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Application of Artificial Intelligence in Basketball Sport

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Abstract

Basketball is among the most popular sports in the world, and its related industries have also produced huge economic benefits. In recent years, the application of artificial intelligence (AI) technology in basketball has attracted a large amount of attention. We conducted a comprehensive review of the application research of AI in basketball through literature retrieval. Current research focuses on the AI analysis of basketball team and player performance, prediction of competition results, analysis and prediction of shooting, AI coaching system, intelligent training machine and arena, and sports injury prevention. Most studies have shown that AI technology can improve the training level of basketball players, help coaches formulate suitable game strategies, prevent sports injuries, and improve the enjoyment of games. At the same time, it is also found that the number and level of published papers are relatively limited. We believe that the application of AI in basketball is still in its infancy. We call on relevant industries to increase their research investment in this area, and promote the improvement of the level of basketball, making the game increasingly exciting as its worldwide popularity continues to increase.

Keywords: basketball; artificial intelligence; wearable electronic devices

Introduction

Basketball was invented by physical education professor James Naismith at Springfield, Massachusetts in 1891. It has a history of 130 years and is among the most popular sports in the world. In the United States, 24.23 million people participated in basketball games in 2018 alone. The International Federation of Basketball Associations estimated that at least 450 million people worldwide participate in this sport (http://www.fiba.basketball/). The National Basketball Association (NBA) game is recognized as the highest-level professional basketball game in the world. In the 2019/20 season, the total revenue of all 30 NBA teams was approximately USD 7.92 billion (https://www.statista.com/). In recent years, many new technologies have been applied to basketball training and competitions, which are of great significance for improving athletes' technical performance level, reducing sports injuries, enhancing game viewing, attracting fans, and promoting the development of basketball-related industries.

AI is a branch of computer science that enables computers to perform tasks that normally require human intelligence. Machine learning is a subset of AI, which automatically improves the performance of computing programs through the learning of data patterns and has been successfully used to various fields [1]. The advantage of AI is that it can quickly analyze and process massive amounts of data, and data analysis methods are constantly improving, enabling users to obtain important information that is difficult to obtain by manual methods. There is no doubt that it is among the most promising technologies for humankind in the future, and its benefits are extending to the sports world. This article gives a comprehensive overview of the application of AI in basketball.

The application of AI in sports

AI technology is being widely used in all aspects of sports. For example, through cameras and wearable sensors, computers can accurately obtain sports data and the physiological data of athletes during training or competitions. Using AI technology to analyze these data can not only help coaches develop personalized training plans for athletes, but also it can also help coaches develop the best game strategy. AI-driven vision processing technology can accurately track the ball to the millimeter. This technique has been used by referees in many sports, such as cricket, tennis, football, baseball, and billiards [2].

Health is very important for athletes. AI technology has become a key tool in the sports team's medical toolkit. It can not only be used to arrange regular physical examinations of athletes and analyze health parameters, but can also be combined with wearable devices to track physical conditions to avoid serious health problems and sports injuries. The cost of recruiting athletes for clubs and countries/regions is high. AI technology and big data analysis can be used to objectively evaluate athletes' performance records, physical conditions, sports parameters, etc., to help teams recruit the most suitable athletes. The review by Claudius et al. explained that the most commonly used AI technologies for predicting injury risk or sports performance in team sports are artificial neural networks, decision tree classifiers, support vector machines, and Markov processes. The team sports with the most AI applications are football, basketball, handball, and volleyball [3].

The broadcasting of sports events is an important part of the sports industry. AI-based software and hardware devices can automatically extract and produce game highlights, and

combine virtual reality, augmented reality, and mixed reality technologies to enhance the audience's experience. AI has been extended to the field of sports writing, an AI natural language platform that can convert the raw data of the game into readable stories, greatly enhancing the reporting capabilities of sports news. Sports teams have used chatbots to answer fan queries, including team history, team statistics, roster, and realtime match information. This will increase the fans' understanding of the team and help the entertainment economy develop to a higher level [4-7].

AI can predict the outcome of the game, which is very important for the odds set by the bookmaker. The global sports betting market is estimated to exceed USD 200 billion. In addition, the prediction of the outcome of the game will also affect the team's strategic and tactical decisions. AI also has very important application value in sports marketing. It can provide marketing advice to stakeholders by analyzing a large amount of Internet information. Almost every major sports league in the United States, such as NHL, MLB, NBA, NFL, and NASCAR, use AI to expand their business [4-7].

AI analysis of basketball team performance

The individual physical capabilities of basketball players can be easily tested under laboratory conditions, but the team performance must be observed during actual games. Using manual methods to evaluate players' team performance is laborious and not objective. In 2007, Perse et al. proposed an AI method with Bayesian networks to automatically evaluate the performance of teams and players in a game. Through the analysis of 63 real trajectories, they found that when the players' real activity type matches the activity type suggested by basketball experts, the score would be three times higher. In-depth analysis of the graphical structure of the Bayesian network could also help coaches to find and eliminate the cause of poor performance in a particular activity [8]. In another study, Wu used a neural network-based fuzzy comprehensive evaluation method to make a comprehensive evaluation of the offensive and defensive capabilities of the 12 women's basketball teams in the 30th Olympic Games. The comprehensive evaluation result is consistent with the actual competition ranking [9]. Kempe et al. used the method of merging the self-organizing map (MSOM) and common dynamical controlled network to analyze players' position data recorded by the Ubisense tracking system in the basketball game. The results showed that both methods could effectively determine the players' tactical patterns [10].

In order to determine the key factors affecting the results of the basketball game, Çene analyzed the 2016-2017 European League season. The cluster analysis was used to divide the game into three groups based on the final score difference, and then Bayesian model averaging was used to determine the key candidate variables. Finally, a conditional interference classification tree was constructed for all matches. The results of the classification tree showed that the true shooting percentage, steals and committed fouls were the main factors determining the outcome when the game results are close. In addition, 2-point field goal made, 3-point field goal made, and defensive rebounds were the key factors [11]. Leicht et al. studied the relationship between match results and 12 team performance indicators during the 2004-2016 Olympics women's and men's basketball games. A binary logistic regression and conditional interference classification tree were used in the analysis, and the results showed that the combination of "field-goal percentage", "defensive rebounds", "turnovers", and "steals" could effectively illustrate the result of the game, and the conditional interference classification tree method was more practical. The authors claimed that this type of analysis might provide

important guidance for designing training and competition strategies [12, 13]. Tian et al. developed a machine learning model that automatically recognizes and classifies offensive and defensive strategies by analyzing the tracking data of the entire team in a basketball game. The trajectory data set of players and balls in nearly 630 basketball games in the 2012/13 NBA was used in this study. The results showed that SVM was the best machine learning solution, and its classification accuracy was 68.9%. The author believed that this technology was helpful for coaches to guide player training and formulate game strategies and team tactics [14].

The automatic analysis of sports video data, such as technical statistical data collection and tactical analysis, is very important for the team to develop appropriate game strategies. In 2010, Xing et al. proposed a solution to the problem of tracking multiple highly dynamic and highly interactive athletes in sports videos, such as football and basketball. The algorithm was based on gradually established observations and uses a unified dual-mode two-way Bayesian inference method to express the multiple object-tracking problem. This method obtained satisfactory tracking results in many typical real world sports videos, and the author believed that this method could also be used for onsite automatic analysis [15]. Hojo et al. used a 3D optical motion capture system with six cameras to record the time and space data of the player and the ball. Based on the analysis of video data, they proposed an automatic identification system for strategic cooperative plays. In this study, a set of video data came from 10 male players from Japan's top university basketball teams. The players were divided into two teams and played a five-on-five half-court basketball game alternately. The data of the real games came from the international games held in 2015. They analyzed the data with support vector machines (SVM). The results showed that this method could classify cooperative plays in various situations on the arena. The preliminary analysis indicated that inconspicuous participants play an important role on the field [16]. Yoon et al. introduced a system that can automatically identify and track the movement trajectories of athletes and basketballs in basketball games. The system could perform real-time analysis of basketball game videos shot with the camera angle dynamically changing, such as a publicly broadcast live video of NBA games. The AI algorithm used in the system was a convolutional neural network. The system could also recover any lost track information from the motion history extracted from previous video frames. The authors believed that although the accuracy of the system must be further improved, the system could effectively reveal the key determinants of team performance and help coaches design better game strategies [17].

In a recently published review paper, Vangelis et al. summarized the statistical metrics used in the NBA and the European League to evaluate the performance of basketball teams and players. These basketball metrics can be used for athlete career improvement, team composition, evaluation of the strengths and weaknesses of own and opponent teams, tactical optimization, and prediction of game results. Moreover, the author speculates that in future basketball sports analysis, the use of machine learning and data mining techniques combined with data obtained by wearable sensors and cameras will significantly improve the level of sports analytics [18].

AI analysis of basketball players' performance

Currently, the evaluation methods for basketball players mainly rely on the coach's experience and lack objective evaluation methods. In 2013, Lu established a comprehensive evaluation model using a radial basis function neural network based on the physical fitness (100 m run, 5.8m × 6 shuttle run, standing long jump, running vertical jump, etc.) and basic technical indicators (rebounding skills, overall pass and layup, comprehensive dribble, etc.) of young basketball players. This model could help coaches monitor and adjust the training of young

basketball players [19]. In another study, Huo introduced a system that used a wireless three-axis acceleration sensor and machine learning to evaluate basketball players' performance on the court. An improved Bayesian algorithm and fuzzy comprehensive evaluation method were used to the establish athlete value evaluation model. The author used this method to evaluate the fast dribbling ability and shooting accuracy of 492 young male and female basketball players between the ages of 18 and 20. The results showed that the model had better evaluation results and fairer value distribution compared with the results of coaches [20]. Fans have closely watched the annual draft for prospects of the NBA and the prediction of the future performance of these prospective players. Kannan et al. analyzed the 2009-2014 NBA draft data and the performance of these players in 174 NBA games with the random forest classification method. The results showed that the players' draft pick and collegiate performance were the best predictors of NBA success [21].

The prediction of competition results by AI

The prediction of match results is very popular among fans in sports betting. However, this is a very complicated issue as there are many factors that affect the outcome of a basketball game, such as player performance, cooperation between players, playing field, and audience. In addition, fans will also reduce the accuracy of predictions due to emotional preferences or the use of inappropriate data. In this regard, various AI models have been developed to solve this problem.

In 2010, for the prediction of NBA game results, Miljković et al. proposed a data mining technique to solve this problem. They transformed the problem of predicting game results into a classification problem, compared several classification methods, and found that the Naive Bayes classifier provided the best test results. They used the system to predict 778 games in the 2009/2010 season of the NBA league, and correctly predicted 67% of the games [22]. In another study, Cao used Simple Logistics Classifier, Artificial Neural Networks, SVM, and Naïve Bayes algorithms to build a model for predicting NBA game results. Five regular NBA season data sets were used for model training, and one regular NBA data set for model evaluation. The results showed that the Simple Logistics Classifier had the highest accuracy, 69.67% [23]. Pai et al. developed a hybrid model that combines SVM technology and the decision tree method to analyze game results in the NBA. The forward reasoning function of the model could be used to predict the outcome of the game, and backward reasoning could provide coaches with the essential factors used for adjusting the game strategy. The empirical results showed that this model could obtain a relatively satisfactory prediction accuracy (85.25%) [24]. Horvat et al. compared seven different classification machine learning algorithms to predict the outcome of NBA games based on 13 basic features related to a team's performance (such as the number of three pointers made/attempted, two pointers made/attempted, and free throws made/attempted). They verified the prediction results with two verification methods (Train and Test and cross validation). The results showed that the prediction results produced by the machine learning algorithms were similar, but the nearest neighbor algorithm obtained the best results. Cross validation was a better verification method. Using the up-to-date data led to a better prediction. However, the best prediction result can only reach 60%, which may be due to the fact that the features used for prediction are too limited [25]. Ozkan introduced a hybrid intelligent system called a concurrent neuro fuzzy system. The author reported that the accurate prediction rate of the system was 79.2% [26].

In the 2013-2014 season, the NBA installed cameras and tracking software systems in all 30 arenas. These systems allow the coordinates of all players and balls to be recorded and processed digitally. Through the analysis of the tracking data, every aspect of the game, including every pass, screen, and defensive rotation, can be quantitatively analyzed. Skinner et al. proposed a method to analyze the relationship between the players' personal skills and the team's success in different games with a network-style model. This method could automatically learn the players' skills by analyzing their tracking data and then predict the performance of the untested 5-man lineup. They used this model to analyze games from the 2011 playoff series between the Memphis Grizzlies and the Oklahoma City Thunder, and the results showed that the model could successfully predict the players' interactions in a specific lineup based on their performance in different lineups [27].

More than 300 teams participate in the National College Athletics Association Basketball Tournament (NCAAB). There are huge differences in funding, facilities, and national exposure. Each team can play 30 games in a season, and they can choose many opponents by themselves. Therefore, it is a challenge to predict the outcome of the game. Zimmermann et al. used the results of the 2009-2013 NCAAB competition as training and test data sets to compare the predictive accuracy of several machine learning models, including decision trees, rule learners, artificial neural networks, Naive Bayes classifier, and random forest classifier. It turned out that the artificial neural network with multilayer perceptron is the most effective model. Teams' attributes are more important than models, but there is an upper limit of predictive quality, which is 74%. The author believes that the reason for limiting the accuracy of prediction is that certain attributes do not have objective standards, and new attributes must be added to improve prediction capabilities [28].

For the prediction of the outcome of basketball games in other countries, Li applied an improved back propagation (BP) neural network to establish a mathematical prediction model for basketball. Based on the sports scores (including shooting rate, three-point shooting, assist statistics, and rebounding) of the Chinese men's basketball team in the 2004 Olympic Games, the 14th World Basketball Championship, the 2006 Intercontinental Cup basketball game, and the 2004 Athens Olympic Games, this study used MATLAB software to predict the sports performance of the 2012 London Olympics, and the results showed that the prediction error was very small [29]. Cai et al. developed a hybrid ensemble learning framework by combining the bagging strategy and random subspace methods to predict the outcome of basketball games. This framework included 12 parameters, namely, two-point, three-point, free-throw, attack, defense, assist, foul, steal, blunder, blocked-shot, fast break, and dunk. The data set used for training and testing contained 380 games of 20 teams in the 2016/2017 Chinese Basketball Association regular season. The authors compared the hybrid ensemble learning framework with other machine learning models (such as Naive Bayes, Markov Models, Artificial Neural Networks, Apriori, Logistic Regression, and Poisson Regression) and found that the hybrid ensemble learning framework was the best; the accuracy rate reached 84% [30].

AI analysis and prediction of shooting

In a basketball game, the shooting percentage determines the outcome. AI technology can be used for the analysis of shooting actions and the prediction of shooting. Schmidt et al. used the artificial neural network method to analyze the movement patterns of basketball free throwers of different skill levels. By analyzing the action videos taken from the three dimensions of each free thrower, the method used the trajectories of multiple neurons in the combined

network to reflect the complex characteristics of the movement pattern, and successfully classified the throwing pattern [31]. In basketball training, collecting and analyzing athletes' posture data can help coaches design scientific training plans and improve training effects. Ji proposed a basketball shooting gesture recognition method based on image feature extraction and machine learning (Gaussian latent variable model). The author analyzed the video images from the Human Eva database of Brown University in the United States, and the results showed that this method could accurately identify basketball shooting actions. The author believed that this method could provide a data reference for basketball training [32]. Yu and Liu proposed an AI-based method for the automatic detection of shooting motion image features, which may be helpful to the training of basketball shooting [33].

Shah and Romijnders applied a recurrent neural network to predict the success of a three-point shot. More than 20,000 data from NBA SportVu were used for training and testing. The results showed that the accuracy rate of prediction was 84.3% based on the continuous position data of the ball at half a second and 8 feet away from the basket [34]. Zhao et al. applied deep bidirectional long short-term memory and mixture density network methods to predict the trajectory of the three-point shot. The authors used the SportVu (a database of video recording basketball and players' spatial positions in the game) database from the NBA 2015-2016 season, a total of 631 games, and 20,780 three-point shots to train and test the model. The results showed that the model was better than other models in terms of convergence speed and accuracy. When the basketball was 8 feet away from the basket, the prediction accuracy rate reached 86.9%. The author believes that this method can help coaches and players decide when and where to shoot [35]. Przednowek et al. used the particle swarm optimization algorithm to establish a system that could automatically detect and track the trajectory of the ball during the free throw. The system analyzed the influence of four distances, three speeds, and three angle parameters on free throws. The study used a 100 Hz monocular camera to collect free throw data from 30 Polish basketball players in the 2015-2017 game. The results revealed the relationship between the differences of these parameters and free throw hits and provided a guidance for training free throw techniques [36].

OpenPose, developed by Carnegie Mellon University, used a simple webcam to obtain real-time moving images and could identify the bone information of multiple people in these images. Nakai et al. established a basketball free throw prediction model through a support vector machine using the bone movement information obtained by OpenPose. The results showed that the model obtained sufficiently significant prediction accuracy. The author believed that the method had the advantages of simple equipment, low cost, and high efficiency, and predictive accuracy could also be improved by collecting three-dimensional data [37].

AI basketball coaching system

In addition to the above analysis, AI technology can also be used to assist basketball teaching. In 2016, Li introduced a college basketball intelligent teaching system based on AI. The system was a multilevel dynamic interactive multimedia presentation system, which mainly includes a knowledge base, student models, teacher models, and a man-machine interface. The system designed a personalized teaching mode according to the level of each student and tracked the learning records of the students to adjust the teaching mode, with good interactivity and adaptability. The teaching experiment revealed that the effect of the AI teaching system was significantly better than the control class [38]. According to reports, there is an intelligent computer-assisted system (ICAI) that can integrate the teaching methods and experiences of

multiple teachers to help students in individualized and autonomous learning. Zhao and Xie used a questionnaire survey method to evaluate the effect of ICAI in basketball training. The survey results showed that students and teachers were satisfied with the effects of ICAI, but there were deficiencies in the use process that must be further improved [39]. Moreover, Yang introduced an AI basketball coaching system based on the Baum–Welch algorithm. The system could formulate and adjust the training plan based on individual players' physical conditions, athletic ability, and changes in sport skills measured during training. The author conducted an experimental study on 20 junior basketball players to compare the training effects of the AI basketball coaching system and traditional coaching method. The results showed that the AI technology significantly improved the training efficiency of basketball players [40].

AI basketball training machine

Intelligent machinery can improve the training efficiency of basketball players. Liu and Li introduced an intelligent basketball shooting training vehicle, which could improve athletes' basketball shooting target capture ability and response speed. Based on the shooting training practice, the authors confirmed that the equipment could effectively improve the athletes' shooting percentage [41]. Basketball training robots are increasingly used in basketball training. In order to avoid injury caused by the collision between the mobile training robot and the athlete, Xu and Tang used ultrasonic signals of obstacles collected around the robot as input and applied an improved Q-learning algorithm based on machine learning, so that the robot can effectively avoid collisions with athletes during the training course and allow athletes to receive scientific and efficient training [42].

Intelligent arena

Liu et al. proposed a deep learning-based basketball video analysis solution for use in an intelligent basketball arena. This solution could automatically broadcast basketball games, detect scores, and generate highlight videos in real basketball games. The program was implemented into a business intelligence basketball arena application, "Standz Basketball". According to a comprehensive evaluation, the program was significantly better than other methods [43]. Fu et al. developed a system for the real-time reporting of basketball game scores through camera video recording. The system included object detection based on convolutional neural networks and motion detection based on frame difference. The authors used the system to analyze the video of a real basketball game, and the results showed that the system reached a relatively satisfactory accuracy (92.59%). At present, the intelligent basketball analysis system using this method has been installed on multiple basketball courts in Beijing [44]. Žemgulys et al. developed a machine vision system that automatically recognizes the hand gestures of basketball referees. The system was based on a histogram of oriented gradients and local binary pattern features, as well as SVM and RF classifiers. This study analyzed a recorded basketball game video, and the results showed that the accuracy reached 95.6%. The system could be used for the real-time analysis of basketball games, thereby increasing the attractiveness of the game and helping to resolve disputes in the game [45].

Application of AI to sports injury prevention

Sports injuries can cause serious negative effects on players and teams. In recent years, AI technology has been used to prevent sports injuries. Wu used the random forest method to analyze the 13,975 recorded data sets of 277 NBA players who played at least 20 minutes in the

fourth quarter of 2016 (824 games in total, including 27 injuries). The results showed that injury was highly correlated with the performance of the players in the most recent game, that is, playing more actively, shooting more shots, and being more likely to be injured in the next game, while weight, height, and intensive training were not related to injury. The author believed that as injuries were relatively rare events, the data set was unbalanced. More accurate injury prediction models require more data and parameters to be collected and analyzed [46]. Jauhiainen et al. used L1 normal logistic regression and random forest to analyze the sports and physiological data of 314 young basketball and floorball players, as well as the moderate and severe knee and ankle injuries during the three-year follow up. The results showed 10 indicators that were the injury predictors jointly determined by the two algorithms, including sex, body mass index, hamstring flexibility, and knee joint laxity [47]. Sarlis et al. used data mining technology and machine learning algorithms to analyze 1,298 NBA players, a total of 11,225 injuries, and related game records from 2010 to 2020. The results showed that injuries to the musculoskeletal system of the lower limbs, trunk, and upper limbs were the most common and serious, especially the ankles and knees. There was a weak positive correlation between injury and performance, which showed that although performance was negatively affected by injury, it was also affected by other important factors. Player injuries not only affect the competition results but also affect the financial situation of the club. Therefore, the author proposed the use of a variety of technologies in the future, such as video, GPS, wearable sensors, and social network activities, to analyze the physiological and psychological indicators of players in order to formulate the optimal training and game plan to avoid sports injuries [48].

Application of wearable devices in basketball

The monitoring and analysis of physiological and exercise parameters is an important research field of sports science. The analysis of these data helps to optimize training plans, improve athletes' performance, and prevent injuries during exercise. Camera-based technology is the most commonly used method, but this method has certain limitations, such as the inability to distinguish specific movements and to record various physiological indicators. However, wearable, miniaturized smart sensor devices provide new tools for sports science. Using smart sensor devices in basketball can provide important information on body movement and physiological needs during practice and competition. Although the NBA currently does not allow the use of wearable technologies in official games, they are playing an increasingly important role in coaching. In a review by Li et al., the movement sensors (including pedometers, accelerometers/gyroscopes, and global positioning satellite (GPS) devices) and physiological sensors (including heart rate monitors, sleep monitors, temperature sensors, and integrated sensors) are introduced in detail [49].

For the collection of physiological parameters, Montgomery et al. introduced a personal heart rate telemetry system, which was connected to software that can estimate oxygen consumption in real time and a three-axis accelerometer to quantify the physical movement of athletes in basketball games [50]. Monitoring energy expenditure can help athletes to accurately determine energy requirements. Taylor et al. introduced a multi-sensor device (SenseWear Mini Armband) worn on the upper arm to measure energy expenditure during physical exercise. The device used Cosmed K4b2 indirect calorimetry to determine energy expenditure. The authors examined the accuracy of the device in female basketball players during training of various intensities, and found that the device had a certain accuracy, but for intermittent sports basketball players, the algorithm must be further improved [51]. Clothing manufacturers have integrated

textiles with sensors, for example, a fitness suit made by a Finnish company, Clothing Plus Oy, that can monitor athletes' physiological indicators from heart rate and body temperature to brain waves during the game, so that coaches and team doctors can accurately monitor the athletes' health statuses [52].

Since the global positioning system (GPS) can record the time and space trajectory of athletes, it has been widely used in sports science. Metulini et al. introduced a method of attaching GPS microchips to athletes' clothes to collect the positions of their x-axis, y-axis, and z-axis (jump height) in a basketball game, with 1 m2 pixels as the unit [53]. In order to find a way to visually display the movement patterns of basketball players on the court reflecting the team's performance, they analyzed the trajectory data collected from a friendly match in the city of Pavia with a GPS microchip placed on jerseys. They used motion charts to visualize the temporal and spatial movements of players in the arena. Then, they performed cluster analysis to characterize the spatial pattern of players on the court. The study used convex hulls and found some interesting patterns in player movement patterns, which provides inspiration for future research [54]. The RFID tracking chip is another wireless location technology that uses a radio-frequency identification to track players' position, movement, and speed. In the future, coaches will no longer rely solely on visual observation and intuition but can rely on exact data to guide player training and competition [52].

For the monitoring of exercise status, Nguyen et al. introduced an inertial measurement sensor system that can be used to record and recognize the movement of players in basketball games. The system included five sensors, which were placed on the feet, calves, and waist. They tested the system and found that it can identify four types of exercises with different intensities, including walking, jogging, running, and sprinting, and also can distinguish shooting executions [55]. Bai et al. introduced a system called weSport that could detect the number of shots made by each player in a one-to-one basketball game. The system was based on the analysis of the movement data transmitted by the inertial sensors of the two players' wristbands and the smartphones [56]. Mangiarotti et al. introduced a wearable wireless system that can track and recognize certain gestures performed by two or more basketball players. The device used a thriaxis accelerometer and a gyroscope to detect the state of motion. The two sets of devices were worn on both wrists of the players during competition or training. The authors used two machine learning algorithms (K nearest neighbor and support vector machine) to recognize the three gestures of passing, shooting, and dribbling, and the results showed that the accuracy reached 99.46%. The author believed that the device could assist coaches in training players [57]. In the current sporting goods market, there are varieties of sensing devices used to record athletes' movements on the market, such as the Blast Basketball Jumpshot mounted on the belt, the VERT mounted on the waist or chest clothes, and the UA SpeedForm mounted on the shoes. These devices can track and record athletes' movements, such as acceleration, rotation. and jumping. In addition, there are varieties of motion sensors installed on the arm or wrist, such as ShotTracker, SOLIDshot, and Hoop Tracker, which are specifically used to record athletes' dribbling, shooting, and other arm movements [58].

In addition to sensor devices that record athletes' exercise statuses, there are also "smart basketballs" on the market, such as the Wilson X Connected Basketball, 94fifty Smart Sensor Basketball, and DribbleUp. The principle is to place motion sensors or special identification marks on the basketball, so that the corresponding software system can obtain the force, motion speed, rotation, and arc data of the basketball. After these data are processed, they will be immediately fed back to the athletes, thus playing the role of a coach [58].

Summary and conclusion

Currently, the application of AI technology in basketball has been extensively studied, including analyzing the performance of teams and players, predicting game results, analyzing and predicting shooting, basketball teaching, intelligent training machinery and arena, and preventing sports injuries. The results showed that AI technology and wearable devices have significant effects on improving the training level of basketball players, helping coaches formulate game strategies, and preventing sports injuries, etc. Nevertheless, it must be highlighted that the current application of AI in basketball is still in the research and exploration stage, and the number and level of related papers are relatively limited. Basketball is among the most popular sports in the world, and its related industries have reaped huge economic benefits. Therefore, we call on basketball-related interest groups to actively support the application study of AI in basketball and provide more research funding for universities and research institutes. We believe that AI technology will promote the improvement of the level of basketball, making the game increasingly exciting as its worldwide popularity continues to increase.

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