31]. In Pyeongchang Winter Olympics, a Skiing Robot Competition was held that robots entered into the skiing field. Park et.al. proposed to utilize ZMP control approach and deep learning vision recognition model to achieve carved turn motion [32].

4. Conclusion and Suggestion

With the development of artificial intelligence, machine learning, computer vision and intelligent sensors techniques, robotics research is popular in many fields such as sport. The robots act as practice partners for professional players or competitive team members in sports events. The shape of the robots may be humanoid, wheeled, flying or with fixed position. Most of the applications are ball sports that the robots mimic human's motion and showing intelligence like a human. In the meanwhile, other sports related robots are designed and applicated.

Consequently, the research and teaching work of sports majors should shift from traditional methods to an era of interdisciplinary integration. High tech sports equipment and instruments need to be introduced into physical education and training. These not only enhance more scientific of sports training, but also increase its fun. Students with interdisciplinary knowledge will open their minds and develop better in their future career development.

Acknowledgements

This paper is supported by the First-class Curriculum Cultivation Project of Zunyi Normal University in 2023, (JKPY2023012), the Labor Education Curriculum Construction Project of Zunyi Normal University in 2023, (TSKC2023006) and the Ordinary Undergraduate Universities Research Project (Youth Project) of Guizhou Provincial Department of Education in 2023, (QJJ [2022] No.322).

References

[1] A. Liu, R.P. Mahapatra, A.V.R. Mayuri. Hybrid design for sports data visualization using AI and big data analytics [J]. Complex & Intelligent Systems, 2023, 9(3): 2969-2980.

[2] M.S. Yasar, T. Iqbal. A scalable approach to predict multi-agent motion for human-robot collaboration [J]. IEEE Robotics and Automation Letters, 2021, 6(2): 1686-1693.

[3] R. Whall, C.A. Palmer. Developing an intelligent body–what does it mean to be physically educated? [J]. Journal of Qualitative Research in Sports Studies, 2021, 15(1): 77-104.

[4] L. Xu. Application analysis of sports robots based on pose recognition and action feature analysis [J]. International Journal of System Assurance Engineering and Management, 2023, 14(2): 519-528.

[5] J. Tebbe, Y. Gao, M. Sastre-Rienietz, et al. A table tennis robot system using an industrial kuka robot arm[C]//Pattern Recognition: 40th German Conference, GCPR 2018, Stuttgart, Germany, October 9-12, 2018, Proceedings 40. Springer International Publishing, 2019: 33-45.

[6] D. Büchler, S. Guist, R. Calandra, et al. Learning to play table tennis from scratch using muscular robots [J]. IEEE Transactions on Robotics, 2022, 38(6): 3850-3860.

[7] Gossard T, Tebbe J, Ziegler A, et al. SpinDOE: A ball spin estimation method for table tennis robot[C]//2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2023: 5744-5750.

[8] Y. Wang, Z. Sun, Y. Luo, et al. A Novel Trajectory-Based Ball Spin Estimation Method for Table Tennis Robot[J]. IEEE Transactions on Industrial Electronics, 2023:1-11.

[9] Y. Sun, Y. Wang, C. Qu, et al. A novel ball-racket rebound model for table tennis robot based on continuous contact force[J]. IEEE Transactions on Instrumentation and Measurement, 2024.

[10] S. Mori, K. Tanaka, S. Nishikawa, et al. High-speed humanoid robot arm for badminton using pneumatic-electric hybrid actuators[J]. IEEE Robotics and Automation Letters, 2019, 4(4): 3601-3608.

[11] Z. Cao, T. Liao, W. Song, et al. Detecting the shuttlecock for a badminton robot: A YOLO based approach [J]. Expert Systems with Applications, 2021, 164: 113833.

[12] J. Xie, G. Chen, S. Liu. Intelligent badminton training robot in athlete injury prevention under machine learning[J]. Frontiers in neurorobotics, 2021, 15: 621196.

[13] H. Ye. Intelligent Image Processing Technology for Badminton Robot under Machine Vision of Internet of Things[J]. International Journal of Humanoid Robotics, 2023, 20(06): 2250018.

ISSN 2618-1576 Vol. 6, Issue 3: 80-85, DOI: 10.25236/FSR.2024.060310

[14] Narayanan A, Desai F, Stewart T, et al. Application of raw accelerometer data and machine-learning techniques to characterize human movement behavior: a systematic scoping review[J]. Journal of Physical Activity and Health, 2020, 17(3): 360-383.
[15] T. Xu, L. Tang. Adoption of machine learning algorithm-based intelligent basketball training robot in athlete injury prevention[J]. Frontiers in Neurorobotics, 2021, 14: 620378.
[16] J. Zhang, D. Tao. Research on deep reinforcement learning basketball robot shooting skills improvement based on end-to-end architecture and multi-modal perception[J]. Frontiers in Neurorobotics, 2023, 17: 1274543.
[17] S. Zhang, G. Zhao, P. Lin, et al. Deep Reinforcement Learning for a Humanoid Robot Basketball Player[C]//2023 IEEE International Conference on Robotics and Biomimetics (ROBIO). IEEE, 2023: 1-6.
[18] A.F. Rochim, D. Eridani, P.J. Rustam. Basketball Arm Shooting Robot Design by Implementing Parabolic Motion[C]//2023 6th International Conference on Information and Communications Technology (ICOIACT). IEEE, 2023: 1-4.
[19] F. Shi, X. Hu. Fuzzy dynamic obstacle avoidance algorithm for basketball robot based on multi-sensor data fusion technology[J]. International Journal of Foundations of Computer Science, 2022, 33(06n07): 649-666.
[20] J. Tian, H. Liu, S.L. Dai, et al. A real-time football goalkeeper robot system based on fuzzy logic control[C]//2021 China Automation Congress (CAC). IEEE, 2021: 3258-3263.
[21] Adarsh P, Rathi P, Kumar M. YOLO v3-Tiny: Object Detection and Recognition using one stage improved model[C]//2020 6th international conference on advanced computing and communication systems (ICACCS). IEEE, 2020: 687-694.
[22] S. Liu, G. Lever, Z. Wang, et al. From motor control to team play in simulated humanoid football [J]. Science Robotics, 2022, 7(69): eabo0235.
[23] D. Zhou, G. Chen, F. Xu. Application of Deep Learning Technology in Strength Training of Football Players and Field Line Detection of Football Robots[J]. Frontiers in Neurorobotics, 2022, 16: 867028.
[24] T. Haarnoja, B. Moran, G. Lever, et al. Learning agile soccer skills for a bipedal robot with deep reinforcement learning[J]. Science Robotics, 2024, 9(89): eadi8022.
[25] M. Wang, Z. Liang. Cross-modal self-attention mechanism for controlling robot volleyball motion [J]. Frontiers in Neurorobotics, 2023, 17: 1288463.
[26] M. Latifinavid, A. Azizi. Development of a vision-based unmanned ground vehicle for mapping and tennis ball collection: A fuzzy logic approach[J]. Future Internet, 2023, 15(2): 84.
[27] F. Gao, S. Li, Y. Gao, et al. Robots at the Beijing 2022 winter olympics[J]. Science Robotics, 2022, 7(65): eabq0785.
[28] C. Hong, I. Jeong, L.F. Vecchietti, et al. AI world cup: robot-soccer-based competitions[J]. IEEE Transactions on Games, 2021, 13(4): 330-341.
[29] D. Kim, S. Kim. A model for user acceptance of robot journalism: Influence of positive disconfirmation and uncertainty avoidance[J]. Technological Forecasting and Social Change, 2021, 163: 120448.
[30] T.C. Tsai, M.H. Chiang. A lower limb rehabilitation assistance training robot system driven by an innovative pneumatic artificial muscle system[J]. Soft Robotics, 2023, 10(1): 1-16.
[31] A. Harfoush, M. Hossam. Modelling of a robot-arm for training in fencing sport[J]. International Journal of Intelligent Robotics and Applications, 2020, 4(1): 109-121.
[32] C. Park, B. Kim, Y. Kim, et al. Carved turn control with gate vision recognition of a humanoid robot for giant slalom skiing on ski slopes[J]. Sensors, 2022, 22(3): 816.