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Application of Artificial Intelligence Technology in Sports Training

Yong Zhou*

School of Liberal Arts Education , Liuzhou Railway Vocational Technical College,
Lizhou Guangxi, China
Lie174@126.com

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Abstract. Artificial Intelligence (AI) techniques are crucial in sports training, enhancing athlete performance and improving training regimens. The automated training process requires effective learning systems to maximize athlete performance. Therefore, this study explores the in-depth exploration of AI in the sports training process. The athlete data has been examined using machine learning like deep learning and Natural Language Processing (NLP) to create personalized training programs and fine-tune the coaching training strategies. Along with this, the research examines the role of AI in rehabilitation, real-time monitoring, and injury prevention to manage the athlete's well-being and health condition. The ethical considerations and challenges of AI in sports training adoption are also discussed to minimize the complexity of the training process. The effective creation of the AI-based sports training process enhances the athlete's performance in various criteria.

Keywords: athlete performance, sports training, machine learning, Artificial Intelligence, Natural Language Processing

1 Introduction

In the previous era, the coach-athlete relationship [1-3] was a main factor in young athletes' improvement of their sports performance. The training process influences an athlete's performance positively and negatively. Sports training plays an important role in the overall development of athletes. The sports training is organized in a structured aspect to improve the sportsperson's fitness [4]. The training process expands strength, flexibility, endurance, and cardiovascular health and minimizes chronic diseases. The sports training process develops personal skill, provides the platform for effective teamwork, discipline, resilience, character building, stress relief, and ensure long-term health habits [5, 6]. The manual sports training improves athlete's activities and is highly beneficial. However, it has a few challenges that vary according to the sports, individual factors, and competition level [7]. The manual training process highly encompasses physical exertion and contact, which maximizes the injuries and respective risks. During training sessions, the athletes face fractures, sprains, strains, and injuries [8]. Overtraining causes burnout fatigue and decreases performance. Therefore, athletes and coaches require additional attention to manage the training to avoid the discussed issues.

The other important factor is time constraints because the trainer and coaches have other commitments like academics and work. These commitments reduce training performance, and they struggle to do physical activities [9]. Weather conditions such as extreme heat, rain, and temperatures often disrupt training schedules and influence the athlete's ability during practices. Finally, the manual training process creates mental stress and anxiety during high-pressure situations like competitions [10-12]. Therefore, Artificial Intelligence (AI) [13] is incorporated into sports training, offering various techniques and tools to address the issues in manual training. The AI uses a large volume of data that helps to create effective competitions and training sessions. The gathered data consists of biomechanical information to identify the relationship between the coaches and athletes. Artificial intelligence (AI) algorithms can assess an athlete's [14] strengths, weaknesses, and unique requirements to provide customized training plans. This practice guarantees the training program is customized to suit each athlete's qualities and objectives. Artificial intelligence (AI) systems can dynamically adapt training regimens in real time, considering an athlete's performance and advancements. This ensures that the training regimen maintains an appropriate level of intensity and focus. Artificial intelligence (AI) can effectively track and analyze several physiological indicators of athletes, including heart rate, fatigue levels, and sleep patterns [15]. This information

* Corresponding Author

facilitates the identification of indicators of overtraining, mitigating the likelihood of injuries, and enhancing the recuperation process. Artificial intelligence (AI) can assess historical data, enabling predicting injury risks and recommending preventative actions [16]. This empowers athletes and coaches to adopt proactive measures to mitigate injuries. Artificial intelligence (AI) has the potential to aid in the visualization of intricate performance data, hence facilitating the comprehension and targeted analysis of many training components for athletes and coaches. Therefore, the study focuses on the depth analysis of AI techniques to create the sports training process. The AI technique uses machine learning techniques such as neural networks, support vector machines, learning techniques, and multi-variable classifiers to predict athlete activities. According to their activities, the training program is formulated to reduce the difficulties in manual training. In addition, Natural Language Processing (NLP) [17, 18] techniques are incorporated to personalize the training process and fine-tune the coaching training strategies. Additionally, the study investigates the impact of artificial intelligence (AI) in rehabilitation, real-time monitoring, and injury prevention to manage the overall well-being and health status of athletes effectively. The ethical considerations and obstacles to implementing artificial intelligence (AI) in sports training are also deliberated upon to mitigate the intricacies associated with the training process.

2 Related Work

J. G. Claudino et al. [19] provide a comprehensive evaluation of current approaches in applying AI to assess injury risk and predict performance in team sports. The authors critically examine various methods and technologies, offering valuable insights into progress and obstacles in this rapidly-developing field. The systematic review offers a beneficial synthesis of existing knowledge, facilitating a deeper understanding of the dynamic application of AI in sports science.

Sadr et al. [20] introduced deep learning algorithms, particularly Recurrent Neural Networks (RNNs) and Convolutional Neural Networks (CNNs), to identify and predict sports injuries. The system intends to manage the reliability and large volume of biometric and motion data while forecasting injury patterns. The collected information is processed by applying RNN architectures such as Long Short-Term Memory (LSTM) and Gated Recurrent Units (GRU), enhanced with sequential and temporal feature learning. The network uses multiple layers that recognize injuries with maximum recognition accuracy, where the LSTM model achieved the highest performance at 91.5%, outperforming GRU and CNN models.

Rajšp and Fister Jr. [21] thoroughly examines the current intelligent data analysis techniques employed to improve the effectiveness of smart sports training. The survey comprehensively reviews various methodologies, algorithms, and technologies in examining sports-related data. This study provides valuable insights into the dynamic field of intelligent data analysis within athletic training, enhancing our understanding of using advanced analytical approaches to optimize training regimens and promote progress in intelligent sports training.

Stetter et al. [22] combined wearable sensors and machine learning to enhance knee joint force assessment in dynamic sports, aiming to minimize challenges and enhance injury prediction accuracy. However, sensor data inconsistency, difficulties implementing the findings, and the need for additional verification were constraints. Insights contribute to future research to optimize knee joint force estimation and enhance biomechanical analysis in sports.

Cust, E. E. et al. [23] used deep and machine learning techniques to recognize specific sports movements. They analyzed 52 studies, processed the collected information through preprocessing and model development. Initial data was processed by IMU to categorize movements, then vision-based studies and CNN were used to classify movements based on sports.

Wang, T., & Park, J. [24] aimed to investigate the convergence of sports training and mental health education, designing and implementing a customized intelligent system for college students to enhance their mental well-being. The deployment of the intelligent sports training system highlights the importance of using technology for comprehensive education and the interconnectedness of physical exercise and psychological well-being.

Li, B., & Xu, X. [25] examine current approaches and technical solutions that utilize artificial intelligence (AI) to improve many aspects of basketball, such as training, performance analysis, and strategic decision-making. This study aims to thoroughly examine the present status of artificial intelligence (AI) incorporation in sports, clarifying its possible advantages and consequences. The study is expected to highlight the accomplishments in improving training and strategic understanding while also recognizing the difficulties and factors to be considered in the changing role of artificial intelligence in basketball applications.

Rommers, N. et al. [26] used machine learning to assess football players' injury risk. The study collected data

on 734 players, including weight, sitting height, and fitness levels. The Extreme gradient-boosting algorithm predicted injuries based on pre-season tests. The system's efficiency was evaluated with 85% precision and recall. Machine learning analyzed athletes' activities to enhance sports training. Details on AI-based sports training follow.

3 Artificial Intelligence-based Sports Training

The continued interactions between trainers and athletes are called sports training. The trainer guides the athletes in their activities and organizes the trainers in the training section. The trainer frames and organizes the athlete's training exercise according to their demands, which helps to maximize their performance. Multiple exercises are organized in a single unit named training session during the training. Different phases, such as planning, realization, control, and evaluation, are utilized during training to improve athlete performance. Then, the phases involved in the sports training are illustrated in Fig. 1.

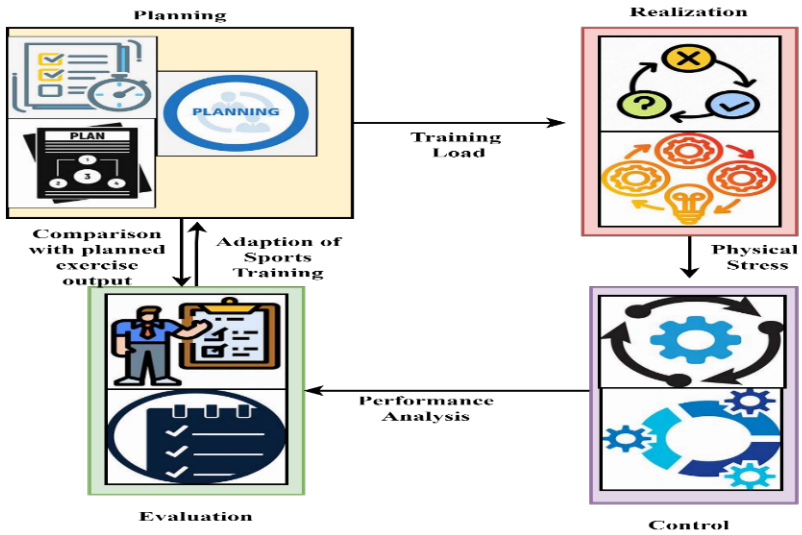


Fig. 1. Phases involved in sports training

Fig. 1 demonstrates the phases involved in the traditional sports training process. The training process covers planning, realization, control, and evaluation. Each phase significantly contributes to their function during the training process. The detailed working process of each phase is explained as follows.

3.1 Planning

Proper exercises are selected according to their requirement, sports, and potential in the planning phase. In addition, an exercise schedule has been framed to improve overall performance. The planning stage is used to understand the athlete's health and mental condition, which helps to prepare for competition. The proper planning strategies reduce the risk factors and injuries. Initially, the athlete's demand and sports requirements are gathered, including the athlete's fitness level, skill level, injury history, workout report, and age. According to the requirement, the short-term and long-term goal has been defined, which should be measurable, specific, relevant, time-bound, and achievable. Then, they divided the training program into in-season, pre-season and off-season. These seasons, training durations, intensity, and volume have been adjusted to reach the goal. Then, training components are defined to balance the sports and athlete requirements. The developed components maximize the athlete's skill, flexibility, agility, speed, strength, fitness, and condition. The trainer should select the appropriate training approach to reach the goal with minimum injuries. A progression monitoring procedure is also planned

to maximize the athlete's performance in upcoming competitions. Finally, the planning phase covers the monitoring, communication, and adaptability examination meeting to analyze the athlete's improvements in their performance.

3.2 Realization

The next phase is realization, in which framed exercises are executed with the help of the trainer roles such as equipment preparation, psychophysical evaluation, session monitoring, and enhancing tactics. The realization phase in sports training combines detailed preparation and the initiation of practical execution. As athletes progress from the initial stages of preparation to the implementation of their training program, their attention turns towards the practical execution of the tactics that were established during the planning phase. This stage encompasses implementing meticulously chosen training techniques, including cardiovascular conditioning, strength and agility workouts, skill enhancement, and other drills tailored to the individual sport. Athletic coaches diligently oversee the adherence of athletes to the prescribed training program and promptly make any adjustments in real-time. The realization phase places significant emphasis on incorporating periodization concepts, which aim to ensure that the intensity and volume of training are appropriately aligned with the precise objectives established for each training period. When athletes participate in organized training sessions, it is crucial to prioritize good technique and form to optimize the exercises' efficacy and reduce the likelihood of injuries. Regular assessments and feedback methods are crucial to evaluate progress and make informed decisions regarding the ongoing training program. Maintaining effective communication between coaches and athletes is more important in this period, as it enables the prompt adaptation of techniques by individual responses and performance outcomes. In a broader sense, the realization phase signifies an uncertain progression from the planning stage to the implementation stage, wherein athletes actively participate in the training regimen with a collective dedication toward attaining their performance goals.

3.3 Control

During the training exercise, data was collected and analyzed in the control phase, where a comparison was made with the planned exercise output. The control process was done in two phases: contemporary and video analysis. The control phase employed a proactive strategy to deal with emergent obstacles such as performance plateaus, injuries, or unscheduled disruptions. Coaches could refine training intensities, adapt workouts, or integrate supplementary recovery procedures to meet the developing needs of the athletes. This stage also involved modifying the periodization strategy to ensure that the training regimen remained consistent with broader objectives and timetables. Overall, the control phase functioned as a dynamic feedback loop that enabled coaches to make informed decisions that optimized the effectiveness of the training program, supported athlete well-being, and fostered a resilient and flexible team.

3.4 Evaluation

Finally, a single training load and total training cycle load are evaluated. The outputs are compared with the planned output, which helps to fine-tune the training process. Training requires frequent interconnections and transmission to improve the athlete's performance. The basic procedures are incorporated with the Artificial Intelligence (AI) techniques to maximize the athlete training program. The manual training process requires continuous observations, also the scheduled tasks are varied depending on external factors like health conditions, weather, etc. Therefore, the automatic sports training system is created with the help of AI techniques that can manage and fine-tune the program according to external factors. The process of AI-based sports training process is illustrated in Fig. 2.

Implementing artificial intelligence in sports training encompasses a comprehensive and finely organized procedure consisting of several phases (Fig. 2), all contributing to enhancing and optimizing athlete performance. The first stage of the research process involves gathering data, which is accomplished by utilizing various sensors, like as wearables and cameras. These sensors capture a wide range of information, including biomechanical movements, physiological reactions, and environmental circumstances during training sessions. Following the data collection procedure, rigorous preparation involves thoroughly cleaning to remove errors or outliers, nor-

malizing to establish consistent scales, and feature engineering to extract pertinent information. This establishes the context for the data analysis phase, during which machine learning methods are utilized. Descriptive analysis offers valuable insights into the inherent qualities of the data, while predictive modeling leverages previous data to forecast future performance or anticipate potential harm risks.

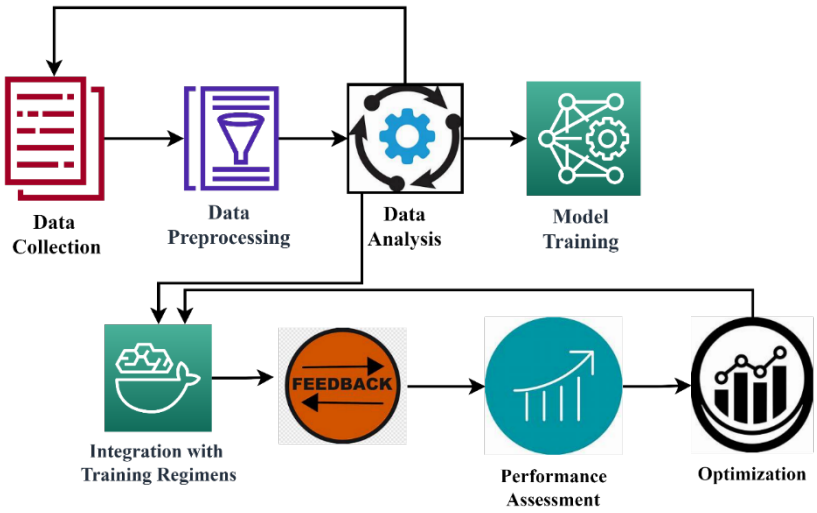


Fig. 2. Process of AI-based sports training

Additionally, prescriptive analysis provides recommendations for training improvements based on the findings derived from the study. The model training phase is crucial in machine learning, encompassing several supervised, unsupervised, and reinforcement learning techniques. Supervised learning is employed when dealing with tasks that have labeled data, while unsupervised learning is utilized for finding patterns or clusters in the data. Additionally, reinforcement learning optimizes decision-making processes by iteratively learning from trial-and-error experiences. During the integration phase, AI insights are included in training regimens, enabling the development of individualized plans considering individual athlete characteristics.

Additionally, real-time feedback is provided during training sessions. Adaptive planning is a process that involves the dynamic adjustment of training plans in response to ongoing performance data. Establishing a continuous feedback loop is of utmost importance, which entails constantly monitoring data, refining models to ensure current analysis, and incorporating subjective athlete feedback to improve the overall system. The performance assessment phase includes the evaluation of quantitative metrics produced from AI analysis, such as biomechanical efficiency or physiological indicators, and qualitative assessments aimed at capturing subjective elements, such as an athlete's well-being and mental state. The optimization phase involves the iterative enhancement of AI models and training plans, which are informed by a continuous feedback loop. This step also requires adjusting the system to accommodate variations in athlete attributes, training objectives, and external influences. The dynamic and developing nature of AI-based sports training assures a cyclical and adaptive approach to optimizing athlete performance and well-being. The AI-based sports training process is used to fine-tune the coach's training strategies. The utilization of AI-generated insights serves as the fundamental basis for developing customized coaching tactics. In contrast to standardized methodologies, artificial intelligence (AI) enables coaches to customize their techniques following the distinct attributes and specific needs of individual athletes. This encompasses modifying training programs following an athlete's preferred learning style, current physical state, and individual response to various training stimuli. The objective is to develop a customized coaching strategy that optimizes the athlete's maximum potential. Constructing a continuous feedback loop is a fundamental component of AI-enhanced coaching. During the training and competition process, the AI system consistently checks the performance of athletes. The utilization of a real-time feedback loop facilitates the acquisition of current and timely information by coaches regarding the athlete's performance, hence empowering them to implement adaptive modifications to their coaching approach. The purpose of this practice is to maintain consistency between coaching strategies and the changing requirements of the athlete. Developing an adaptable training environment

results from refining coaching strategies using AI. Coaches can apply specific interventions by modifying training intensity areas of focus and even providing psychological support, all based on the insights given by artificial intelligence. The ability to adapt cultivates a setting that is not solely receptive to the athlete's capabilities and limitations but also favorable for achieving their highest potential.

3.5 Intelligent Methods Utilized in this Study

The utilization of Artificial Intelligence (AI) has emerged as an important factor in revolutionizing sports training by integrating a diverse range of intelligent techniques to enhance athlete performance and optimize training plans. One crucial aspect involves utilizing machine learning algorithms, which analyze past data to forecast future performance trends and uncover patterns in an athlete's behavior. Predictive analytics allows trainers to proactively anticipate and address foreseeable obstacles, customizing training programs to optimize performance. Applying Natural Language Processing (NLP) techniques enhances the analysis of athlete feedback and communication, providing valuable insights into the psychological dimensions of training through sentiment analysis and voice recognition [27]. The feedback obtained from athletes and coaches is analyzed by using NLP techniques. Initially, irrelevant information, like phrases, is removed from the text. The URL, special characters, and conjunctions are removed from the text. After that, tokenization is performed to get the root word. The root words are further processed by Term Frequency-Inverse Term Frequency (TF-ITF), which derives the frequency appearance. The derived features help to understand the athlete's and coach's opinions and training status. In addition, computer vision techniques are applied to improve the athlete's movements. Computer vision is a crucial element that contributes to improving biomechanical analysis to optimize techniques and mitigate the risk of accidents. Examining body posture, joint angles, and movement patterns achieves this. Simultaneously, the recognition of actions facilitates the identification of particular regions that require enhancement throughout both training sessions and competitive events.

Reinforcement learning facilitates the integration of flexibility inside training programs, enabling artificial intelligence systems to dynamically modify parameters in response to real-time feedback dynamically, thus enhancing an athlete's performance progressively. Virtual Reality (VR) and Augmented Reality (AR) technologies can fully engage athletes in simulated training situations, hence facilitating the development of decision-making skills and situational awareness within controlled settings. In contrast, data fusion involves amalgamating data from diverse sources, including biometric sensors and video analysis, to generate full profiles of athletes. Expert systems, which integrate knowledge derived from seasoned coaches, provide contextually sensitive recommendations for training strategies and improving techniques. The utilization of wearable technology in the Internet of Things (IoT) enables the acquisition of real-time data on an athlete's physical state. This facilitates the ongoing monitoring, analysis, and modification of training programs.

Genetic algorithms are employed to optimize training regimens by considering the unique qualities of individual athletes, their response to training stimuli, and their recovery patterns. Fuzzy logic is employed to mitigate the effects of ambiguity and imprecision in athlete data, thereby offering decision-making assistance to coaches when acquiring accurate information may pose difficulties. Integrating these intelligent methodologies leads to a comprehensive and evidence-based approach to sports training, wherein individualized coaching, adaptable training settings, and data-informed decision-making intersect. The advancement of artificial intelligence (AI) [28] in 18 sports training can potentially transform athlete development and enhance performance optimization significantly. This can reshape the current practices and methodologies employed in sports coaching and training.

4 Rehabilitation and Injury Prevention

The automatic AI-based sports training process is widely utilized in rehabilitation and injury prevention. Artificial intelligence (AI) tools continuously monitor multiple facets of an athlete's health and condition. This encompasses many biometric data, including heart rate, sleep patterns, muscle tiredness, and other physiological indicators. Sensors and wearable devices can continuously collect and transmit data, providing valuable information regarding an athlete's physiological state during training sessions and daily activities. The data collected in real-time is submitted for ongoing analysis using artificial intelligence techniques. The algorithms undergo training to identify trends and abnormalities that could indicate the likelihood of sustaining an injury. Through analyzing an athlete's physiological characteristics over time, artificial intelligence (AI) can detect subtle indications that may

not be readily observable using traditional approaches. Artificial intelligence (AI) systems possess the capability to forecast potential injury risks through the examination of past data and the identification of patterns that precede occurrences of injuries. For instance, an escalation in the intensity of exercise without sufficient time for recovery, changes in the manner of movement, or regularly heightened stress levels could serve as early indications of future damage. Through the identification of these recurring patterns, artificial intelligence (AI) offers coaches and athletes valuable insights that enable them to implement measures proactively. AI can provide individualized injury prevention measures based on the study of individual athlete data. Possible adjustments can include alterations to the intensity of training, adaptations to technique, implementation of targeted workouts to enhance the strength of susceptible regions or improvements to recuperation regimens. The abovementioned tactics have been designed to mitigate the distinct risk factors connected with individual athletes effectively.

Artificial intelligence (AI) is crucial to the rehabilitation process, assisting in the development of individualized rehabilitation regimens by considering factors such as injury type, recovery history, and real-time physiological data. This includes providing workout recommendations, monitoring progress, and making necessary adjustments to the rehabilitation program. By using AI analysis, athletes and coaches can proactively implement strategies to reduce the likelihood of injuries, such as altering training intensity and volume, integrating specific exercises, adapting recovery methods, or allocating additional rest periods. The objective is to proactively intervene before mild disorders become more severe injuries. AI significantly enhances the overall welfare and durability of athletes' professional careers by proactively mitigating injury risks and implementing individualized rehabilitation protocols. Implementing continuous monitoring and a proactive approach to injury prevention not only facilitates the achievement of current performance objectives but also plays a significant role in promoting long-term health.

5 Ethical Consideration and Challenges

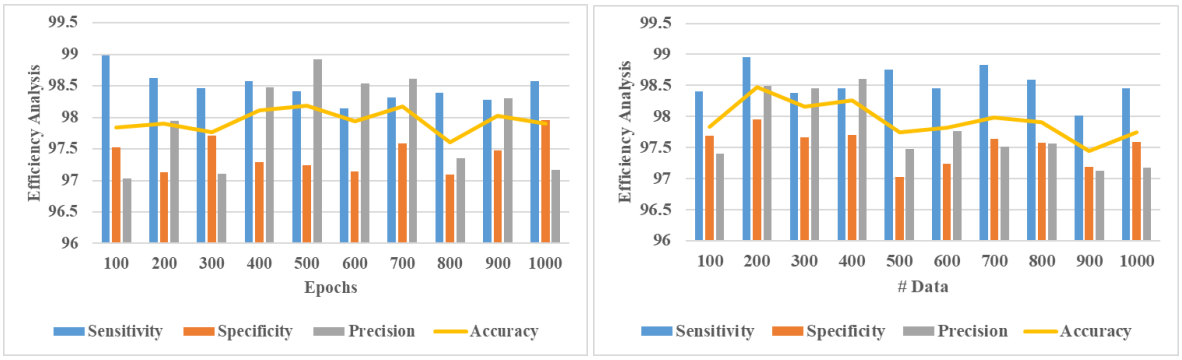
Incorporating artificial intelligence (AI) into sports training raises many ethical problems and challenges that warrant meticulous scrutiny. This study highlights the necessity of employing responsible practices in utilizing AI, focusing on upholding ethical norms, safeguarding data privacy, and ensuring transparency throughout its implementation. One crucial ethical challenge related to the imperative of utilizing AI technology to promote the well-being of athletes while simultaneously avoiding any actions that may compromise the integrity of competitions or infringe upon athletes' rights. Within the data privacy domain, ethical principles dictate the necessity of a comprehensive structure that empowers athletes to exercise authority over their personal information while safeguarding the requirement of informed permission. Athletes must receive comprehensive information regarding the incorporation of artificial intelligence (AI) in their training regimens, allowing them to comprehend and consent to the conditions that regulate the utilization of these technological advancements. The importance of transparency in AI algorithms cannot be overstated, as it necessitates a clear understanding of the decision-making processes employed by these systems. This level of transparency is crucial in fostering confidence and enabling coaches and players to make well-informed judgments. The ethical framework also identifies and mitigates biases that artificial intelligence (AI) systems may unintentionally perpetuate, necessitating ongoing awareness and adaptations to avert discriminatory tendencies. Establishing explicit definitions for accountability and liability is important to attribute responsibility for the consequences of actions driven by artificial intelligence (AI).

Furthermore, athlete autonomy is maintained, allowing them to have authority over the incorporation of AI into their training programs. To safeguard the application of AI in sports training from potential ethical pitfalls, a comprehensive framework that incorporates continuous monitoring, education, and frequent ethical audits should be established. This approach ensures a responsible and ethical adoption of AI technologies in sports training.

6 Results Analysis

This section examines the efficiency of AI-based sports training efficiency using public dataset on long-distance running training in 2019 and 2020. The dataset consists of 10,703,609 records from 2019 to 2020 from 36412 athletes. AI techniques, specifically deep learning, are used to analyze the dataset and predict athlete performance. The deep learning network consists of various layers that utilize the SoftMax activation function to predict student performance. This process helps to derive athlete's training strategies and identify challenges for fu-

ture training. The effective utilization of the activation functions and process helps to derive the athlete's various activities. Then the obtained sample result is illustrated in Fig. 3.



(a) Efficiency analysis of various epochs (b) Efficiency analysis of various data

Fig. 3. Efficiency analysis on deep learning based sports training

Fig. 3 illustrates the efficiency analysis of the Deep Learning technique-based sports training process. The utilization of deep learning models, particularly neural networks, in an AI-driven sports training system enables the attainment of a notable level of accuracy, ranging from 90% to 97%. These models possess the ability to extract intricate patterns and correlations from extensive datasets. The models undergo training using large datasets, which encompass past player performance, game recordings, and coaching notes. This training process aims to cultivate a thorough comprehension of the sport and the various elements that contribute to effective training and performance. The training phase of deep learning models encompasses several epochs, during which the model undergoes repeated learning and parameter refinement to enhance its prediction skills. The model's ability to grasp nuanced nuances and subtleties within the data improves as the number of epochs increases, resulting in enhanced accuracy in its analysis and suggestions. Moreover, the presence of extensive datasets is essential for the AI-driven sports training system to attain such exceptional precision. The model's ability to generalize and make correct predictions improves when it is exposed to a larger volume of data. The system has the ability to develop a thorough comprehension of the sport, player behavior, and training tactics by utilizing various data sources such as video footage, sensor data, and textual records.

The AI-based sports training system incorporates a range of deep learning architectures to address its technical requirements. These architectures include convolutional neural networks (CNNs) for analyzing images and videos, and transformers for processing coaching notes and player feedback in natural language, and multi-modal models that integrate diverse data modalities to offer comprehensive insights.

The deep learning models are trained utilizing sophisticated optimization techniques, including gradient descent and adaptive learning rates, in order to effectively explore the intricate parameter space and achieve convergence towards an optimal solution. Furthermore, the utilization of transfer learning and data augmentation techniques is frequently employed to improve the performance of the model, especially in scenarios when there is a scarcity of training data. Likewise, the optimization techniques are incorporated with AI techniques that effectively reduce the classification and optimization problems. In addition, the optimized learning techniques help to improve the further learning process in sports industries.

7 Conclusion

The paper discusses the integration of AI into sports training, highlighting its transformative impact on revealing athletes' full capabilities. AI spans multiple domains, including tailored training programs, enhanced coaching tactics, and injury prevention and recovery initiatives. AI partners in augmenting athletic performance, providing customized training addressing unique strengths and weaknesses, simplifying preparation, and enabling flexible adaptations informed by insights and performance data. AI's importance is particularly evident in injury prevention and rehabilitation, where its analytical capabilities are crucial for identifying potential hazards and

implementing proactive measures and strategies. Integrating AI into the sports community must prioritize ethical considerations to ensure these technologies function as instruments of empowerment, not harm or abuse. Guaranteeing a harmonious equilibrium between innovation and ethical dimensions is imperative to optimize AI's advantages in sports training.

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