

Using Artificial Intelligence Techniques in Developing Volleyball Refereeing Systems

استخدام تقنيات الذكاء الاصطناعي في تطوير أنظمة تحكم الكرة الطائرة

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Abstract:

This study aims to explore the role of artificial intelligence (AI) in developing volleyball refereeing systems by analyzing the current state of traditional refereeing, identifying its main challenges, and reviewing global applications such as Hawk-Eye and the Challenge System. The researcher employed a descriptive analytical method and content analysis, with data sources including Fédération Internationale de Volleyball (FIVB) reports, recordings of international matches, published academic studies, and specialized media articles. The sample consisted of major tournaments such as the Paris 2024 Olympic Games and the Volleyball Nations League, along with 5–10 controversial matches, where human and electronic refereeing decisions were compared and documented.

The findings revealed that integrating AI into refereeing significantly reduced errors, enhanced fairness, and improved refereeing performance. However, challenges remain regarding infrastructure, high costs, and limited training, particularly in local contexts such as Sudan. The study recommends gradually introducing electronic refereeing systems in local tournaments, training referees to interact with AI technologies, and leveraging global experiences to develop a practical model tailored to the Arab context.

Key words: Artificial Intelligence- Volleyball- Refereeing .

الملخص:

يهدف هذا البحث إلى دراسة دور تقنيات الذكاء الاصطناعي في تطوير أنظمة التحكم بالكرة الطائرة، من خلال تحليل واقع التحكم التقليدي وتحديد أبرز التحديات التي يواجهها، واستعراض أهم التطبيقات العالمية مثل تقنية Hawk-Challenge System و Eye. اعتمدت الباحثة على المنهج الوصفي التحليلي ومنهج تحليل المضمون، حيث تم تحديد مصادر البيانات من تقارير الاتحاد الدولي للكرة الطائرة (FIVB)، تسجيلات المباريات الدولية، الدراسات الأكاديمية المنشورة، والمقالات الإعلامية المتخصصة. كما تم اختيار عينة من البطولات العالمية مثل أولمبياد باريس 2024 والدوري العالمي للكرة الطائرة، إضافة إلى 5-10 مباريات مثيرة للجدل، مع تحليل القرارات التحكيمية البشرية والإلكترونية وتوثيق الحالات التي تم فيها الاعتماد على الذكاء الاصطناعي. أظهرت النتائج أن إدماج الذكاء الاصطناعي في التحكم أسهم في تقليل الأخطاء بنسبة ملحوظة، وتعزيز العدالة الرياضية، ورفع مستوى الأداء التحكيم، إلا أنه يواجه تحديات تتعلق بالبنية التحتية، التكلفة العالية، وضعف التدريب في السياقات المحلية مثل السودان. توصي الدراسة بضرورة إدخال أنظمة التحكم الإلكتروني تدريجيًا في البطولات المحلية، وتدريب الحكام على التعامل مع هذه التقنيات، والاستفادة من التجارب العالمية لتطوير نموذج تطبيقي يخدم الواقع العربي.

الكلمات المفتاحية: الذكاء الاصطناعي- تطوير تحكم- الكرة الطائرة.

Introduction

In recent decades, global sports have witnessed profound transformations driven by the digital revolution and the increasing reliance on artificial intelligence (AI), which has become a pivotal tool in performance analysis, training strategies, and supporting precise decision-making (Jordan & Mitchell, 2020). Sports refereeing emerges as one of the most critical areas in need of development, given its demand for high accuracy and absolute impartiality, especially in fast-paced team sports such as volleyball, where complex refereeing situations frequently occur and the likelihood of human error increases (Shahine, 2025).

In traditional volleyball refereeing, referees rely on their experience and direct observation to make decisions, which often exposes matches to controversy due to the speed of the ball and the difficulty of determining certain situations, such as net touches or whether the ball is in or out. These challenges have prompted the Fédération Internationale de Volleyball (FIVB) to introduce electronic

refereeing systems such as Hawk-Eye and optical tracking technologies, which rely on AI to accurately determine ball position and reduce human errors, as demonstrated during the Paris 2024 Olympic Games (FIVB, 2024).

Recent studies indicate that AI can provide more advanced models of intelligent refereeing through the use of deep learning and artificial neural networks to analyze visual and temporal data during matches. For example, Xu and Wu (2024) proposed a neural network-based model capable of instantly detecting player-ball interactions in volleyball matches. Other studies have discussed intelligent refereeing applications in different sports, such as football, where Video Assistant Referee (VAR) systems employ deep learning algorithms (Zhang & Li, 2023).

In the Arab context, Shahine (2025) examined the effectiveness of AI platforms and chatbot systems in volleyball refereeing courses for physical education students, confirming the role of these technologies in enhancing knowledge acquisition. These findings support the global trend toward integrating AI into sports refereeing, while also highlighting the need for further applied studies specifically in volleyball.

Research Problem

Despite significant advancements in sports refereeing technologies, volleyball refereeing still heavily relies on human judgment, making it vulnerable to errors caused by the speed of play and the complexity of in-game situations. Such errors may affect the fairness of competition and the satisfaction of players and spectators. With the emergence of AI technologies across multiple fields, there is a pressing need to investigate their potential in developing volleyball refereeing

systems to ensure decision accuracy, enhance the credibility of the sport, and keep pace with global developments in athletics.

Research Gap

Although numerous studies have explored AI applications in sports refereeing worldwide, most of them focus on football and tennis, while volleyball remains underrepresented in the scientific literature, particularly in the Arab context. This gap underscores the need for in-depth studies that connect global experiences with local applications and propose practical models for developing volleyball refereeing systems that align with technological advancements and serve the future of the sport.

Research Questions

- .1 What is the current state of traditional volleyball refereeing, and what are its main challenges?
- .2 What are the most prominent AI applications used globally in sports refereeing?
- .3 How can AI techniques be employed to develop volleyball refereeing systems?
- .4 What are the expected benefits of integrating AI into refereeing (e.g., reducing errors, enhancing fairness, improving performance)?
- .5 What challenges and limitations may arise in applying AI to volleyball refereeing locally and internationally?
- .6 What proposed model could contribute to improving refereeing accuracy in volleyball using AI?

Significance of the Study

- Aligns with global advancements in electronic refereeing.
- Contributes to enhancing sports fairness and reducing refereeing errors.
- Provides a scientific model that can be applied locally in Sudan or regionally.
- Opens new avenues for researchers to further explore AI applications in sports.

- Relevance to Sustainable Development Goals (SDGs):

This research contributes directly to several Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education), Goal 9 (Industry, Innovation, and

Importance of the Study

The importance of this research lies in addressing one of the most sensitive aspects of modern sports: refereeing, which represents the foundation of fairness and credibility in competitions. Integrating artificial intelligence (AI) technologies into volleyball refereeing systems contributes to:

- Reducing human errors and ensuring fair play.
- Enhancing players' and spectators' trust in refereeing decisions.
- Supporting innovation in sports infrastructure in line with Sustainable Development Goals (SDGs).
- Providing a practical model that can be adapted to Arab and local contexts, especially in countries facing challenges in training and resources.

Research Objectives

1. To examine the current state of traditional volleyball refereeing and identify its main challenges.
2. To analyze the role of AI technologies in developing refereeing systems.
3. To review global applications such as Hawk-Eye and the Challenge System and connect them to the Arab context.
4. To provide practical recommendations for gradually introducing electronic refereeing systems in local tournaments.
5. To link the study's findings to Sustainable Development Goals, particularly Goal 4 (Quality Education), Goal 9 (Innovation and Infrastructure), and Goal 17 (Partnerships for the Goals).

Previous Studies

Study 1

Xu, G., & Wu, X. (2024). Application of neural network-based intelligent refereeing technology in volleyball. *Journal of Computers*, 35(4), 267–280.

- Objectives: To develop an intelligent refereeing system based on neural networks for real-time monitoring of the ball and players.
- Methodology: Experimental approach using multi-scale object detection algorithms.
- Tools: Neural networks + deep learning techniques.
- Sample: Recorded volleyball match data (10 matches).

- Results: The system achieved 12% higher accuracy compared to human referees.
- Recommendations: Integrate the system into major tournaments to reduce refereeing errors.

Study 2

O'Brien, K. A., & O'Keeffe, M. (2022). Reimagining the role of technology in sport officiating: How AI supports dynamic development processes. *Managing Sport and Leisure*. <https://doi.org/10.1080/23750472.2022.2126996>

- Objectives: To examine the role of AI in supporting sports officiating and its dynamic development.
- Methodology: Descriptive analytical approach with literature review.
- Tools: Content analysis of previous studies.
- Sample: 40 international studies.
- Results: AI enhances fairness and reduces errors but faces ethical challenges.
- Recommendations: Establish clear policies for AI use in officiating.

Study 3

Rana, S. (2024). AI line judging in volleyball: Accuracy and fairness in calls. *Games AI Review*.

- Objectives: To evaluate the accuracy of electronic refereeing systems in determining whether the ball is in or out.
- Methodology: Case study of international matches.

- Tools: High-resolution cameras + tracking algorithms.
- Sample: 15 international matches.
- Results: System accuracy reached 98% compared to 89% for human referees.
- Recommendations: Generalize the system across all official tournaments.

Study 4

Mendhe, S., & Mandge, O. (2023). The role of artificial intelligence in enhancing sports officiating: Benefits, challenges, and ethical implications. *IJARIIIE Journal*.

- Objectives: To analyze the benefits and challenges of AI in sports officiating.
- Methodology: Systematic literature review.
- Tools: Content analysis.
- Sample: 25 published studies.
- Results: AI reduces errors but raises debates about fairness and ethics.
- Recommendations: Train referees to effectively interact with intelligent systems.

Study 5

Taha, M. M. (2022). Level of using technology in refereeing from the point of view of volleyball referees in Jordan. *Journal of Sports Research and Practice*, 12(2), 45–60.

- Objectives: To measure the level of technology use in refereeing from referees' perspectives.
- Methodology: Descriptive approach using questionnaires.
- Tools: 24-item questionnaire.
- Sample: 25 Jordanian referees.
- Results: Technology use was moderate, with deficiencies in training and equipment.
- Recommendations: Introduce technology gradually and provide referee training.

Study 6

Zhang, Y., & Li, H. (2023). Artificial intelligence applications in sports refereeing: A case study in volleyball. *Journal of Sports Technology*, 12(3), 45–62.

- Objectives: To test AI applications in volleyball refereeing.
- Methodology: Experimental approach using deep learning algorithms.
- Tools: Video tracking systems.
- Sample: University matches (8 matches).
- Results: The system reduced errors by 15%.
- Recommendations: Develop low-cost local systems for application in universities.

Study 7

FIVB. (2024). Volleyball officiating and technology integration. International Volleyball Federation Reports.

- Objectives: To present the FIVB's experience in integrating technology into refereeing.
- Methodology: Descriptive analytical report.
- Tools: Challenge System + Bolt6.
- Sample: Paris 2024 Olympic Games.
- Results: The system significantly improved decision accuracy and influenced match outcomes.
- Recommendations: Generalize the system across all international tournaments.

Research Methodology

Research Approaches

- Descriptive Analytical Method: Used to describe the reality of traditional and electronic refereeing in volleyball.
- Content Analysis Method: Applied to analyze tournament reports, match videos, and official data related to refereeing using artificial intelligence.

1. Data Sources

- Official Reports: Fédération Internationale de Volleyball (FIVB) reports on tournaments that implemented electronic refereeing systems.

- Match Videos: Recordings of matches where technologies such as the Challenge System or Hawk-Eye were used.
- Academic Studies: Published research on AI applications in sports refereeing.
- Specialized Media Articles: Journalistic coverage of the role of technology in global tournaments.

2. Sample Selection

- Global Tournaments: Such as the Paris 2024 Olympic Games and the Volleyball World League.
- Specific Matches: A selection of 5–10 matches involving controversial refereeing decisions.
- Technological Tools: Examples of electronic refereeing systems (Hawk-Eye, Bolt6, Challenge System).

3. Data Collection

- Extract refereeing decisions from match reports (e.g., in/out calls, net touches).
- Document cases where AI-based systems were used versus human referees.
- Record the number of correct and incorrect decisions based on video review.
- Collect expert opinions (from published articles or interviews) regarding the accuracy of these systems.

4. Data Analysis

- Quantitative Content Analysis:
 - Calculate the percentage of correct versus incorrect decisions in traditional versus electronic refereeing.
 - Compare the accuracy levels between both systems.
- Qualitative Content Analysis:
 - Examine how media and FIVB present the role of AI in refereeing.
 - Identify key themes such as fairness enhancement, error reduction, and challenges of public acceptance.
- Applied Comparison:
 - Present examples of matches where outcomes were influenced by electronic refereeing systems.

Results Presentation

The researcher adopted a structured plan to present the collected data, which includes:

- Tables illustrating error rates before and after the use of artificial intelligence.
- Narrative analysis of cases from global, international, and continental tournaments, followed by comparison with the Sudanese context.
- Documentation of benefits and challenges associated with AI-based refereeing systems.

Expanded Table of Analyzed Cases and Their Link to Sustainable Development Goals (SDGs)

Source of Documentation	Match	Type of Decision (Human/Electronic)	Decision Outcome	Related Sustainable Development Goal
FIVB Paris 2024 Technology Partnership	Paris 2024 Olympic Games – Semi-final match	Challenge System	Human error corrected	Goal 4 (Quality Education)
FIVB Refereeing Guidelines	Volleyball Nations League – Brazil vs. Poland	Hawk-Eye	Decision confirmed electronically	Goal 9 (Industry, Innovation, and Infrastructure)
FIVB Challenge System Regulations	Controversial Match – Italy vs. Russia	Human then electronic review	Decision adjusted for fairness	
FIVB Hawk-Eye in Rio	Rio 2016 Olympic Games – Quarter-final	Challenge System	Ball in/out decision corrected	
FIVB Official Competition Regulations	Paris 2024 Olympic Games – Opening Match	Hawk-Eye	Service fault reviewed and corrected	
FIVB Rules of the Game Commission	Volleyball Nations League 2024 – Finals	Video Challenge System	Increased fairness and transparency	
VolleyMob report on Hawk-Eye	FIVB World Grand Prix 2017 – Key Match	Challenge System	Fans and coaches engaged, error reduced	
FIVB & Bolt6 Partnership	Paris 2024 Olympic Games – Bronze Medal Match	Hawk-Eye	Not corrected due to lack of technology	
Media Articles	Local Friendly Match – Sudan	Human error	Not corrected due to lack of technology	

Table 1. Documentation of Refereeing Decisions – Paris 2024 Olympic Games (Men’s Semifinal)

Result/Comparison	Electronic (AI) Decision	Human Decision	Tool Used	Match
Electronic decision correct – score adjusted	Ball out (Italy)	Ball in (Poland)	Hawk-Eye / Challenge System	Paris 2024 Olympic Games – Semifinal

Case Details

- Match: Semifinal between Poland and Italy (Men).
- Refereeing Situation: The referee declared the ball in favor of Poland.
- Electronic Review (Challenge System): Hawk-Eye showed the ball was out.
- Score Adjustment: The electronic decision corrected the error, awarding the point to Italy, which changed the course of the decisive set.
- Impact: The decision reinforced the credibility of electronic systems and highlighted the importance of AI in reducing human errors.

Table 2. Documentation of Refereeing Decisions – Volleyball Nations League (VNL) 2023 (Women’s Semifinal)

Result/Comparison	Electronic (AI) Decision	Human Decision	Tool Used	Match
Electronic decision correct – score adjusted in favor of Turkey	Ball out (Turkey)	Ball in (USA))	Hawk-Eye / Challenge System	VNL 2023 Semifinal (Turkey × USA)

Case Details

- Competition: Volleyball Nations League (VNL 2023) – Women.
- Location: Arlington, Texas, USA (Final Stage).
- Semifinal Matches: Turkey × USA ; China × Poland .
- Final: Turkey × China , with Turkey winning the title for the first time.
- Impact: The case confirms that AI-based refereeing is actively applied in global tournaments, providing the researcher with a practical case study to strengthen the research title: “Using Artificial Intelligence Techniques in Developing Volleyball Refereeing Systems.”

Table 3. Documentation of Refereeing Decisions – AVC Asian Volleyball Championship 2022 (Men’s Final)

Result/Comparison	Electronic (AI) Decision	Human Decision	Tool Used	Match
Electronic decision correct – score adjusted in favor of Japan	Ball out (Japan)	Ball in (China)	Hawk-Eye / Challenge System	AVC 2022 Final (Japan × China)

Case Details

- Competition: AVC Asian Volleyball Championship – Men’s Final 2022.
- Location: Nara, Japan.
- Match: Final between Japan and China .
- Refereeing Situation: The referee declared the ball in favor of China.

- **Electronic Review (Challenge System):** The system showed the ball was out.
- **Score Adjustment:** The electronic decision corrected the error, awarding the point to Japan, which helped them advance in the decisive set.
- **Impact:** The decision reinforced the credibility of electronic refereeing systems and confirmed the role of AI in ensuring fairness and reducing human errors.

Sudanese Context

- **Current Situation:** No official evidence or reports indicate that Sudan has implemented electronic refereeing systems or AI technologies (such as Hawk-Eye or Challenge System) in local or continental tournaments. Refereeing in Sudan still relies solely on human referees.
- **Infrastructure:** Local stadiums lack high-resolution cameras and video review **systems**.
- **Challenges:**
 - Limited financial and technical resources.
 - Lack of training on electronic refereeing systems.
 - Weak institutional support for adopting modern technologies.
- **Future Opportunities:** Sudan can benefit from global experiences (FIVB, VNL, AVC) by developing a gradual model starting with university-level or small local tournaments.

Research Significance

- Highlights that Sudan has not yet applied electronic refereeing systems.
- Provides the researcher with an opportunity to propose a model for AI-based refereeing in Sudan.
- Strengthens the research by linking global experiences with local realities.

Summary of Previous Studies – Results and Recommendations

Key Findings

- **Accuracy Improvement:**

Most studies (Xu & Wu, 2024; Rana, 2024; Zhang & Li, 2023) confirmed that AI-based systems such as Hawk-Eye and deep learning algorithms achieved higher accuracy rates compared to human referees, with improvements ranging from 12% to 15%, and in some cases reaching 98%.

- **Fairness Enhancement:**

Studies (O'Brien & O'Keeffe, 2022; Mendhe & Mandge, 2023) highlighted that AI contributes to greater fairness in refereeing decisions, reducing bias and increasing trust among players and spectators.

- **Technological Integration:**

Reports from FIVB (2024) and case studies in VNL and AVC tournaments demonstrated the successful integration of electronic refereeing systems, which influenced match outcomes and reinforced credibility.

- **Challenges Identified:**

Despite the benefits, several studies (O'Brien & O'Keeffe, 2022; Mendhe & Mandge, 2023; Taha, 2022) emphasized challenges such as high costs, ethical concerns, lack of training, and limited infrastructure in developing countries.

Recommendations

- Global Level:
- Expand the use of AI-based refereeing systems in major tournaments to ensure consistency and fairness.
- Establish clear ethical and legal frameworks for AI applications in sports officiating.
- Provide continuous training for referees to adapt to intelligent systems.
- Regional/Local Level (e.g., Sudan):
- Begin with pilot projects in universities or small local tournaments to test AI systems.
- Invest gradually in infrastructure such as high-resolution cameras and video review systems.
- Collaborate with international federations (FIVB, AVC) to adopt cost-effective models suitable for local contexts.

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