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Advancing the Game: AI and IoT Applications in Football

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Abstract

Football, with over 270 million players worldwide, is increasingly influenced by emerging technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT). This paper examines the integration of these technologies in modern football, emphasizing their roles in player health monitoring, officiating accuracy, and performance optimization. Key applications discussed include IoT-based systems for real-time health supervision, Video Assistant Referee (VAR) and goal-line technology for officiating, as well as innovations like the Al Rihla smart ball and FIFA Player App showcased during the 2022 World Cup. These advancements not only provide coaches and referees with enhanced data-driven insights but also contribute to reducing injuries and improving tactical strategies. Unlike previous reviews, this study offers a comprehensive synthesis that bridges both AI and IoT applications in football, incorporating recent case studies and highlighting underexplored intersections such as predictive injury prevention and AI-driven tactical modelling. The findings indicate that these technologies enhance decision-making, improve player safety, and promote overall game fairness. The study concludes by identifying future opportunities for deeper integration of IOT and AI-driven analytics, such as predictive injury prevention and advanced player performance modeling, to further advance the sport.

Keywords: Artificial Intelligence, Internet Of Things(Iot), Video Assistant Referee(Var), Goal-Line Technology, Football, Al Rihla, Soccer

1. Introduction

Provide background, motivation, and significance. Identify gaps in prior research and state objectives. End with a summary of the paper's organization.

The 21st century has witnessed two transformative technologies: the Internet of Things (IoT) and Artificial Intelligence (AI). IoT enables the connection and control of physical objects via the internet, while AI emulates human intelligence to automate decision-making. Together, they have revolutionized various sectors, including football, reshaping both fan engagement and player performance.

In football, the convergence of IoT and AI allows real-time monitoring of player performance, offering coaches data-driven insights for improved decision-making. AI also enhances user experiences by delivering personalized recommendations and precise data analysis. This research explores a range of AI and IoT applications in football, beginning with IoT-based systems for player supervision that inform coaching decisions and mitigate health risks.

Further attention is given to the influence of Video Assistant Referees (VAR) and IoT-based systems for detecting out-of-play balls, both of which aim to improve refereeing accuracy (Rao and Sridhar, 2018, He eta al, 2021) The final segment highlights innovations from the 2022 FIFA World Cup in Qatar, including the Al Rihla match ball and the FIFA Player App—technologies that represent the forefront of football's technological evolution (Spitz et al, 2021).

2. Literature Review

Nowadays, technology provides a huge amount of services that are increasingly convenient, safe, and reliable. Several recent research efforts have focused on developing football game monitoring systems using IoT and AI systems. This paper sheds light on a set of techniques used in football based on IoT and AI. Presenting the benefits of these technologies and their impact on all aspects of the football system.

Football was a game based on 22 players, meaning that the human element was the most important part of the game. The digital transformation of healthcare has enabled a new wave of healthcare solutions that made use of the Internet of Things (IoT) to provide access to better and more efficient healthcare services. In particular, IoT healthcare systems have been widely used in sports to provide enhanced monitoring and surveillance of athletes.

(Rao and Sridhar, 2018) explored a novel technique used in football that offers several advantages, particularly in supporting medical staff to anticipate and address potential health issues in players. Their study compared this modern approach with traditional methods that aimed to achieve similar goals but were often limited by various challenges. In a fast-paced 90-minute match, referees are under constant pressure to make accurate decisions in real time, often in front of thousands of spectators. Any error can unfairly impact the outcome for

one of the teams. This underscores the importance of introducing supportive technologies to assist referees in making fair and precise judgments. One such innovation is an IoT-based system designed to detect when the ball goes out of play, helping officials make faster and more accurate calls.

(He et al., 2021) proposed a system to address the various factors that contribute to referee errors during football matches. Their solution involves the use of infrared sensors positioned around the edges of the pitch, along with embedded sensors in the ball itself. Together, these technologies help determine with precision whether the ball has gone out of play, reducing the burden on referees and improving the accuracy of in-game decisions.

In parallel, the use of the Video Assistant Referee (VAR) system has significantly impacted how referees make decisions. Studies have shown that VAR, which allows officials to review incidents in slow motion from multiple angles, can enhance decision-making in critical scenarios such as goals, penalties, red cards, and cases of mistaken identity. However, some research also suggests that slow-motion reviews may sometimes lead to stricter judgments than necessary.

These innovations reflect a broader trend in football toward embracing advanced technologies—especially those powered by the Internet of Things (IoT) and Artificial Intelligence (AI). For example, the 2022 FIFA World Cup in Qatarvoted the best World Cup of the century in a (BBC Sport poll, 2022)—was notable for its use of such technologies. Qatar introduced several groundbreaking systems to enhance the accuracy and fairness of the game.

One of the most prominent examples was the integration of AI into the VAR system. Adidas, in collaboration with FIFA, developed the Al Rihla match ball, see figure 1, which included a sensor capable of capturing movement data at 500 frames per second. Additionally, twelve specialized cameras tracked both the ball and player positions in real time, significantly improving offside decisions.(Ponsano, 2020)

Another innovation debuted at the tournament was the FIFA Player App, which gave players access to personalized performance data immediately after each match. The app provided detailed metrics covering physical performance, gameplay statistics, and football intelligence—based on tracking data, event analysis, and expert input from FIFA's performance analysts.(Maria, 2025)

As noted by (Ponsano et al.,2020), there is still a need for a comprehensive review that covers the full scope of these emerging football technologies. Such a review would help provide a clearer understanding of how AI and IoT are reshaping the game for players, officials, and fans alike.

Figure 1**: The Al Rihla IoT-enabled football used in the 2022 FIFA World Cup in Qatar **(Adidas Al Rihla,2023)

3. Football Technology Applications

IoT-Based System For Footballer Healthcare Supervision

An IoT-based system for footballer healthcare supervision could involve the use of wearable devices that track and monitor various health indicators of football players (Ikram et al, 2015). Figure 2 illustrates the proposed architecture of the footballer supervision healthcare system, showing the interaction between wearable sensors, wireless communication, central processing, and healthcare decision-making.

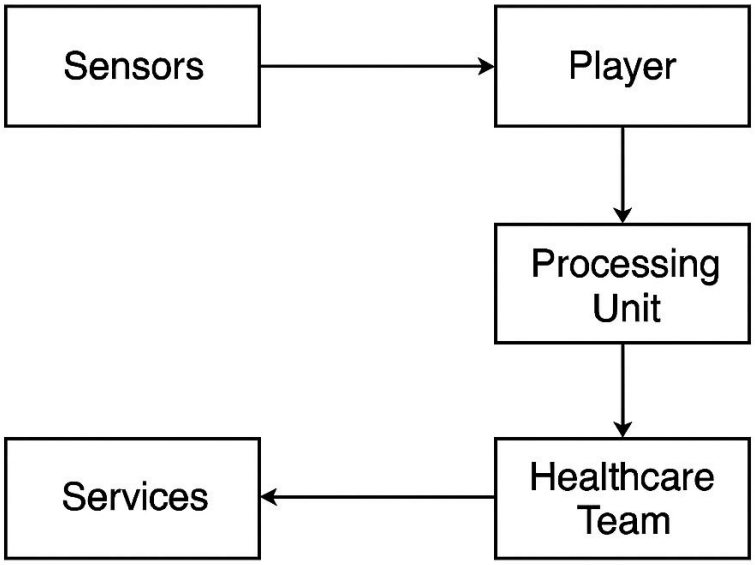

Figure 2: The Architecture of the Footballer Supervision Healthcare System

These devices could include sensors to measure things like heart rate, respiratory rate, and body temperature, as well as more specialized sensors to monitor things like muscle fatigue and strain (Yang et al, 2021), and location(Lv and Li, 2022). The data collected by these devices could be transmitted wirelessly to a central server, where it could be analyzed and used to identify trends or potential health issues. For example, if a player's heart rate or body temperature is consistently elevated during training sessions, it could be a sign of illness or over-training. By monitoring these indicators in real-time and using AI, coaches and medical staff can take proactive measures to ensure the players are healthy and able to perform at their best (Pilka et al, 2023).

The Architecture Of Footballer Supervision Healthcare System

Wearable devices: These sophisticated instruments are designed to be worn by football players, featuring an array of sensors meticulously calibrated to measure an assortment of crucial health parameters. Examples of these wearable devices encompass but are not limited to smartwatches, fitness tracker bands, or specialized sports performance monitors (Aroganam, 2019).

Modern IoT systems in football leverage a variety of sensors to capture both **biometric** and **biomechanical** data:

- **Inertial Measurement Units (IMUs):** Accelerometers and gyroscopes embedded in vests, footwear, or ankle tags track key metrics like sprints, acceleration/deceleration, kick speed, and jump frequency—particularly useful for analyzing performance and load on specific positions (e.g. strikers, midfielders). (Rossi et al, 2017, Hexoskin, 2024, Seshadri et al, 2019)
- **GPS and LPS Systems:** Devices (such as Catapult, StatSports, Kinexon) monitor player positioning, distance covered, high-speed running zones, and positional heatmaps. These systems inform workload management and tactical planning.(Chokkattu,220)
- **Smart Vests/Shirts:** Often using chest-worn Bluetooth-connected sensors or textile-integrated biosensors (e.g. Hexoskin), these monitor **heart rate**, **heart rate variability**, respiratory rate, and body temperature in real-time(Jones et al,World Rugby, 2023)
- **Smart Insoles/Shoe Sensors:** Example: Adidas and Google Jacquard insole uses embedded accelerometers and AI to infer foot movement, kicking actions, power, and pace in real time (Hangi et al, 2017)
- **Smart mouthguards**: With mini accelerometers and gyros, they detect head impacts and concussion risks, providing immediate feedback to medical staff.(Khan et al, 2013, Cox and Hyde,1997).
- **Real-Time Data & Coaching/Medical Actionability**

IoT ecosystems transmit continuous data back to cloud or edge-processing platforms. Machine learning models classify motion patterns (e.g. sprints vs. kicks), and system alerts notify staff directly on tablets or wearables(Yaseen et al, 2025). Examples include (Jones et al, 2023, Haghi et al, 2017, Khanet al, 2013):

- **Fatigue and injury-risk alerts**: Sudden spikes in accelerations or heart rate variability decline can indicate high injury risk, prompting coaches to rest the athlete or modify training. Studies show wearable systems can forecast injuries with over 70% accuracy using ECG and accelerometer data combined with ML models.

- **Load management**: Coaches monitor cumulative high-speed distances and sprint counts to balance training intensity across the squad, limiting overuse injuries and optimizing match readiness.
- **Immediate concussion detection**: Smart mouthguards or helmets rapidly relay data on head impacts, enabling instant medical evaluation instead of delayed identification through observation or post-match screenings.

Wireless Communication: These wearable devices are equipped with wireless communication capabilities to facilitate seamless data transmission. This data transmission, integral to the system's functionality, necessitates a proficient infrastructure utilizing diverse technologies such as Bluetooth, WiFi, or cellular connectivity (Cox and Hyde, 1997).

Central Server: A pivotal element in this architecture is a highly secure, cloud-based central server. This repository serves as the storage and processing hub for the comprehensive health and performance data captured by wearable devices. Access to this central server is meticulously restricted to authorized personnel, notably coaches and medical staff, who leverage this centralized resource to monitor the health and performance metrics of the players (Yaseen et al, 2025).

Data Analysis and Visualization Tools: A suite of sophisticated data analysis and visualization tools constitutes a fundamental component. These tools are instrumental in scrutinizing the wealth of data collated by wearable devices. They encompass state-of-the-art machine-learning algorithms and specialized software packages. These tools empower coaches and medical staff to effectively analyze, interpret, and derive actionable insights from the data (Lee snd Qin, 2005, Talal et al, 2019) .

Alerts and Notifications: This healthcare supervision system is intelligently configured to trigger alerts and notifications under predefined conditions. These notifications are relayed to coaches and medical staff when certain thresholds are breached or when potential health issues are discerned through data analysis. Such real-time alerts play a pivotal role in ensuring timely intervention, guaran(teeing that players receive necessary care or prescribed periods of rest as warranted by their health status (Awolusi et al, 2019). This meticulously designed architecture synergies seamlessly to provide comprehensive health monitoring and performance assessment for footballers, amalgamating cutting-edge technology with a dedicated focus on player welfare and optimal performance on the field. The utilization of an

IoT-based system for footballer healthcare 4 supervision offers a spectrum of potential advantages, contributing significantly to the welfare and performance of the players, as well as the overall efficacy of the medical and coaching staff. These advantages encompass:

Advantages of Using Player Healthcare System

Real-time Monitoring: As discussed in the Literature Review, real-time monitoring enables proactive health management and injury prevention. This functionality empowers coaches and medical professionals to promptly identify and address emerging health concerns as they unfold, fostering a proactive approach to player well-being (Ballantyne et al,2014).

Enhanced Player Performance: The early detection and mitigation of potential health issues, made possible by IoT-based systems, translate into an environment where players are primed to perform at the zenith of their capabilities. This ensures that players consistently operate at their optimal performance thresholds (Alhalaybeh et al, 2023).

Augmented Player Safety: Through vigilant real-time monitoring of players' health indicators, coaches and medical staff gain the capacity to proactively institute precautionary measures aimed at averting injuries and preserving the overall health and safety of the players. This proactive stance is instrumental in mitigating risks and enhancing player safety (Kariuki et al, 2016, Humphreys et al,2006).

Alleviated Workload for Medical Staff: The implementation of an IoT-based system streamlines the healthcare supervision process by automating the monitoring of health indicators. This automation equips medical staff with a real-time alert mechanism that promptly notifies them of emerging issues, obviating the need for manual, individualized health checks. This enhanced efficiency in monitoring significantly reduces the workload on medical staff, affording them the bandwidth to concentrate on more complex and mission-critical tasks (Rossi et al, 2017).

Improved Team Performance: By assuring the sustained health and optimal performance of individual players, an IoT-based healthcare system invariably contributes to elevating the collective performance of the entire team. A team operating with its athletes at peak physical condition is better poised to excel, resulting in an improved overall team performance (Ullah et al, 2021) .

Case Study : Wearable IoT Devices for Player Health Monitoring

Several top football clubs, including FC Barcelona and Manchester United, have integrated

wearable IoT devices that monitor players' physiological parameters such as heart rate, body temperature, and fatigue levels during training and matches. For instance, during the 2018-2019 season, these devices helped detect early signs of dehydration and potential injury risks, enabling coaching staff to intervene timely. This has contributed to reducing injury rates and optimizing player performance through personalized training regimens.(Kanan et al, 2023)

limitations of using a Player Healthcare System

Cost Implications: The implementation and sustenance of an IoT-based system may entail substantial expenditures, particularly when incorporating specialized sensors or other high-value hardware components.

Data Security Concerns: IoT-based systems necessitate the transmission and storage of sensitive health data, rendering them susceptible to potential cyber threats. Robust security protocols are imperative to safeguard the integrity and confidentiality of this data (Ghayvat et al,2015)

Sensor Accuracy Variability: The precision of sensors integrated within IoT-based systems exhibits variability. Some sensors may be predisposed to errors or may lack the capability to accurately measure specific health parameters. This divergence in sensor accuracy can potentially undermine the reliability of the collected data (Rao et al, 2018, Alzubi et al, 2024).

Potential for Human Error: Despite the automation inherent in IoT-based systems, a facet of human involvement persists in tasks ranging from data collection to analysis and interpretation. Consequently, there exists a latent risk of human error throughout these processes.

Technological Dependency: The efficacy of an IoT-based system remains contingent upon the reliability of the underlying technology. In the event of system downtime or sensor malfunction, the continuous monitoring of player health could encounter disruptions, potentially impacting the effectiveness of the system (Imbrisevic, 2023).

Video Assistant Referees (VAR) Video Assistant

Referees (VAR) are a system used in professional soccer to assist referees in making decisions during 3 matches. The VAR system consists of a team of officials who watch the match from a remote location and have access to video replays of the game. If the on-field referee makes a decision that is later called into question, the VAR team can review the play using video footage

to determine if the decision was correct. If it is determined that the on-field referee's decision was incorrect, the VAR team can communicate this to the referee, who can then use a headset to review the play and make a revised decision if necessary (Spitz, et al, 2021, Nahum et al, 2020).

The VAR system is intended to help referees make more accurate decisions, particularly in cases where the action on the field is difficult to see or interpret. It is typically used to review goals, penalty kicks, red cards, and cases of mistaken identity. The use of VAR has been controversial in some quarters, as some argue that it slows down the game and takes away from the human element of refereeing. However, many believe that it helps to increase the fairness and accuracy of officiating in soccer

The Architecture Of Video Assistant Referees (VAR) The architecture of a Video Assistant

Referee (VAR) system typically consists of the following components (Spitz, et al, 2021)

Multiple cameras: These are positioned around the soccer pitch and capture video footage of the match from different angles.

Video assistant referees (VARs): These are trained officials who watch the match from a remote location and have access to the video footage captured by the cameras

Video operations room (VOR): This is the location where the VARs watch the match and review video footage. It is typically equipped with multiple monitors and other specialized equipment.

Communication system: This allows the VARs to communicate with the on-field referee and other match officials. It may include headsets, radios, or other communication devices.

Review area: This is a designated area near the field where the on-field referee can review video footage using a monitor.

Video review system: This is the software or other tools used by the VARs to review video footage and make decisions. It may include tools for marking up or annotating the footage, as well as specialized algorithms for analyzing the footage.

Decision-making protocols: These are the guidelines and procedures that the VARs follow when reviewing video footage and making decisions.

Advantages Of Using Video Assistant Referees (VAR)

Enhanced Decision Accuracy: Building on the benefits outlined in the Literature Review, VAR supports referees in making accurate and consistent decisions, improving fairness and overall match integrity.(Spitz, et al, 2021, Wikipedia, 2018, BBC Sport, 2018)

Augmented Fairness: By ensuring correct decisions are made, VAR heightens overall fairness in matches, reducing controversial calls that could affect game outcomes.

Improved Consistency: VAR fosters consistent treatment of similar plays across different matches, mitigating the potential for officiating inconsistencies.

Enhanced Player Safety: VAR can review instances of foul play or violence on the field, contributing to player protection.

Elevated Spectator Experience: By minimizing incorrect calls impacting match outcomes, VAR enhances the overall spectator experience.

Case Study : Video Assistant Referee (VAR) in the 2018 and 2022 FIFA World Cups

VAR technology, which uses multiple camera feeds and AI-powered video analysis, was first introduced globally at the 2018 World Cup and further refined in the 2022 tournament. It assists referees in making critical decisions such as offsides, fouls, and penalty calls. For example, in the 2018 World Cup match between France and Australia, VAR corrected a penalty decision, ensuring fairness and accuracy in the game outcome. The technology has significantly reduced human error and controversies by providing real-time video review capabilities.(Held et al,2023, Hou et al, 2023)

Problems with using Video Assistant Referees (VAR) (Wikipedia, 2018, BBC Sport, 2018)

Game Pace Impact: VAR has faced criticism for potentially slowing the game due to the time-consuming process of reviewing plays .

Decision-Making Inconsistencies: VAR application has been inconsistent across different matches and leagues, leading to confusion among players, coaches, and fans.

Human Interpretation Risk: Despite VAR's assistance, human interpretation of video footage remains a potential source of error in decision-making.

Cost Implications: Establishing and maintaining a VAR system can be financially burdensome,

involving specialized equipment and trained personnel .

Human Element Diminishment: Critics argue that VAR diminishes the human element of refereeing, eroding the authority of on-field officials and eroding trust in the officiating process.

Integration of AI Techniques in Football Systems

Artificial Intelligence (AI) plays a pivotal role in processing and interpreting the vast amount of data generated by IoT systems in football. Various AI techniques have been integrated into current technologies, including **Convolutional Neural Networks (CNNs)** for visual data analysis in Video Assistant Referee (VAR) systems and goal-line technologies, enabling high-accuracy object detection and decision-making in real time. **Recurrent Neural Networks (RNNs)** and **Long Short-Term Memory (LSTM)** models are used to analyze time-series data from wearable devices to predict fatigue or potential injuries based on physiological trends. Additionally, **reinforcement learning** is being explored to support real-time tactical recommendations by learning from historical match outcomes and adjusting strategies dynamically. These models are trained on large datasets collected from sensors and video feeds, and are evaluated using metrics such as accuracy, precision, recall, and F1-score to ensure reliability. The integration of such AI-driven analytics supports coaches, referees, and medical staff in making timely, data-informed decisions that enhance both player safety and game fairness (Held et al, 2023).

4. AI Techniques in Football

Various AI techniques such as CNNs, RNNs, and reinforcement learning have been employed in football analytics. Table X summarizes their key applications and specific football use cases. See Table 1.

Table 1: AI Techinques in Football

AI Technique	Football Use Case	Description / Example
Convolutional Neural Networks (CNNs)	**Player and ball tracking in video analysis**	**CNNs process video frames to identify and track players and ball positions for performance and tactics analysis.**
Recurrent Neural Networks (RNNs)	**Match event sequence prediction**	**RNNs analyze sequences of match events (passes, shots, fouls) to predict next actions or outcomes during a game.**
Reinforcement Learning	**Tactical decision-making and strategy optimization**	**RL models simulate football scenarios and learn optimal strategies by trial and error, supporting coaching decisions.**

CNNs are primarily used for visual data processing, enabling accurate tracking of players and the ball. RNNs help in understanding temporal sequences of game events, facilitating prediction of plays. Reinforcement learning models contribute to optimizing tactical decisions by learning from simulated scenarios.

IoT-based Systems to Detect Out-of-pitch Balls in a Football Match

An IoT-based system engineered for the detection of outof-pitch balls in a football match represents a sophisticated solution that amalgamates sensors and wireless technology to meticulously monitor the ball's location throughout a soccer match. This system leverages advanced techniques, including infrared radiation and precision sensors, to accurately ascertain the ball's real-time position, even in rapid motion or under limited visibility conditions. In instances where the ball transgresses the boundaries of the playing field, the system promptly dispatches an alert or notification to notify match officials. These officials can then access the pertinent data to make informed decisions regarding which team should be awarded possession. This IoT-based system exhibits the potential to surpass conventional methodologies employed for out-of-play ball detection, such as deploying additional match officials or installing complementary camera systems. It signifies efficiency, precision, and a paradigm shift in football officiation, underpinned by cutting-edge technology.

The architecture of IoT-based System for Out-of-pitch Ball Detection in a Football Match

The architectural framework of the IoT-based system for out-of-pitch ball detection comprises the following integral components:

Infrared Cameras: These strategically positioned cameras around the soccer pitch capture infrared imagery of the match. These cameras possess sensitivity to infrared radiation, emitted by objects warmer than their surroundings. Consequently, the ball, being warmer than the surrounding air, appears brighter in the infrared images (He, 2021).

Infrared Sensors: Embedded within the ball itself, these sensors are designed to detect the infrared radiation emanating from the ball. The sensor data is wirelessly transmitted to a central server for processing (Ariyo,2022).

Wireless Communication: The system necessitates seamless wireless data transmission to a central server, potentially facilitated through diverse technologies such as WiFi, Bluetooth, or cellular connectivity (Abqari et al,2020).

Central Server: A secure and cloud-based server serves as the repository for storing and processing data collected by the system. Access to this server is restricted to authorized personnel, including match officials, who utilize the data for determining out-of-play ball situations (Liang et al, 2023).

Data Analysis and Visualization Tools: These tools are instrumental in scrutinizing the data collected by the system, and presenting it in a user-friendly format. They encompass specialized software packages and custom-built tools that empower officials to comprehensively analyze and interpret the data (Liang et al, 2022).

Alerts and Notifications: The system configuration includes provisions for sending alerts or notifications to match officials in the event of a ball going out of play. This feature plays a pivotal role in ensuring precise decision-making during the match (He et al, 2021).

Advantages Of Using IoT-based System to Detect Outof-pitch Balls in a Football Match (Hu etal, 2022, Kennedy,2022)

Elevated Accuracy: Through the utilization of infrared radiation and precision sensors, this system adeptly tracks the ball's position, ensuring real-time accuracy, even during rapid movement or limited visibility .

Augmented Fairness: By guaranteeing accurate decisions regarding out-of-play balls, this system enhances the overall fairness of the match .

Workload Reduction for Officials: The system's automated detection of out-of-play instances alleviates the burden on match officials, streamlining their responsibilities .

Enhanced Spectator Experience: Ensuring precise decisions about out-of-play balls contributes to an improved overall spectator experience .

Cost-Efficiency: Implementing and maintaining an IoT-based system may be more cost-effective than traditional methods involving additional officials or supplementary camera installations .

Challenges in Employing IoT-based System for Out-of-pitch Ball Detection in a Football Match (Hu et al, 2022, Zaheer et al, 2022)

Dependence on Technology: Relying extensively on an IoT-based system for ball tracking and out-of-pitch detection may introduce a dependence on technology, which could be susceptible to malfunctions or disruptions .

Reliability: The system's sensors and hardware may encounter reliability issues, leading to erroneous or missed out-of-pitch detections .

Interference: Environmental factors and electronic devices could potentially introduce interference, affecting the accuracy of the system's sensors and hardware .

Data Privacy Concerns: The collection and storage of data by the system may trigger apprehensions regarding data privacy and the potential misuse of personal information .

Legal Considerations: The adoption of an IoT-based system for officiating in football matches may be subject to legal challenges and regulatory scrutiny, necessitating comprehensive compliance and adherence to established protocols .

Al Rihla match ball

The official match ball chosen for the prestigious 2022 FIFA World Cup in Qatar is none other than the Adidas Finale 21. It stands as a pinnacle of soccer ball engineering, meticulously crafted to meet the most stringent criteria for performance and durability. The ball boasts a synthetic leather cover complemented by a butyl bladder, delivering exceptional air retention

properties. Its construction is a testament to precision, with each ball being meticulously hand-stitched to ensure unwavering quality. Notably, the Adidas Finale 21 incorporates an array of sensors and components designed to amplify its performance, including a layer of EVA foam that augments ball control and touch. Its design pays homage to tradition, adorned with the iconic Adidas logo and signature stripes (Adidas,2022).

Al Rihla Sensors (Adidas,2022, Sumartiningsih,2020)

Ultra-Wide Band (UWB) Sensor: Employing cutting-edge UWB technology, this sensor surpasses traditional GPS or Bluetooth systems in delivering precise positional data. Moreover, it facilitates real-time data transmission, enabling continuous tracking of the ball's position .

Inertial Measurement Unit (IMU) Sensor: Designed to discern subtle movements in three-dimensional space, the IMU sensor contributes to an exhaustive understanding of the ball's trajectory and behavior .

Al Rihla Features: Engineering Excellence

The Al Rihla match ball boasts an amalgamation of features that elevate its performance:

CRT-CORE: Positioned at the core of the ball, this technology serves as its beating heart, offering speed, accuracy, and unwavering consistency. It facilitates rapid-paced gameplay and ensures maximal shape retention, air retention, and rebound accuracy .

SPEEDSHELL: This innovation encompasses a textured PU skin, combined with a novel 20-piece panel configuration. The result is a ball that excels in terms of accuracy, flight stability, and swerve, owing to both macro- and micro-textures, as well as surface debossing .

Advantages of Implementing Al Rihla

Impeccable Construction: Distinguished by its hand-stitched craftsmanship, synthetic leather cover, and butyl bladder, the Al Rihla ball epitomizes durability. It maintains its shape and bounces consistently over time

Performance Enhancement: The incorporation of various sensors and components, including the EVA foam layer, bolsters the ball's performance. It enhances touch and control, elevating gameplay to new heights.

Visibility: With its classic design featuring the iconic Adidas logo and signature stripes, the Al Rihla ball offers exceptional visibility. This aids players in tracking and interacting with the ball

seamlessly during matches

Professional Suitability: The Al Rihla ball adheres rigorously to the official size and weight specifications for professional soccer balls, rendering it apt for deployment at the highest echelons of competition

It is essential to acknowledge that information regarding the intricate details and technological underpinnings of the smart World Cup ball, Al Rihla, remains limited. FIFA, as the custodian of the ball, has exercised stringent control over the dissemination of information concerning its structure and the technologies harnessed within.

Case Study 2: Al Rihla Smart Ball, 2022 FIFA World Cup

The Al Rihla smart ball, embedded with motion sensors, accelerometers, and gyroscopes, was used officially during the 2022 World Cup. This IoT-enabled ball transmits data on ball speed, spin, and trajectory in real-time to referees and analysts. This information aids referees in verifying goal-line decisions and improves broadcast analytics for fans and coaches. The ball's precise tracking has enhanced the accuracy of officiating and provided deeper tactical insights into player interactions with the ball.(Al-Asadi and Tesdemir, 2021)

FIFA Player Application

The FIFA Player App represents a pioneering mobile application meticulously crafted by FIFA (Fed´ ration Internationale ´ de Football Association) to cater to the discerning needs of soccer aficionados, encompassing players, coaches, and devoted fans alike. This versatile app unfolds a rich tapestry of features and resources encapsulating the essence of soccer, offering users a comprehensive suite comprising news updates, match scores, statistical insights, and a repository of training drills. Distinguished by its "My Performance" functionality, the app empowers users to meticulously monitor and dissect their soccer training and performance, all while fostering seamless collaboration with peers and mentors. Available for download on both iOS and Android platforms, the FIFA Player App stands as a beacon of soccer enlightenment (Anam et al, 2022).

FIFA Player App component (Anam et al, 2022 , Playermaker, 2024)

The FIFA Player App boasts an extensive repertoire of features and components, with specific offerings potentially varying based on the app's version and the chosen platform. However,

fundamental functionalities remain consistent, comprising:

News and Scores: Users enjoy access to real-time news updates and scores emanating from soccer leagues and tournaments spanning the globe.

Stats: A comprehensive reservoir of statistics and data about soccer players, teams, and competitions equips users to undertake performance analysis and predictive modeling .

Training Drills: A treasure trove of training drills and exercises has been thoughtfully integrated, fostering skill enhancement and physical fitness for users .

My Performance: This pivotal feature empowers users to meticulously track, scrutinize, and share their soccer training and performance journey with friends and coaches .

Social Features: The app's social facet facilitates seamless connectivity between users, enabling interaction with fellow soccer enthusiasts and players, and fostering the exchange of news and scores among friends .

FIFA Player Performance Applications

Futwiz: An indispensable tool tailored for enthusiasts of FIFA Ultimate Team (FUT), this app lends users an insightful glimpse into player performance within the game mode. It offers comprehensive player statistics, alongside analytical tools facilitating squad enhancement

FIFA Analytics: A haven for aficionados seeking in-depth performance data for FIFA players, this app offers statistics covering passing, shooting, dribbling, and more. Additionally, users can engage in player stat comparisons and fashion bespoke leaderboards

FIFA Pro: Crafted as a holistic performance enhancer, this app empowers users with an extensive toolkit to dissect and elevate their FIFA performance. It encompasses a spectrum of features such as player statistics, match analysis, and an array of training drills (Anam et al, 2022).. In the realm of soccer engagement, the FIFA Player App and its companion applications shine as beacons of knowledge, offering a multifaceted experience designed to elevate every facet of the beautiful game.

Case Study : FIFA Player App and AI-driven Analytics

The FIFA Player App, introduced in recent tournaments, combines IoT data and AI algorithms to analyze player performance metrics such as distance covered, sprint speed, and recovery

times. During the 2022 World Cup, teams used the app to adjust in-game strategies by monitoring opponent fatigue and positioning in real-time. AI-powered predictive analytics helped coaches make data-driven substitutions and tactical changes, which impacted match outcomes positively.(Playermaker, 2024)

5. Discussion

The integration of IoT and AI technologies in football is gradually transforming the sport through more informed decision-making, enhanced player safety, and data-driven coaching strategies. This discussion section presents a comparative analysis of the reviewed systems, evaluates their advantages and limitations, and offers insights based on our perspective.

Comparison of Reviewed Technologies

Several technologies were examined throughout the paper, including IoT-based systems for player healthcare supervision, VAR (Video Assistant Referee), out-of-pitch ball detection, the Al Rihla match ball, and the FIFA Player App.

- **Healthcare Monitoring Systems** provide real-time physiological data to medical staff, allowing for early intervention and injury prevention.
- **VAR** improves refereeing accuracy by enabling slow-motion, multi-angle video reviews.
- **Out-of-Pitch Ball Detection Systems** use infrared and sensor technology to assist referees in determining whether the ball has crossed the boundary lines.
- **Al Rihla Smart Ball** incorporates UWB and IMU sensors for precise movement tracking.
- **FIFA Player App** delivers personalized performance metrics to players and coaching staff.

Each of these technologies contributes to different aspects of football, offering unique capabilities while also facing implementation challenges. See Table 2.

Table 2 : Pros and Cons of the Technologies

Technology	Advantages	Limitations
Healthcare Monitoring Systems	Real-time alerts, injury prevention, improved player performance	High cost, sensor accuracy variability, data privacy concerns
VAR	Improved fairness and decision accuracy, multi-angle support	Game flow disruption, subjective interpretation, expensive infrastructure
Out-of-Pitch Ball Detection	Accurate boundary detection, reduced referee burden	Technological dependency, interference risks
Al Rihla Smart Ball	High-precision tracking, integration with VAR	Limited technical transparency, high development costs
FIFA Player App	Data-driven training, enhanced performance feedback	Reliance on accurate data collection, limited real-time use during matches

While the integration of IoT and AI technologies in football presents significant opportunities for enhancing performance and decision-making, a critical analysis of their trade-offs is essential to understand their practical applicability. For example, IoT devices such as the Al Rihla smart ball offer precise real-time data that can directly impact gameplay and training. However, these devices face challenges related to durability, battery life, and the physical demands of a fast-paced sport, which may limit their long-term usability without frequent maintenance or replacement.

In contrast, AI-driven analytic platforms provide comprehensive insights through predictive modeling and tactical analysis. Yet, these systems often require access to extensive datasets, powerful computational resources, and robust data pipelines, which can constrain their deployment in real-time scenarios or resource-limited environments. Moreover, the reliance on AI introduces complexities in interpretability and transparency, making it challenging for coaches and players to fully trust and act upon automated recommendations without human oversight.

The implementation of technologies such as Video Assistant Referee (VAR) systems exemplifies infrastructural and operational challenges. VAR demands significant investment in

camera networks, data transmission, and processing capabilities, which may be prohibitive for lower-tier leagues or developing regions, potentially exacerbating inequalities in technology access across the sport. Furthermore, the adoption rates among stakeholders vary considerably: coaches are generally receptive to AI-driven tactical tools that can enhance competitive advantage, while players may express concerns regarding wearable sensors affecting comfort, privacy, and performance. Referees, tasked with upholding the fairness of the game, might resist AI-based decision aids due to fears of diminished autonomy and trust issues.

Balancing these factors requires a nuanced approach that weighs the benefits of technological sophistication against usability, cost, and acceptance. Future efforts should prioritize designing adaptable systems that can scale according to the needs and capacities of different stakeholders, while fostering transparency and education to build trust in AI-supported tools. Only through such cross-disciplinary collaboration—combining expertise in sports science, data analytics, engineering, and human factors—can football technology realize its full potential and achieve widespread adoption.

6. Conclusion and Future work

While the application of IoT is well-established across these technologies, the role of AI remains more implicit or supportive rather than fully elaborated in existing literature. For example, AI's potential in predictive analytics, tactical decision-making, and automated referee assistance is significant but not yet fully integrated into mainstream football systems. Among the reviewed systems, the combination of the Al Rihla smart ball and VAR provides the most tangible and high-impact integration of IoT and AI.

Future research should explore AI-based injury prediction models that leverage real-time biometric and biomechanical data to proactively manage player health. Additionally, developing AI-driven real-time tactical adjustment systems could provide coaches with dynamic strategies during matches, enhancing competitive performance. Another promising direction involves integrating edge computing and AI-powered decision-making tools for

referees to improve the speed and accuracy of in-game calls, thereby enhancing the fairness and flow of matches.

These insights not only reflect the current landscape but also provide a forward-looking roadmap for stakeholders aiming to enhance the sport through intelligent technology.

To summarize, this review underscores the clear establishment of IoT technologies in football, with AI playing a supportive yet underdeveloped role in the current landscape. The most impactful example to date—the integration of the Al Rihla smart ball and VAR—demonstrates the tangible benefits of combining these technologies. Emphasizing the future, the potential for cross-disciplinary collaboration is crucial. By bridging expertise from fields such as sports science, data analytics, computer engineering, and artificial intelligence, innovative solutions can emerge that holistically enhance player performance, coaching strategy, injury prevention, and officiating. Such collaborative efforts will be key to driving the next generation of intelligent sports technologies.

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8. Conflict of Interest

Authors has no conflict of interest to declare

9. References

Abqari Rahizad, M. A., Razak, T. R., Mohd Fauzi, S. S., Gining, R. A. J. M., & Ismail, M. H. (2020). Designing an IoT-based system to detect the out-of-pitch balls in a football match. Journal of Computer Research and Innovation, 5(3), 34–42. https://doi.org/10.24191/jcrinn.v5i3.164

Adidas. (2022, July 1). Adidas reveals the first FIFA World Cup™ official match ball featuring connected ball technology. https://news.adidas.com/football/adidas-reveals-the-first-fifa-world-cup--official-match-ball-featuring-connected-ball-technology

Al-Asadi, M. A., & Tasdemir, S. (2021). Empirical comparisons for combining balancing and feature selection strategies for characterizing football players using FIFA video game system. IEEE Access, 9, 149266–149286. https://doi.org/10.1109/ACCESS.2021.3124931

Alhalaybeh, A. A., Alkhatib, R. N., Albustanji, S., Elmanaseer, S., Kanan, T., & Alsakarnah, R. (2023). Facilitating metaverse integration in education via extended reality and the Internet

of Things: An overview. In Proceedings of the 2023 International Conference on Information Technology (ICIT) (pp. 38–42). https://doi.org/10.1109/ICIT58056.2023.10226029

Anam, K., Nurrachmad, L., Setiowati, A., Indardi, N., Yuwono, I., Irawan, F. A., Gulsirirat, P., Susanto, N., & Pranoto, N. W. (2022). Application of FIFA 11+ kids: Method to minimize sports injuries in youth football. Journal Sport Area, 7(2), 262–270. https://doi.org/10.25299/sportarea.2022.vol7(2).9467

Ariyo, S. O. (2022). The future of AI in sports decision making. SSRN. https://papers.ssrn.com/abstract=4158689

Aroganam, G., Manivannan, N., & Harrison, D. (2019). Review on wearable technology sensors used in consumer sport applications. Sensors, 19(9), 1983. https://doi.org/10.3390/s19091983

Awolusi, I., Nnaji, C., Marks, E., & Hallowell, M. (2019). Enhancing construction safety monitoring through the application of Internet of Things and wearable sensing devices: A review. In Computing in Civil Engineering 2019 (pp. 530–538). https://doi.org/10.1061/9780784482438.067

Ballantyne, N., & LaMendola, W. (2014). Eternal vigilance Inc.: The satellite tracking of offenders in real time. https://doi.org/10.4324/9781315872421-3

BBC Sport. (2018, June 16). World Cup 2018: VAR used to award France a penalty against Australia. https://www.bbc.com/sport/football/44508993

Chokkattu, J. (2020, March 10). Google's new shoe insole analyzes your soccer moves. WIRED. https://www.wired.com/story/how-google-jacquard-adidas-gmr-insole-tech-works/

Cox, R. W., & Hyde, J. S. (1997). Software tools for analysis and visualization of fMRI data. NMR in Biomedicine, 10(4–5), 171–178. https://doi.org/10.1002/(SICI)1099-1492(199706/08)10:4/5<171::AID-NBM453>3.0.CO;2-L

Ghayvat, H., Mukhopadhyay, S. C., Gui, X., & Suryadevara, N. K. (2015). WSN- and IoT-based smart homes and their extension to smart buildings. Sensors, 15(5), 10350–10379. https://doi.org/10.3390/s150510350

Gorman, C. (2020, March 10). How Google and Adidas created a smart insole that turns kicks into data. WIRED. https://www.wired.com/story/google-adidas-gmr-insole

Haghi, M., Thurow, K., & Stoll, R. (2017). Wearable devices in medical Internet of Things: Scientific research and commercially available devices. Healthcare Informatics Research, 23(1), 4–15. https://doi.org/10.4258/hir.2017.23.1.4

He, Y., Deng, B., Wang, H., Cheng, L., Zhou, K., Cai, S., & Ciampa, F. (2021). Infrared machine vision and infrared thermography with deep learning: A review. Infrared Physics & Technology, 116, 103754. https://doi.org/10.1016/j.infrared.2021.103754

Held, J., [Complete author list not provided in original data]. (2023). VARS: Video assistant referee system for automated soccer decision making from multiple views. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW) (pp. 5086–5097). https://doi.org/10.1109/CVPRW59228.2023.00537

Hu, Y., & Liu, J. (2022). Research on application of computer big data technology in robot soccer simulation platform based on OpenGL. In Proceedings of the IEEE 2nd International Conference on Power, Electronics and Computer Applications (ICPECA) (pp. 764–767). https://doi.org/10.1109/ICPECA53709.2022.9719248

Humphreys, J. S., Wakerman, J., & Wells, R. (2006). What do we mean by sustainable rural health services? Implications for rural health research. Australian Journal of Rural Health, 14(1), 33–35. https://doi.org/10.1111/j.1440-1584.2006.00750.x

Ikram, M. A., Alshehri, M. D., & Hussain, F. K. (2015). Architecture of an IoT-based system for football supervision (IoT football). In Proceedings of the IEEE 2nd World Forum on Internet of Things (WF-IoT) (pp. 69–74). https://doi.org/10.1109/WF-IoT.2015.7389029

Imbrišević, M. (2023). Sport, law and philosophy: The jurisprudence of sport. Taylor & Francis.

Jones, C. M., Austin, K., Augustus, S. N., Nicholas, K. J., Yu, X., Baker, C., Chan, E. Y. K., Loosemore, M., & Ghajari, M. (Year not provided). An instrumented mouthguard for real-time measurement of head kinematics under a large range of sport-specific accelerations.

Kanan, T., Elbes, M., Maria, K. A., Maria, M., & Alia, A. (2023). Exploring the potential of IoT-based learning environments in education. International Journal of Advanced Soft Computing Applications, 15(2). https://doi.org/10.15849/IJASCA.230720.11

Kariuki, J. M., Were, M. C., Wambua, S., Muthee, V., Chepngeno, V., & Biondich, P. G. (2016). Automating indicator data reporting from health facility EMR to a national aggregate data system in Kenya: An interoperability field-test using OpenMRS and DHIS2. Online Journal of Public Health Informatics, 8(2). https://doi.org/10.5210/ojphi.v8i2.6722

Kennedy, D. (2022). The World Cup football: A case study in commodity fetishism. Critique, 50(4), 727–738. https://doi.org/10.1080/03017605.2023.2199582

Khan, Z., Anjum, A., & Kiani, S. L. (2013). Cloud-based big data analytics for smart future cities. In Proceedings of the IEEE/ACM 6th International Conference on Utility and Cloud Computing (pp. 381–386). https://doi.org/10.1109/UCC.2013.77

Lv, Z., & Li, Y. (2022). Wearable sensors for vital signs measurement: A survey. Journal of Sensor and Actuator Networks, 11(1), 19. https://doi.org/10.3390/jsan11010019

Maria, K. A. (2025). Bridging the gap: AI-driven agent-based systems in modern software engineering. Journal of Information Systems Engineering and Management, 10(43s), 839–848. https://doi.org/10.52783/jisem.v10i43s.8486

Pilka, T., Grzelak, B., Sadurska, A., Górecki, T., & Dyczkowski, K. (2023). Predicting injuries in football based on data collected from GPS-based wearable sensors. Sensors, 23, 1227. https://doi.org/10.3390/s23031227

Ponsano, N., Hosseini Varde'i, C., Izzo, R. E., & Cejudo, A. (2020). The role of fatigue in football matches, performance model analysis and evaluation during quarters using live GPS technology at 50 Hz. Sport Science, 13(1), 30–35.

Rao, R. N., & Sridhar, B. (2018). IoT-based smart crop-field monitoring and automation irrigation system. In Proceedings of the 2nd International Conference on Inventive Systems and Control (ICISC) (pp. 478–483). https://doi.org/10.1109/ICISC.2018.8399118

Rossi, A., Pappalardo, L., Cintia, P., Iaia, M., & Fernandez, J. (2017). Effective injury forecasting in soccer with GPS training data and machine learning. arXiv. https://arxiv.org/abs/1705.08079

Seshadri, D. R., Li, R. T., Voos, J. E., Rowbottom, J. R., Alfes, C. M., Zorman, C. A., & Drummond, C. K. (2019). Wearable sensors for monitoring the internal and external workload of the athlete. NPJ Digital Medicine, 2, 71. https://doi.org/10.1038/s41746-019-0149-2

Spitz, J., Wagemans, J., Memmert, D., Williams, A. M., & Helsen, W. F. (2021). Video assistant referees (VAR): The impact of technology on decision making in association football referees. Journal of Sports Sciences, 39(2), 147–153. https://doi.org/10.1080/02640414.2020.1809163

Talal, M., Zaidan, A. A., Zaidan, B. B., Alamoodi, A. H., Albahri, A. S., Albahri, O. S., & Alsalem, M. A. (2019). Smart home-based IoT for real-time and secure remote health monitoring of triage and priority system using body sensors: Multi-driven systematic review. Journal of Medical Systems, 43(3), 42. https://doi.org/10.1007/s10916-019-1158-z

Ullah, A., Anwar, S., Shah, S. B. H., Kamal, M. A., & Khan, M. K. (2021). Secure healthcare data aggregation and transmission in IoT—A survey. IEEE Access, 9, 16849–16865. https://doi.org/10.1109/ACCESS.2021.3052850

Wikipedia. (2023). Adidas Al Rihla. https://en.wikipedia.org/wiki/Adidas_Al_Rihla

Wikipedia. (2024). Hexoskin. https://en.wikipedia.org/wiki/Hexoskin

Wikipedia. (2024). 2018 FIFA World Cup Group C. https://en.wikipedia.org/wiki/2018_FIFA_World_Cup_Group_C

World Rugby. (2023, October 9). World Rugby integrates smart mouthguard technology to the head injury assessment. https://www.world.rugby/news/875212/world-rugby-integrates-smart-mouthguard-technology-to-the-head-injury-assessment-as-part-of-new-phase-of-global-player-welfare-measures

Yang, G., Wang, L., Xu, X., & Xia, J. (2021). Footballer action tracking and intervention using deep learning algorithm. Journal of Healthcare Engineering, 2021, 1–9. https://doi.org/10.1155/2021/5518806

Yaseen, G., Albadrany, Q. H. A., Dajani, D., & Al-Afaishat, M. M. (2025). Artificial intelligence regulation: A bibliometric analysis. International Journal of Advanced Soft Computing Applications, 17(1). https://doi.org/10.15849/ijasca.250330.12

Zaheer, M., & Kausar, A. R. (2022). Fading knowledge of hand-stitched football production. Journal of Humanities & Social Sciences, 30(1), 52–66