

Evolution of Sports with Artificial Intelligence

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ABSTRACT. We cannot imagine things without AI in today's world, everywhere and is playing a important role and today it's a day where we can witness that slowly and steadily Artificial Intelligence creeping in into sports as well features like augmented reality and virtual reality are revolutionising the sports. This paper is about examining the impact of technology in sports performance analysis with focus on improving performance of athletes, improved decision making and improving the training methods. And also exploring the challenges of introducing technology into existing practise and also providing solutions to overcome the hurdles and emphasizes the role of DV, AI, VR and AR in revolutionizing the field. Also looking into the success stories of AI into non- sports industry and insights from sports science experts we are able to identify the challenges to apply technology like AI in Elite sports with focus in particular on AI controllability, Data collection an explainability of results. These findings are further more distilled into major key challenges faced by the community of sports analytics providing the road map for research in future and its application.

1. Introduction

Mimicking human behavior with the help of technology is known as Artificial intelligence or AI. This had already fascinated the researchers with its history tracing to early mechanical innovations. It was after 1950's that AI emerged as a formal field with computer technology and also has experienced rapid growth and at times stagnation referred to as AI winters. But it did witness a rapid growth in late 1990's. This was all because of breakthrough in deep learning, machine learning, increasing computational power and emergence of big data. These were the factors that allowed data to penetrate various aspects of daily life right from the virtual assistant Siri and Alexa to autonomous vehicle and the victory of Alpha Go in 2016 which was historic over the world's best Go player. AI's growth has been rapid and widespread and advancements that seemed unimaginable. Now, slowly and steadily AI is also making advancements in sports. The example of athletics in Oakland in early 2000's called Moneyball approach, where machine learning driven statistical analysis revolutionized player recruitment and team strategy. The AI has so evolved in sports that its slowly and steadily helping in decision making for the referee which is called goal line technology also in rehabilitation to training to planning.

2. Research Methodology

- Evaluation of Impact of AI on sports
- Accessing the AI and VR role in Athletic coaching and training
- Examining the application of data visualization in analytics of sports
- Proposing a framework for including AI in sports

- Identifying the Solutions and also the challenges for implementation of AI technology

3. Literature Review –

The review was carried out using great deal of research on both sports specific and general academic data base. The primary data bases include

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Google Scholar

Journal Shortage

Springer Link

A total of 540 publications in 7 countries with 9 different experts. The countries were Austria, Australia, Cannada, China, Germany Russia and Switzerland. Out of 9, 3 experts were hired at main national institute of elite sports in their respective countries. While the 6 others were affiliated with sports science as faculty at universities

- ## 4. Current and complete projects –
- The information of current and completed projects in the field of elite sports was provided by the interviewee

Technologies used – The technologies utilized are divided into four different methods (image processing, signal processing modelling and planning and user interaction).

Benefits and challenges – The benefits of AI and challenged face were highlighted and discussed by the experts.

Future Prospects – The future directions of AI in elite sports including potential advancements, some areas that required more

investigation were the insights provided by the interviewee.

5. Data Analysis –

Qualitative data –

The data obtained from the interviewee was transcribed and analysed by using thematic analysis. In this the interview are coded to determine the themes and patterns related to the application of AI in Elite sports. This helps in understating the practical benefits and challenges with the perspective of experts who are closely involved.

Quantitative data – This involves the analyzation of the literature involved the distribution of AI applications across various sports.

Ethical Consideration – This information was primarily utilized for the research purpose and the interviewees were not allowed to reveal any data outside

6. Overview –

This Review offers an comprehensive examination of historic development and growth of performance evaluation in sports science. This gives a view of both shortfalls and advantages of current practices. It also offers precise overview and definition of all keys topics.

Then the focus shifts on the emerging technologies, which includes AI, VR, AR and DV. We identify how AI streamlines the collection of information and its processing also discuss the roles of AR and VR in creating and truly connective and interactive training environment and also evaluates the DV's ability of simplifying the compound information into simple visual data

It gives a vast scope of this topics and each could have a dedicated review. This paper emphasizes on the previous background and current trends in evaluation of performance.

7. Performance Analysis –

It is a methodological procedure of documenting, analyzing and interpreting data to enhance performance of a team or an individual. Which includes keeping a track of important performance matrix which varies across sports including tactics, skills as well as physiological markers. in both training and competition. Beyond this it also prevents injuries and talent identification. Common methods used include observational, video,

notational, information from wearable technology, time motion analysis each offering distinct perspectives on sports performance.

8. Methods of Analysis –

Observational Method – In this method the data is directly collected by observing the performance of the Athlete in sports event. This approach provides precise assessments of the SWOT of an Athlete. This can be done without any tools and with the help of some supporting data.

Video Analysis – In this method the game and recorded and then observed carefully frame by frame which helps the coach, team and the Athlete to know how the team is playing which are the tactics being used, movement of the players etc. and also helps to scrutinize every action

Notional Analysis – These records the discreet incidence that takes place during practise and also during the match. After that these occurrences are coded to quantify the data. This data provides insights on the efficiency of the tactics, strategies and action of an individual also the data provides objective record of the performance

Time Motion Analysis - This method involves tracking and categorizing an athlete's motion during a workout or a game to measure the physical demand of the sport. It offers valuable data on the duration, intensity, and frequency of different actions, as well as the intervals of rest. The insights gained are used to inform training and recuperation strategies and assess players' physical performance throughout competitions.

Analyses of data from wearable technology – This is gaining prevalent in games. Tools like accelerometer, heart rate monitor and GPS tracker are commonly utilized. These devices measure biochemical and physiological data including distance travelled, heart rate and speed. Body temperature and sleeping patterns. Analysts use this data to monitor athlete health, assess physical demands in games and training and improve performance.

9. How AI can Contribute to sport performance analysis

Sports performance analysis is the only one of the many industries that AI has revolutionized including finance, health care, automobiles and entertainment. Traditional method of gathering, interpreting and processing data have been altered by the use on AI in sports analytics.

More accurate and scalable data is made possible by AI powered solutions which do away with the bias and constraints of manual collection of data. Beyond this AI is highly skilled at processing and analyzing enormous volume of data, revealing trends and insights that a human analyst would miss. In addition to reducing the data more manageable levels, this capability reveals insightful information that can improve performance and guide strategy creation. Furthermore, AI's ability to learn from historical data allows it to continuously increase its accuracy of its prediction, yielding even more useful insights.

AI has transformed video analysis in sports –

This allows it to be more quick and detailed than old manual procedures, computer vision and machine learning algorithm can track and analyze objects and players motion delivering realistic data that improves comprehension of tactics formation and player performance. This technology also help uncover trends in opponents strategies provide an competitive insight that can otherwise overlooked by subjective analysis. AI can be used to identify certain movements in sports allowing semi-automatic or fully automated analyzing system. Furthermore, computer driven AI contributes to injury prevention and recovery by accessing biomechanics and unsafe movement patterns as well as recommending technique improvements to reduce injury risk.

AI automates action identification and recording, leading to more accurate and efficient notional analysis during play. For example: computer vision and machine learning. Alternatively swimming stroke allows for complete event tracking. AI can analyze extensive game footage to assess the efficiency of strategies and tactics based on player action over a period of time. AI is transforming real time and motion analysis by providing insights into player's energy expenditure and tiredness leading to more effective player management and substitute decision.

Real world sports demonstrate AI's practical impact

-Which influences strategies and shapes how data is used in decision making. AI's productivity is crucial for reducing by analyzing wearable technology data and recommending specific training adjustments. AI driving sports analyses has led to advancement of video analyses tools, motion tracking system and GPS tracking system from firm's like Kinexon™, Short Tracker™, Second Spectrum™, Catapult Sports™, Stat Sport™, Hudl™. This advancement has significantly increased the tools available to athletes, Coaches and Analysts resulting in data driven performance increase. AI is transforming sports performance analyses in several aspects, including:

- **Collection of Data:** AI replaces traditional methods with precise, large-scale data collection, minimizing bias.

- **Advanced Analysis of data:** AI automates data analysis, revealing hidden patterns within large datasets to improve performance and inform strategies.
- **Improved Video Analysis:** AI accelerates video analysis, delivering more detailed and accurate insights into movements of the player and, team formations tactic.
- **Analysis of Notion:** AI automates the annotation of specific actions, and recognition making notational analysis accurate and efficient.
- **Analysis of Time and Motion:** AI transforms time-motion analysis, giving up to date information on weariness and energy use to optimize player substitution.
- **Data Analysis of Wearable device:** AI processes real-time data from wearable technologies forecasting health hazards and recommending tailored programmes for trainings.
- **Prevention of injuries:** AI analyses biomechanics to detect harmful patterns and suggest modifications, improving player safety and injury prevention.

10. Augmented Reality and Virtual Reality in Performance Analysis of sports

AR and VR are transforming training, sports coaching and analysis of performances, offering new ways for the athlete to improve skills and strategies. These are remodeling traditional training methods by **providing** interactive and **controlled** environments that promote skill refinement, team coordination, and injury prevention. By simulating real-world scenarios, VR allows athletes to train in complex, dynamic settings, while AR provides real-time information and feedback.

VR's capabilities are in its ability to recreate realistic training conditions where athletes can practice specific scenarios repeatedly, improving decision-making and technique. In contrast, Physical environment is overlaid by the AR's digital transformation, offering athletes immediate tactical insights, such as a player of soccer getting real

time feedback during a game. AR is also beneficial for coaches, who can visualize strategies and formations using virtual markers and lines to improve team performance. Spectators can also benefit from AR, with

statistics and dynamic graphics enhancing their viewing experience.

These technologies create immersive training, from 360° VR to using pre-recorded video to computer-rendered environments that adapt to user actions. These environments replicate sensory feedback, helping athletes refine the skills with real-time feedback that accelerates skill development. While AR and VR are extremely promising, and not suitable for all sports—especially those that rely on tactile feedback, like swimming—and current technical and cost barriers limit widespread adoption. Moreover, the skill transfer from virtual to real-world scenarios is still debated, though these innovations show great potential in rehabilitation, where virtual environments can assist in recovery and injury prevention.

In addition to physical training, AR can be used to improve mental preparedness, Cognitive ability and the ability to make decision under stress. By reducing the gap between mental clarity and physical fitness, these technologies provide a new way to improve psychological readiness in addition to physical performance. The following are the main ways that AR and VR can transform sports performance analysis:

Immersive Environment for Training: AR and VR create lifelike scenarios for athletes to receive real-time feedback during training.

Skill and Strategy Development: allowing repetitive practice of game strategies, enhancing tactical and technical proficiency.

Insights about Tactics: athletes are provided with instant, on-field information to support strategic decision-making with the help of AR.

Real-time Feedback: Athletes can adjust their performance mid-training based on instant data displayed in the vision of their field.

Data-Driven Decision taking: players and coaches access detailed metrics to make informed, tactical choices.

Rehabilitation Support: AR and VR aid in injury recovery and prevention by offering targeted virtual exercises.

Mental Preparedness: These tools help athletes sharpen their cognitive abilities, such as reaction times and decision-making.

Performance Visualization: AR and VR allow

athletes to better comprehend performance information, leading to improved mental and physical performance.

Enhanced Spectator Experience: AR enriches real-time stats and graphics live broadcaster offering deeper game insights for fans.

11. Performance Analysis by Data Visualization (DV) in Sports

Complex data is made easier to grasp by data visualization which transforms it into visual format such as heatmaps, motion paths and scatter plots. With the use of these images athletes, analysts and coaches may find trends, derive important insights and make data driven choices. Data visualization provides great knowledge of tactics and positioning by exposing hidden data, such as an athlete's field motions, that traditional statistics are unable to capture.

In addition to providing raw statistics, DV's craft stories that provide more insightful nuanced understanding of performance. Data visualization tools can analyze elements including player positions, shot attempts and velocity by merging data from wearable technology tracking systems and records. For instance, a soccer player's tracking data visualization is possible as a heat map showing high-activity zones on the field. Other techniques, like scatter plots and bar graphs, present information on sprint speeds, shot accuracy, and endurance. This helps coaches track performance evolution and adjust training and strategies.

Additionally, DV draws on previous data which creates a trend line, helping teams identify weaknesses strengths, and improvement areas. Real-time data can also be presented on dynamic dashboards, enabling better decisions. With the help of DV, predictions about future performance seeing present data and past trend can be made.

Key areas where DV impacts performance analysis in sports:

Simplified Data: difficult information or data is made easier to interpret.

Insight Extraction: DV uncovers actionable insights, supporting informed decision-making.

Tactical Analysis: Visualizations, like heatmaps, help in analyzing player movements and tactics.

Narrative Building: DV creates visual stories that enhance understanding of the game.

Real-Time Decision-Making: Live dashboards with stats allow for timely, informed decisions during matches.

Historical Trends: DV identifies trends and performance patterns, aiding in strategic planning.

Predictive Analytics: on bases of past and present data, DV enables predictions on team performance and player contributions.

Tools that can be used –

1 Stat Sports:

Uses Tracking the performance of the players

How it works

It tests players speed, movement, heart rate and other metrics through wearable GPS device. It processes detailed analysis which helps the coach in training and also helps the athletes.

2.Hawk – eye innovation

Use – Sports officiating and referee decision support

How it works

It uses cameras which can track faster movements. It tracks the movements of the ball in tennis, football and cricket and also interaction between the players.

3.Second spectrum

Use – advanced level of analysis in sports like basketball and football.

It uses Machine learning and AI to analyze video footage and track movements of the players and also interactions between them. Provides deep insights player performance, strategy effectiveness, and predictive modelling

4.Catapult Sports

Use: Athlete monitoring and performance analysis.

How It Works: Catapult combines wearable devices with AI to monitor athletes' biometrics, including speed, acceleration, and heart rate variability. The AI tools help predict injuries, optimize performance, and fine-tune training programs.

Sports: Rugby, basketball, football, and more.

5 WY scout

Use - Scouting and player performance analysis.

How It Works: WY scout provides AI-driven video analysis and statistics for scouting and evaluating football players. The platform analyses match data, tactical information, and player movements, allowing clubs to make informed transfer decisions.

Sports: Football (soccer).

6 Zone7

Use -Injury prediction and prevention.

How It Works: Zone7 uses AI to analyze players' physical data and predict injury risk. It processes historical and real-time data to provide actionable insights, helping athletes avoid injuries through smarter training loads and recovery strategies.

Sports: Football, rugby, and others.

7.Kin duct

Use -Athlete data management and analysis.

How It Works: Kin duct's AI platform integrates and analyses various types of data (biomechanics, physical testing, wellness) to give coaches a 360-degree view of athletes. It helps in injury management, performance optimization, and team selection.

Sports: Multiple sports, including basketball, football, and hockey.

8.Coach AI

Use Personalized training programs.

- **How It Works:** Coach AI uses machine learning to deliver customized training programs to athletes based on their performance data. It continuously adapts training plans as the athlete progresses, providing real-time feedback.
- **Sports:** Fitness, football, running, and more.

9.Shot Tracker

- **Use** Real-time basketball performance tracking.

- **How It Works:** Shot Tracker uses sensors on players and basketballs, combined with AI, to deliver real-time statistics during games. It tracks metrics such as shooting accuracy, player movements, and shot charts, offering valuable insights for coaches.

- **Sports:** Basketball.

10. Player maker

- **Use:** Football player performance analytics.
- **How It Works:** Player maker is a device attached to players' boots, tracking foot movements, ball touches, and overall gameplay. AI analyses this data to perception on the performance of the player, technique, and workload.
- **Sports:** Football (soccer).

11. Homecourt AI

- **Use:** Basketball skills development.
- **How It Works:** Homecourt uses AI to analyse basketball drills, shooting form, and movement patterns using just a smartphone camera. It offers real-time feedback and progress tracking, helping players improve their skills.
- **Sports:** Basketball.

12. Hudl

- **Use:** Video analysis and performance review.
- **How It Works:** Hudl provides a suite of video analysis tools powered by AI. Coaches and players can break down games, analyse strategies, and review player performance. The platform integrates AI to automatically tag key moments in games for deeper tactical insights.
- **Sports:** Football, basketball, volleyball, and more.

13. Deep eye Sports

- **Use:** Football match analysis.
 - **How It Works:** Deep eye Sports uses AI and computer vision to analyse football games, identifying tactical patterns, player of the player, and strategy optimization. It helps analysts and coaches understand game flow, ball movement, and positioning.

14. Sports: Football (soccer).

These AI tools are revolutionizing how sports teams, athletes, and coaches operate, providing more precise, data-driven insights that allow for improved training, better decision-making, and enhanced performance.

12. Challenges:

Data Privacy – As the data of the individual is collected there are possibilities that data can be steered which creates risk for the individual

Bias and fairness – Biases can be introduced in the data by AI and hence biased results are the output

Ethical Consideration – The AI needs to be addressed with the ethical considerations

Cost of Implementation - It involves huge amount of money and it hinders the accessibility to all sports.

13. Future Direction –

Based on the ideas covered we suggest an integrated performance analysis model that extends to include the many technologies that we have looked at here in addition to conventional method for data assessment. This approach upholds performance analysis core goal which is to improve athletes' performance. Information Technology goes one step further though, by describing the smooth data flow at each step of this procedure. Further more it emphasises how crucial sports analytics are as the hub of data **processing it is important to remember** that analyst is crucial to extraction of key performance indicators, a notion that applies to both established and novel methodologies. As previously stated traditional approach have historic legitimacy and particular advantage but they are not without.

14. Conclusion –

The future of sports performance analysis, driven by the integration of AI, VR, AR, and data visualization, is full of potential. Although substantial advancements have been made, we're still at the early stages. With ongoing research, collaboration, and innovation, the peak of data-driven, tech-enhanced sports performance is within reach.

15. REFERENCES

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