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The Practical Application of Embedded AI in the Field of Sports

Siqi Wu

Beijing-Dublin International College, Beijing University of Technology, Beijing, China
wusiqi2025@outlook.com

Abstract. This paper mainly studies the application of embedded Artificial Intelligence (AI) in the category of sports. Embedded AI is playing an increasingly important role in the field of sports. Then this paper introduces the specific application scenarios of embedded AI in the field of sports. The application of embedded AI in motion scenarios is classified by application purpose, including body condition assessment, sports analytics and visualization system. In the introduction of each application, this study starts from its necessity and then analyzing the technology it uses. The research covered a wide range of different groups. These include professional athletes, amateur athletes, referees in competitions, etc. As an application, each of these technologies considers its feasibility in reality. Some of these technologies are already mature, such as the wearable devices mentioned in this article. This technology has been widely used in people's lives. Others are in the experimental and research phase to be put into use in the future. Then this paper explains the comprehensive application of TinyML in the category of sports, such as sports real-time commentary. In the following paragraphs, this paper discusses the current challenges from interpretability, applicability and convenience. In view of the above three challenges, this paper gives the possible direction of solving the problem in the future. Overall, this paper summarizes the uusage of embedded AI in the sports world, with its usage in some specific scenes as the main body.

Keywords: AI sports, TinyML, machine learning

1. Introduction

Sports are fairly common in modern people’s lives. As a diverse industry including professional sport, athletics, health preservation, daily exercise and facility management, sports industry professionals are confronted with many challenges [1]. Firstly, in terms of professional sports training, many coaches are short of scientific knowledge about adolescent growth and development characteristics of children and youth, unable to give accurate training plan, which causes injuries even in the long run [2]. Secondly, based on the principle of fairness, sports events such as gymnastics and diving, which require subjective scoring by judge, set higher requirements for the standardization of movements. Moreover, in people's daily exercise, incorrect movement actions and excessive physical activity will cause a series of health problems. These issues ought to be avoided by conducting real-time monitoring of each movement and promptly making corrections. However,

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it is obviously impractical to request real-time guidance from the coaches during every single exercise. Even a large proportion of the participants in the sports activities never paid attention to relevant information. In this case, the effect of exercise has the opposite effect. In order to prevent such a situation from occurring, Artificial Intelligence (AI) is embedded in that it has the potential to assist coach, professional referee and even doctor to a great extent.

Tiny Machine Learning (Tiny ML), as an application method of embedded Al, refers to emerging machine learning, expanding ubiquitous intelligence by squeezing deep learning models into a great number of small Internet of Things (loT) devices and microcontrollers under uniform control [3]. Embedded AI has been put into practical use in field of industrial automation, smart city, autonomous driving health care etc. For example, in the medical field, sensors are able to generate sufficient data and perform data analytics, classification, and predict healthcare conditions [4]. The physiological state of a person during exercise is precisely reflected by this data, making it possible to applied in the field of sports. From healthcare to sports, the portability of the equipment is a problem that every sports participant may take into consideration. Fortunately, whereas powerful processors and Graphics Processing Units (GPUs) have a high requirement of power, it is TinyML that has a significant advantage of high energy efficiency due to its Microprogrammed Control Unit-based (MCU-based) solutions [5]. The low cost also makes it possible to put it to wide use.

This paper will introduce embedded AI from the following aspects, the second section introduces usages of embedded AI in this specific domain, the third section discusses the challenges and future prospects and the fourth part will be the conclusion.

2. Applications for TinyML in sport

2.1. Body condition assessment

Athletic injury is a trouble that most athletes need to confront, which is caused by both intrinsic factors and extrinsic factors. Among the complex factors, training errors become the most common cause. Even without errors, high intensity training often leads to physical fatigue. Therefore, the detection and quantification of exercise-induced fatigue seems extremely important. Wearable devices utilized TinyML may be helpful in supervising the correctness of athletes' movements in actual time and providing more useful information [6]. To monitor these data researchers have made a series of multiple-dimensional attempts.

Sports watches have become more ubiquitous in modern people's lives. They are often associated with mobile phones, computers, etc. and also have the function of monitoring various physiological indicators of the human body. If any abnormal physical indicators occur during the training process, the watch will give a prompt to stop exercising and offer more reasonable suggestions in the next time. TinyML played an important supporting role in it. By automatically identifying stress through a series of complex data including Galvanic Skin Response (GSR), Photo Plethysmogram (PPG), electrocardiogram (ECG), and respiration. ML models need to fulfill the detection job under conditions of limited hardware. In the future, the hardware facilities within are expected to achieve further technological advancements, becoming tinier, more convenient and lower cost [7].

Wearable Technology is not limited to the most common type - the sports watch. In the professional training of athletes, more wearable devices are being used. In addition to the basic physiological indicator mentioned above, biomechanics sensors and location sensors are also used in some specific scene [8]. For example, Inertial Measurement Unit (IMU) is composed of multiple sensors which was not commonly used in small devices in the history. With the micro-electromechanical system (MEMS) IMU was introduced recently, its low cost, compact, and low

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processing power attracted many researchers. They make full use of it to determine movements through captured acceleration, angular velocity, and rotation [9].

To further enhance practicality and feasibility of TinyML in data monitoring, researcher are attempting to skillfully integrate different approaches. For example, a latest experiment led by Yuqiu Zhan combines wearable Inertial Measurement Units (IMU) and Photoplethysmography (PPG) data and deploying lightweight deep models on ultra-low-power MCUs, trying to improve the accuracy and minimize the energy loss [10].

2.2. Sports analytics

In the application process of TinyML in the field of sports, people do not merely limit its use to the analysis of the individual athlete's performance. Instead, it is also applied to more complicated sports competition strategies such as team-based sports.

In soccer matches, it can be observed that during live broadcasts relatively complex data such as players' passes can be quickly calculated. This is due to Streaming Machine Learning (SML) and Edge Computing, which are now fused and used in sports analytics. High-velocity sensors are embedded in players’ shoes and shin guards. To adapt to this rather special sports scenario, researchers compared various models and used TinySML-P as a real-time statistical model to address its particularities. Compared to TinySML, Continual Learning (CL) is not adopted by people due to its previous characteristics and the fact that it is not compatible with the hardware in this scenario [11].

In addition to dealing with analyzing relatively complex sports tactics, TinyML can also predict and deeply analyze athletes' movements based on external sensors. For example, in table tennis, where small changes in a player's movements are enough to cause huge differences in rotation, angle, and speed, a scientific analysis that incorporates TinyML can be extremely useful. By collecting the signals gathered by the hand sensors, the researchers categorized these signals by type of action. The system can achieve more than 90% accuracy in the subsequent prediction of movements. It is expected that the same analysis will be done for more complex movements [12].

TinyML not only analyzes the action in detail, it can also be used as an important part of a multi-dimensional analysis of the game. Various tools allow to observe the game from multiple angles, from the athletes' physical fitness (monitored by the physiological indicators above), specialized movements, tactical movements, etc., and to gain a better and more comprehensive experience of the game [13].

2.3. Visualization system

Wearables can't exactly be used in all sports, and when dealing with these particular sports scenarios, researchers have to visualize them so that every detail can be captured by the researcher.

Conventional approaches to computer vision show its limitation when applying to sports field due to the fact that the computer relies on the extracted definition of the already determined goals [14]. Fortunately, TinyML updated the process and skip the object classification by using machine learning algorithms. As an outcome of the progressive model, researchers tried to analyze pugilism sport gesture with it after the process of collecting data and onboard Bluetooth Low Energy (BLE) radio.

With the development of data visualization, a series of visualization systems supported by A have become a powerful assistant for coaches to instruct athletes. Observation analysis includes these collected data, allowing athletes to pay more attention to their weaknesses. While coaches in the past

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tended to be biased in their statistics from the game through video, AI is now able to visualize formations, techniques, etc. by learning from the videos. AI plays a good role in simplifying and refining it [8].

3. Discussion

All of these technologies mentioned above play an important role in their respective scenarios of application. At this point, practitioners have also thought of combining these technologies to play a greater role and analyze more complex and changing real-world problems. Currently, as people monitor and visualize the trajectory of the field, the players and the ball, a match commentary with high accuracy in all aspects of the judgment has entered people's vision. Single tech technologies are constructed as a whole. Through modeling, this technology takes from object recognition to event understanding and gives accurate feedback to the audience, giving people a better viewing experience [15]. While synthesizing technology and achieving breakthroughs, this research also faces challenges related to adapting to real-world scenarios. Some of the questions to be addressed by researchers are as follows.

3.1. Chanllenges

3.1.1. Interpretability

In modern time, when AI is widely used in various fields, its interpretability has also become a great issue. Machine learning is questioned when it is applied to specific areas such as healthcare. It is difficult for people to fully trust AI in this type of field [16]. From the above assertion of the relevance of the sports field to the medical field, it is easy to learn that the same skepticism that black box methods were expected to face would have been present in his judgment in relation to the various indicators of the human body in sports. Similarly, when working with AI-assisted referees, the judging process is similarly questioned due to the quest for fairness in sporting events.

3.1.2. Applicability

In the course of the research, researchers tend to select specific groups of people to study. For example, when being specific in some sport activities researchers usually prioritize top athletes over general amateurs. However, since the movement specialization of different groups is extremely different, this is likely to affect the accuracy of AI prediction and instruction. The breadth of its application has been greatly questioned [17]. The average hobbyist is looking for more systems tailored to them to more accurately respond to real-world problems.

3.1.3. Convenience

One of the considerations that everyone who actually participates in sports has when choosing this type of equipment is whether it is lightweight and easy to wear, without interfering with their movements. For this reason, wireless devices have a huge advantage over wired devices. However, developers have encountered many problems in adopting wireless technology. Finding the right sensor, wireless technology and designing the right wireless network technology for each individual project is complex. It requires significant development costs [18].

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3.2. Future prospects

1. The tendency to shift from black-box models towards white-box models has become more pronounced in some key areas. This is precisely because experts in different fields such as finance, healthcare, etc. need models that are accurate and easy to understand [19]. If people are willing to commit to accomplishing this change in sports, especially in the scoring of play action and other penalties, it will be a chance to see the longer term. The future of fairness in sport will be strongly supported.

2. To cope with the applicability issue, researchers are considering a more refined longitudinal grouping of the study population. The grouping is divided into different levels according to their level, which will be used to accomplish more accurate guidance [17]. The same Exercise participants can perform very differently in different exercise scenarios. For example, amateurs exercise for fitness and relaxation purposes, athletes train for better performance, and athletes are at their limits when they are trying to win a competition, etc., each of which should be set up as a different mode.

3. Existing wireless technology with biofeedback systems cannot fulfill all types of needs in the market. There is not a single technology that works for every scenario. Feedback loop delay and other constraints are still limiting the usage of TinyML in the field of sports [18]. This requires a more in-depth study of different scenarios. Find the most appropriate combination of technologies in the process. So that wireless technology can be widely used in the field of sports. This can certainly improve the comfort level of users. It could even allow more professionals to use it in training.

4. Conclusion

This article first elaborates in detail on why embedded systems and TinyML are needed in sports. From this, it is obvious to see the unique and rich application prospects of this technology in the sports field. Then this paper introduced the specific applications of TinyML in the category of sport. These include practical application of this technology in various aspects. Consequently, different specific technologies are applied to different scenarios. Finally, this paper presented a comprehensive application that integrates various specific technologies. This study also conducted a corresponding analysis of the challenges and future prospects faced by this technology.

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