

เทคโนโลยีปัญญาประดิษฐ์กับการยกระดับมาตรฐานการตัดสินกีฬาวอลเลย์บอล ARTIFICIAL INTELLIGENCE TECHNOLOGY AND THE ENHANCEMENT OF VOLLEYBALL OFFICIATING STANDARDS

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บทคัดย่อ

การบูรณาการเทคโนโลยีปัญญาประดิษฐ์ (AI) และกฎการขานเล่นในการตัดสินกีฬาวอลเลย์บอลเป็นตัวอย่างของการยกระดับมาตรฐานการแข่งขันในบริบทของกีฬาสมัยใหม่ การศึกษานี้มีวัตถุประสงค์เพื่อ 1) วิเคราะห์ประสิทธิภาพและข้อจำกัดของกฎการขานเล่นในด้านความแม่นยำ ความโปร่งใส และผลกระทบต่อความยุติธรรม รวมถึงข้อจำกัด เช่น ความล่าช้าในการตัดสินและความท้าทายทางเทคนิค 2) ศึกษาการประยุกต์ใช้เทคโนโลยีปัญญาประดิษฐ์เพื่อพัฒนากระบวนการตัดสิน โดยเน้นการใช้หลักการการเรียนรู้ของเครื่อง (ML) ในการตรวจจับการสัมผัสบอล การละเมิดกติกา และการลดข้อผิดพลาดของมนุษย์ และ 3) ประเมินผลกระทบของเทคโนโลยีต่อผู้ชม นักกีฬา และความเหมาะสมของกฎกติกาในบริบทการแข่งขันสมัยใหม่ ผลการศึกษาพบว่า เทคโนโลยีดังกล่าวช่วยเพิ่มความแม่นยำและความโปร่งใสในกระบวนการตัดสิน ส่งผลให้ผู้ชมมีความพึงพอใจและนักกีฬามีความมั่นใจในระบบการแข่งขันมากขึ้น อย่างไรก็ตาม ความท้าทายยังคงอยู่ในด้านข้อจำกัดของทรัพยากร การพัฒนาบุคลากร และการยอมรับจากผู้เกี่ยวข้อง โดยเฉพาะในบริบทของประเทศไทยที่ยังมีข้อจำกัดด้านโครงสร้างพื้นฐานและงบประมาณ นอกจากนี้บทความนี้ยังได้ชี้ให้เห็นถึงโอกาสในการพัฒนาผ่านการสนับสนุนจากภาครัฐ เอกชน และความร่วมมือระดับนานาชาติ ตลอดจนการริเริ่มโครงการนำร่องในระดับชุมชน เพื่อสร้างรากฐานที่มั่นคงสำหรับการยกระดับมาตรฐานการตัดสินกีฬาวอลเลย์บอลไทยให้เทียบเท่าระดับสากลอย่างยั่งยืน

คำสำคัญ: ปัญญาประดิษฐ์ กฎการขานเล่น การตัดสินกีฬา วอลเลย์บอล เทคโนโลยีการกีฬา

Abstract

The integration of artificial intelligence (AI) technology and the challenge system in volleyball officiating serves as an example of elevating competition standards within the context of modern sports. This study aims to: 1) analyze the efficiency and limitations of the challenge system in terms of accuracy, transparency, and fairness, including its constraints such as decision-making delays and technical challenges; 2) explore the application of AI technology to enhance officiating processes, focusing on the principles of machine learning (ML) in detecting ball touches, rule violations, and reducing human errors; and 3) evaluate the impact of technology on spectators, athletes, and the appropriateness of rules in

modern sports competitions. The findings indicate that these technologies significantly improve the accuracy and transparency of officiating, leading to increased spectator satisfaction and greater athlete confidence in competition fairness. However, challenges persist regarding resource limitations, personnel development, and stakeholder acceptance, particularly in Thailand, where infrastructural and budgetary constraints remain. Moreover, this study highlights development opportunities through support from the government, private sector, and international collaborations, as well as pilot initiatives at the community level. These efforts aim to establish a solid foundation for advancing Thailand's volleyball officiating standards to align sustainably with international benchmarks.

Keywords: Artificial Intelligence, Challenge system, Sports officiating, Volleyball, Sports technology

Introduction

In today's era, where sports competitions attract global attention, ensuring fairness and accuracy in officiating has become a critical factor influencing the credibility and integrity of competitive systems. Volleyball, a sport characterized by its high-speed gameplay and complex movements, presents significant challenges for referees, making real-time and precise decision-making crucial. The Challenge Rules have played a vital role as a tool to verify officiating errors, such as ball contact detection, line calls, or rule violations during critical moments (Liu et al., 2023). Particularly in prestigious tournaments like the FIVB Volleyball Nations League and the Olympic Games, these rules not only reduce errors but also improve transparency and minimize disputes between players and referees, ultimately contributing to audience satisfaction and confidence in match outcomes (Rangubhet et al., 2023). Moreover, advancements in challenge systems employing cutting-edge technology, including high-speed cameras and multi-angle replay systems, have continually elevated the standards of volleyball competitions to achieve global recognition (Çevik et al., 2023).

Artificial Intelligence (AI), particularly Machine Learning (ML) systems, is increasingly playing a significant role in enhancing the efficiency and accuracy of decision-making processes in volleyball. AI enables real-time data analysis, automating ball contact detection, player positioning analysis, and processing complex scenarios with exceptional speed and precision—capabilities beyond human limitations in certain situations (Guang & Wu, 2024). The integration of AI with challenge systems in global tournaments, such as the FIVB World Championship and the Asian Volleyball Championship, has demonstrated the potential of this technology to enhance transparency, reduce disputes, and build credibility in decision-making processes (Çevik et al., 2023). Additionally, AI enhances viewer experiences by presenting easily comprehensible data, such as generating 3D visualizations of on-court events and augmented reality (AR) replays to clarify officiating decisions (Rosani et al., 2024).

Beyond minimizing human errors, the development of AI positively impacts the confidence of athletes and teams participating in competitions, particularly in high-precision and fast-paced settings in the digital age (Sun & Zhang, 2022). Moreover, AI-driven innovations extend beyond officiating, with multi-

player tracking and skill recognition frameworks being utilized to refine both decision-making and performance assessment in volleyball (Jiang et al., 2025). Recent developments in AI-powered drone-assisted analytics, such as the VolleyBots system, demonstrate how AI is being leveraged to combine motion control with strategic gameplay analysis, further expanding its role in modern volleyball (Xu et al., 2025). These applications underline AI's ability to not only enhance officiating accuracy but also reshape tactical approaches and training methodologies within the sport.

Despite significant progress in the development of challenge rules and AI integration, challenges and limitations remain. These include delays in reviewing on-court scenarios, which can disrupt the rhythm of the game (Karakaya et al., 2022), as well as resource and infrastructure constraints in developing countries, which hinder the installation and utilization of such technologies (Gottschalk et al., 2022). Additionally, gaining acceptance from stakeholders, including referees and athletes, remains a critical issue, requiring careful consideration for long-term system development. Concerns regarding over-reliance on AI and the diminishing role of human officials highlight the need for balanced technological integration, ensuring that AI serves as an aid rather than a replacement for referees (Lin et al., 2025).

This academic article focuses on analyzing the effectiveness and limitations of challenge rules in volleyball decision-making processes, considering accuracy, transparency, and fairness, as well as technical constraints such as decision-making delays and the complexity of reviews in high-speed scenarios. It also explores the application of AI, particularly ML, to enhance decision-making efficiency, such as ball contact detection and reducing human errors. Furthermore, the study evaluates the impact of these technologies on viewers, athletes, and officiating personnel while examining their suitability within modern volleyball competitions. The article aims to propose recommendations for developing suitable and sustainable decision-making systems for Thailand while laying a foundation to elevate volleyball competition standards to align with international benchmarks. The findings of this study are expected to support future research and contribute to a broader understanding of AI applications in sports officiating, offering insights into how technology-driven decision-making can be effectively implemented across various sports disciplines.

Challenge Rules and Raising the Standards of Refereeing

The development of refereeing systems in volleyball has entered a transformative era, with the integration of advanced technology and AI-driven digital systems to support referees' decision-making processes. Notably, the implementation of Challenge Rules has become a cornerstone of modern officiating, enhancing fairness, transparency, and consistency in global competitions. These advancements reflect the evolving expectations of stakeholders in the digital age, where the demand for precise and unbiased officiating has never been greater. While the Challenge system has significantly improved volleyball officiating, its full potential is now being realized through AI-powered automation, which aims to address limitations and inefficiencies in the current review process.

1. The Significance of Challenge Rules in Volleyball

Challenge rules have emerged as a pivotal mechanism for improving volleyball officiating standards at the international level. These systems reduce human error in complex and high-speed scenarios, allowing referees to make more accurate decisions, especially in crucial match-defining moments (Liu et al., 2023). The FIVB Volleyball Nations League has demonstrated the effectiveness of challenge rules in detecting barely visible ball touches, line violations, and rule infringements requiring high precision (Santi & Rangubhet, 2023).

In major international tournaments such as the FIVB World Championship and the Olympic Games, Challenge Rules have significantly enhanced transparency and credibility in refereeing. By reducing officiating errors, the system has minimized disputes between teams, increased trust among players, and improved audience satisfaction both in stadiums and via broadcasts (Rangubhet et al., 2023). At the continental level, the Asian Volleyball Confederation (AVC) has fully integrated the Challenge system into elite competitions, including the Asian Championship and Asian Games, aligning officiating quality with international standards (Karakaya et al., 2022).

In Southeast Asia, the Southeast Asian Games and the ASEAN Volleyball Championship have also adopted the Challenge system, demonstrating its effectiveness in improving decision accuracy and reducing disputes among competing teams (Jun & Zile, 2024). Recent studies highlight that the Challenge system not only increases referee confidence but also establishes a higher standard for officiating in volleyball, reflecting the technological evolution of modern competitions (Çevik et al., 2023).

Despite its effectiveness, the Challenge system still relies heavily on human intervention, as referees must manually assess video evidence and make final decisions. This human-dependent process introduces delays and potential inconsistencies, an issue that AI-enhanced officiating is expected to address in the near future (Xu et al., 2025).

2. The Effectiveness of Challenge Rules

Evaluations of the Challenge system reveal clear improvements in accuracy and transparency, particularly in high-stakes competitions (Liu et al., 2023). The system minimizes officiating errors in fast-paced situations, reducing conflicts among players, coaches, and referees (Brunnström et al., 2023). The FIVB Volleyball Nations League has demonstrated that challenge rules effectively verify critical incidents, such as ball touches, line calls, and rule violations, leading to more consistent and fair decisions (Rangubhet et al., 2023).

At the international level, data from the Olympic Games and the World Championship indicate that the Challenge system significantly reduces disputes and enhances credibility in officiating (Gottschalk et al., 2022). Moreover, research by the International Volleyball Federation confirms that challenge rules positively influence athlete and spectator confidence, reinforcing the perception of fairness in competitions (Çevik et al., 2023). In 68% of challenge cases, initial referee decisions were overturned, highlighting the system's ability to correct human errors (Liu et al., 2023).

Comparisons between pre- and post-implementation data show a significant reduction in disputes and an increase in audience engagement (Jun & Zile, 2024). However, at the Tokyo 2020 Olympic Games, concerns were raised regarding review delays, with some cases taking excessive time and disrupting match flow (Karakaya et al., 2022). These disruptions indicate a need for further refinements in officiating technology, particularly AI-driven automation, which can reduce review durations and enhance decision-making efficiency (Jiang et al., 2025).

Recent advancements in AI have paved the way for more efficient officiating models, as seen in sports like tennis and football, where AI assists in real-time decision-making (Lin et al., 2025). The SportsBuddy AI system has demonstrated AI-powered video storytelling and analytics, offering referees deeper insights into game dynamics (Lin et al., 2025). In volleyball, similar AI-based innovations are expected to optimize challenge procedures, integrating machine learning algorithms to provide near-instant rulings with minimal human intervention (Xu et al., 2025).

3. Limitations of Challenge Rules

Despite its success, the Challenge system faces inherent limitations, particularly regarding review delays, financial costs, and accessibility in lower-tier competitions (Brunnström et al., 2023). A frequently criticized issue is the prolonged review process, which affects match flow. At the Olympic Games and the World Championship, some challenges took up to 3–5 minutes, leading to disruptions and impacting athlete focus (Karakaya et al., 2022). Additionally, extended review times can diminish audience engagement, particularly for television viewers, reducing the overall entertainment value of matches.

From a technological and financial standpoint, the cost of implementing and operating Challenge systems remains a significant barrier, especially for developing countries (Gottschalk et al., 2022). The financial disparity prevents many national leagues from adopting high-end officiating technology, creating a competitive gap between well-funded and resource-limited regions (Çevik et al., 2023). Training personnel, including referees and technical staff, is also a major challenge, as many countries lack access to specialized training programs (Rangubhet et al., 2023).

Furthermore, technological inequities affect the competitive balance in volleyball, as teams from resource-limited nations often compete without access to challenge systems during training, unlike teams in wealthier regions (Santi & Rangubhet, 2023). This gap reflects broader structural inequalities in global sports, where technological advancements disproportionately benefit wealthier federations.

Additionally, challenge rules struggle to address highly subjective decisions, such as athlete intent and psychological factors, which remain beyond the scope of current AI models (Brunnström et al., 2023). To overcome these challenges, sports organizations must invest in advanced AI systems that can analyze behavioral data and predict decision patterns with higher accuracy (Jiang et al., 2025).

The future of officiating lies in AI-integrated solutions, where machine learning models can assist in automated decision-making, reducing the burden on human referees (Xu et al., 2025). By combining AI-driven tracking with automated challenge procedures, volleyball can further enhance its credibility while preserving match integrity (Lin et al., 2025).

Application of Artificial Intelligence in Sports Officiating

The advancement of artificial intelligence (AI) has revolutionized sports officiating, particularly in volleyball, where precision and rapid decision-making are essential. AI-integrated technologies enhance transparency and fairness, addressing long-standing challenges in officiating accuracy. Modern AI-driven systems now process real-time match data, significantly improving refereeing efficiency and reducing human errors.

1. The Role of Artificial Intelligence and Machine Learning

AI and machine learning (ML) have transformed officiating by analyzing real-time data from high-speed cameras and intelligent sensors, ensuring precise detection of ball touches, line violations, and rule infringements (Sun & Zhang, 2022). Deep learning algorithms trained on extensive match data allow AI to recognize motion patterns and predict high-risk situations, assisting referees in making more informed decisions (Huang & Zou, 2023). Computer vision technology enhances AI's ability to track player movements and analyze ball trajectory, further improving officiating accuracy (Liang & Liang, 2022).

The integration of intelligent sensors into volleyball equipment, such as courts, nets, and balls, has also enhanced real-time data collection (Salim et al., 2024). These sensors transmit precise ball movement data to AI systems, supporting automated challenge procedures and reducing review time (Kautz et al., 2017). AI-powered systems now proactively alert referees about potential rule violations, optimizing the decision-making process and increasing officiating credibility (Çevik et al., 2023).

AI's role extends beyond officiating to multi-player tracking and skill recognition, aiding both referees and coaching staff in performance analytics (Jiang et al., 2025). Recent AI advancements, such as the VolleyBots system, integrate drone-based motion control for in-depth strategic game analysis, further expanding AI applications in volleyball (Xu et al., 2025).

2. Case Studies of Artificial Intelligence in Sports Officiating

Empirical data highlights AI's success in sports officiating. The Video Challenge Review system in the FIVB Volleyball Nations League, powered by high-resolution cameras and AI algorithms, accurately detects key violations, minimizing officiating errors (Liu et al., 2023). Hawk-Eye technology, widely used in international volleyball, provides 3D visualizations of ball trajectories, improving decision-making transparency and reducing disputes (Brunnström et al., 2023; Rosani et al., 2024).

Japan's university-level AI-assisted officiating system, which leverages ML to analyze match data, has significantly enhanced rule enforcement accuracy and minimized human biases (Sun & Zhang, 2022). Additionally, AI-powered systems in football and tennis have demonstrated that automated decision-making can increase fairness and fan engagement (Lin et al., 2025). These cases underscore AI's role in establishing more precise and credible officiating systems across multiple sports.

3. Trends in the Development of Artificial Intelligence Technology

AI development in sports officiating focuses on big data integration and deep learning models to refine officiating accuracy (Cai & Dai, 2024). Real-time AI analytics allow match data to be continuously processed, adapting to new scenarios for enhanced officiating precision (Guang & Wu, 2024).

Advancements in computer vision and AI-driven officiating models have introduced new visualization tools, improving the spectator experience by providing 3D replays and enhanced graphic analyses of referee decisions (Shih et al., 2022). Future AI systems aim to be adaptive across different court environments and sports, further refining global officiating standards (Zhang & Li, 2021).

4. Benefits and Limitations of Using Artificial Intelligence in Sports Officiating

AI-driven officiating offers higher accuracy, reduced officiating errors, and improved fairness in high-speed sports (O'Brien & O'Keeffe, 2022). Real-time AI analysis mitigates conflicts between referees and athletes, increasing trust in officiating decisions (Petersen & Wichmann, 2021). The Hawk-Eye system has proven highly effective in detecting ball positions, reinforcing credibility in major competitions (Brunnström et al., 2023).

However, AI integration poses challenges, particularly high costs and resource disparities, which hinder widespread adoption in developing countries (Goel, 2024; Gottschalk et al., 2022). Additionally, over-reliance on AI may diminish referees' confidence in independent decision-making, altering the balance of officiating dynamics (Silva et al., 2016). AI also struggles with interpreting complex psychological or intent-based decisions, limiting its ability to fully replace human judgment (Conejero Suárez et al., 2020).

To maximize AI's benefits, future development should focus on balancing AI automation with human officiating expertise, ensuring fairness while maintaining referees' roles in decision-making (Lin et al., 2025). The combination of AI-assisted tracking, automated officiating models, and human oversight represents the future of modern sports officiating, fostering sustainable advancements in global competition standards.

The Impact of Technology on Sports Officiating

The integration of technology into volleyball officiating has revolutionized competition standards, audience experiences, and stakeholder perceptions. Advancements such as Hawk-Eye and the Video Challenge Review system have enhanced transparency, reducing human errors and fostering greater confidence in match outcomes (O'Brien & O'Keeffe, 2022; Çevik et al., 2023). These improvements align with broader trends in sports officiating, where digital tools play a crucial role in ensuring fairness and accuracy.

1. Positive Impacts

Technology-driven officiating has significantly increased transparency, fairness, and audience trust (Villarejo-García et al., 2023). AI-powered systems enhance accuracy, reducing disputes between teams and referees by up to 35% in major competitions like the FIVB Volleyball Nations League (Liu et al., 2023). Real-time visualizations and 3D graphical analyses allow spectators to better understand officiating decisions, leading to improved engagement (Rosani et al., 2024; Sousa et al., 2023). For athletes, the increased consistency of decision-making fosters a sense of fairness, allowing them to compete with greater confidence (Silva et al., 2016). Comparative studies highlight that post-technology adoption,

competition standards have improved significantly, reducing officiating controversies and increasing global acceptance of volleyball as a fairer sport (Oliveira et al., 2020; Cai & Dai, 2024).

2. Negative Impacts

Despite its benefits, technology's over-reliance poses key challenges, including frequent game stoppages that disrupt match flow and reduce excitement (Goel, 2024; O'Brien & O'Keeffe, 2022). Excessive review time, particularly in high-stakes moments, diminishes audience engagement and affects athletes' concentration (Villarejo-García et al., 2023).

Global inequality in technology access limits developing nations from implementing high-standard officiating systems, creating a competitive imbalance (Sousa et al., 2023). Resource disparities hinder teams from training in tech-driven environments, widening performance gaps between developed and underdeveloped regions (Silva et al., 2016). Furthermore, over-reliance on AI in officiating may undermine referees' confidence and diminish their role in decision-making (Petersen & Wichmann, 2021; Thomas-Acaro & Meneses-Claudio, 2024). Technology cannot fully replace human judgment, particularly in cases requiring subjective interpretation, such as athlete intent or sportsmanship violations (Conejero Suárez et al., 2020).

Long-term overdependence on technology risks widening the gap between well-funded and under-resourced sports federations, affecting global sports development (Villarejo-García et al., 2023). Addressing these challenges requires international collaboration to develop cost-effective solutions that ensure equitable access to technology in sports officiating.

Development of Rules and Officiating Processes in the Context of Modern Sports Competitions

The development of officiating systems in modern volleyball faces challenges in integrating technology with traditional competition formats while maintaining the sport's essence. Enhancing officiating processes requires balancing accuracy, efficiency, and fairness, ensuring that AI-driven systems align with evolving global standards.

1. Enhancing Challenge Rules

The enhancement of challenge rules plays a crucial role in advancing officiating accuracy and efficiency in volleyball (Brunnström et al., 2023). High-efficiency image-processing algorithms and AI-driven real-time analysis have significantly reduced review times, ensuring faster decision-making while minimizing game disruptions (Çevik et al., 2023; Gottschalk et al., 2022). AI-powered computer vision now detects high-speed rule violations and obscure viewing angles, improving officiating precision (Villarejo-García et al., 2023).

Modern AI systems have reduced event review time by up to 30% in competitions like the FIVB Volleyball Nations League (Jun & Zile, 2024). However, technological improvements alone are insufficient—referee training remains essential to optimize AI-assisted decision-making. Continuous

education programs ensure officials can effectively interpret AI-generated insights, bridging the gap between human judgment and automation.

2. Integration of Artificial Intelligence in Officiating Processes

AI integration in volleyball officiating enhances transparency, consistency, and international standardization (Guang & Wu, 2024; Huang & Zou, 2023). The Fédération Internationale de Volleyball (FIVB) has developed global AI usage protocols, ensuring officiating systems meet the demands of elite competitions (Sun & Zhang, 2022). AI's ability to analyze vast historical datasets improves dispute resolution, predicting high-risk scenarios requiring officiating intervention (Rosani et al., 2024).

For AI integration to be effective, comprehensive referee training and certification programs are critical (Shih et al., 2022). AI's role should complement, rather than replace, human officials, preserving the authority of referees while utilizing AI's analytical precision (Zhekambayeva et al., 2024). Establishing minimum equipment standards—such as camera resolution and real-time data processing capabilities—ensures fairness across different competition levels (Ma & Kabala, 2024).

3. Managing the Technological Impact on Officiating

Managing AI's role in officiating requires balancing technological efficiency with the sport's natural flow (O'Brien & O'Keeffe, 2022). Combining AI with referee decision-making improves officiating accuracy while maintaining human oversight (Gazvin et al., 2024; Thomas-Acaro & Meneses-Claudio, 2024). Educating referees, teams, and spectators about AI-assisted officiating reduces misunderstandings and enhances trust in decision-making processes (Sousa et al., 2023; Oliveira et al., 2020).

Efforts to improve officiating technology must also address potential drawbacks, such as delays in game flow caused by AI-assisted reviews (Karakaya et al., 2022). Optimizing AI algorithms to process data faster ensures minimal disruptions while maintaining decision accuracy (Rosani et al., 2024). Establishing international partnerships between sports organizations fosters knowledge exchange, ensuring AI implementation aligns with global best practices (Ma & Kabala, 2024).

By strategically integrating AI into officiating processes, modern sports competitions can achieve a balance between technological innovation and the integrity of human decision-making, ensuring fair and efficient competition at all levels.

The Impact of Artificial Intelligence on Referees' Decision-Making Skills

Advancements in artificial intelligence (AI) have transformed officiating, improving accuracy, transparency, and referee skill development. AI's role extends beyond decision-making assistance to long-term referee training and preparation, influencing how officials manage games in modern volleyball.

1. The Role of AI in Officiating Processes

AI enhances officiating through two key aspects:

1) Decision-Support System – AI systems like Video Challenge Review and Hawk-Eye analyze real-time match data, creating 3D simulations to assist referees in making precise rulings (Salim et al.,

2024). AI-trained algorithms also predict high-risk in-game events, improving officiating preparedness and strategic decision-making (Rosani et al., 2024).

2) Training and Skill Development – AI facilitates long-term referee training by analyzing past match data, identifying patterns of errors, and simulating complex scenarios for practice (Kautz et al., 2017). Referees can train with AI-generated match situations that require rapid decision-making, enhancing their ability to manage high-stakes competitions (Sun & Zhang, 2022).

2. Positive Impacts on Decision-Making Skills

AI integration in officiating has led to significant improvements in referees' decision-making skills across four key dimensions:

1) Enhanced Decision-Making Accuracy – AI-powered systems like Hawk-Eye and real-time challenge reviews improve refereeing precision, particularly in fast-paced and complex situations (O'Brien & O'Keeffe, 2022; Gazvin et al., 2024). The ability of AI to analyze data with high accuracy minimizes human errors, ensuring greater fairness in competition outcomes.

2) Advanced Learning and Skill Development—AI assists referees in learning from past mistakes by analyzing historical match data and generating simulated training scenarios (Conejero Suárez et al., 2020). This approach helps referees refine their judgment and reaction time, making them better equipped to handle high-pressure matches.

3) Reducing Decision-Making Pressure—AI's role as a decision-support tool alleviates pressure on referees, providing instant, unbiased data analysis during crucial moments (Thomas-Acaro & Meneses-Claudio, 2024; Oliveira et al., 2020). This builds confidence in officiating decisions, allowing referees to focus on game management rather than the fear of making incorrect rulings.

4) Transforming the Future of Referee Development—AI-driven training programs personalize learning paths for referees, adjusting difficulty levels based on individual performance and decision-making patterns (Sun & Zhang, 2022). In Thailand, expanding AI-assisted training for referees at both community and national levels will play a crucial role in elevating domestic officiating standards and ensuring alignment with international benchmarks.

Through these improvements, AI not only enhances referees' real-time decision-making but also shapes their long-term skill development, contributing to a more efficient, transparent, and credible officiating system.

3. The Negative Impact of Artificial Intelligence on Decision-Making Skills

While AI has improved officiating accuracy and efficiency, its integration into refereeing processes presents three critical challenges that require careful management:

1) Overreliance on AI and the Decline of Independent Judgment—Continuous reliance on AI may reduce referees' ability to make independent decisions, particularly in high-pressure situations requiring rapid judgment (Mallen, 2019; Petersen & Wichmann, 2021). If referees become overly dependent on AI recommendations, their instincts and decision-making confidence may weaken, leading to hesitancy in moments requiring quick, discretionary rulings.

2) Erosion of Human Authority in Officiating—AI’s growing influence in decision-making risks diminishing the perceived role of human referees, especially among players, coaches, and spectators (Goel, 2024). When AI-generated decisions overshadow referee calls, public trust may shift toward technology rather than human expertise (O'Brien & O'Keeffe, 2022). This could lead to a scenario where referees are seen as mere operators of AI systems rather than respected decision-makers.

3) AI’s Limitations in Contextual and Psychological Judgment—While AI can analyze technical aspects like ball trajectory and rule violations, it struggles to interpret nuanced factors such as player intent, emotional dynamics, and sportsmanship conflicts (Silva et al., 2016; Sousa et al., 2023). Human referees excel in handling these situations, as they require social awareness, communication skills, and experience-driven decision-making. Over-reliance on AI may reduce the importance of these critical human attributes in officiating.

To mitigate these risks, AI should be developed as a support tool rather than a replacement for referees. Ensuring a balanced approach, where AI aids but does not override human judgment, will be essential in maintaining the credibility and effectiveness of officiating systems in modern sports.

4. Development Strategies to Strengthen Referee Roles

To ensure a balanced integration of artificial intelligence (AI) and human expertise in officiating, referees must be equipped with the right skills and strategies. The following four key approaches can enhance referee capabilities while maintaining their authority in decision-making:

1) Comprehensive AI Training and Skill Development—Referees must be trained not only in AI-assisted decision-making but also in understanding AI's limitations (Zhekambayeva et al., 2024). Training programs should cover real-time data analysis, AI system operation, and judgment-based decision-making to prevent overreliance on technology. Specialized workshops and simulations can help referees refine their ability to interpret AI-generated insights while maintaining control over rulings (Shih et al., 2022).

2) Human-AI Hybrid Officiating Models—AI should be designed to support, rather than replace, human referees, allowing officials to maintain final authority in ruling outcomes (Ma & Kabala, 2024). AI-generated recommendations should be used as advisory inputs, enabling referees to make data-informed decisions while incorporating human judgment, especially in ambiguous situations (Rosani et al., 2024).

3) Developing AI Systems Tailored for Local and International Competitions – AI-driven officiating should be flexible and adaptable to different levels of competition, from community leagues to professional tournaments (Held et al., 2024). Thailand, for example, can develop customized AI models suited to national competitions, allowing local referees to gain hands-on experience with AI-assisted officiating before advancing to international events.

4) Positioning Thailand as a Regional Hub for Sports Technology— Establishing sports technology research centers and AI-driven referee training programs would strengthen Thailand’s position as a leader in Southeast Asian sports officiating (Zhekambayeva et al., 2024). International collaborations with advanced AI sports technology developers from Japan and South Korea could provide critical expertise and support for Thailand’s long-term officiating advancements.

By implementing these development strategies, referees can effectively integrate AI into their officiating processes while maintaining confidence, accuracy, and credibility in decision-making. A structured approach that balances AI support with human expertise will ensure that officiating remains fair, transparent, and respected in modern sports competitions.

5. Case Studies and Examples

Studying the application of artificial intelligence (AI) in sports officiating provides valuable insights into its successes, challenges, and future potential. The following case studies highlight global best practices and Thailand's current progress in AI-driven officiating:

1) International Best Practices in AI Officiating

- **Hawk-Eye and Video Challenge Review in Global Volleyball**— These AI-powered systems have set new standards for transparency and accuracy in officiating, particularly in the Olympic Games and FIVB Volleyball Nations League (Liu et al., 2023; Brunnström et al., 2023). Hawk-Eye provides precise ball-tracking technology and 3D simulations, ensuring that referees make data-driven decisions in high-pressure moments (Rosani et al., 2024).

- **AI-Driven Referee Training in Japan and Europe** – Leading sports federations have integrated AI into referee development programs, using match simulations and real-time data analysis to enhance decision-making skills (Sun & Zhang, 2022). These initiatives have significantly improved referees' ability to manage high-stakes competitions, reducing human errors and increasing game fairness.

- **Football's VAR (Video Assistant Referee) System**— The application of AI-assisted refereeing in football (VAR) has demonstrated both its advantages and challenges (Gazvin et al., 2024). While VAR improves decision accuracy, it has also raised concerns over game delays and referee over-reliance on technology (O'Brien & O'Keeffe, 2022). Lessons from VAR highlight the importance of refining AI systems to ensure balance between technology and human decision-making.

2) Thailand's Progress in AI Officiating

- **Adoption of Video Challenge Review in Thailand Volleyball League**—Thailand has introduced video review technology in its national volleyball competitions, improving officiating transparency and decision accuracy (Chupthaisong & Varothai, 2024a). However, reliance on **foreign AI systems** remains a challenge, emphasizing the need for locally developed AI solutions to enhance domestic sports officiating (Piancharoenwong & Sukcharoenpong, 2024).

- **Potential for AI Integration in Thai Referee Development**—AI has not yet been widely implemented in referee training programs in Thailand. Developing AI-assisted training centers for referees at the community and national levels could significantly improve officiating standards and prepare Thai referees for international competitions (Held et al., 2024).

- **Opportunities for AI Sports Technology Research in Thailand**— Establishing sports technology research hubs focused on AI-driven officiating would position Thailand as a leader in Southeast Asian sports innovation (Zhekambayeva et al., 2024). Collaboration with regional AI sports developers from Japan and South Korea could accelerate Thailand's progress in AI-enhanced refereeing.

By analyzing successful international AI implementations and Thailand's current landscape, future efforts should focus on developing AI systems tailored to local competitions while maintaining global alignment. Investing in AI-driven officiating development will help Thailand bridge the gap with leading sports nations and establish a sustainable, technology-driven sports ecosystem.

Applying Artificial Intelligence in the Context of Thailand: Challenges and Opportunities

The adoption of artificial intelligence (AI) in volleyball officiating in Thailand presents both challenges and opportunities. Understanding these factors is crucial for developing a national officiating system that aligns with international standards while addressing local constraints.

1. Challenges in Implementing AI Officiating in Thailand

Thailand faces several limitations in AI-assisted officiating, primarily related to technological infrastructure, stakeholder confidence, and skilled workforce development:

1) Limited Technological Resources—Many Thai sports facilities lack essential infrastructure such as high-speed cameras, AI processing systems, and real-time image analysis software. Budget constraints further restrict access to advanced officiating technologies. Solutions include investing in cost-effective AI systems, securing government funding, and forming partnerships with private and international organizations to improve technology accessibility.

2) Stakeholder Confidence and Acceptance—AI-assisted officiating is still a relatively new concept in Thailand, with concerns about its reliability and accuracy in complex game situations. Increasing awareness through training programs, AI demonstrations, and pilot implementations in local competitions can help build trust among referees, athletes, and spectators.

3) Shortage of Skilled AI Personnel—Thailand lacks specialists trained in AI sports officiating. Addressing this requires AI-focused training programs, specialized courses in sports technology, and international exchange programs with AI-driven sports nations such as Japan and South Korea. Developing a local talent pool will ensure sustainable AI adoption in Thai sports officiating.

2. Opportunities for AI Development in Thai Officiating

Despite these challenges, AI technology offers major opportunities to elevate Thailand's sports officiating standards and position the country as a leader in Southeast Asian sports technology.

1) Aligning Thai Sports with International Standards—AI-driven officiating improves accuracy, transparency, and credibility at all levels of competition, preparing Thailand to host global tournaments under international regulations. Integrating high-speed cameras and AI-enhanced sensors into domestic competitions will help meet FIVB requirements and attract global attention.

2) Enhancing Community-Level Sports – Developing user-friendly, cost-effective AI officiating systems will benefit youth and grassroots sports, ensuring fairness in officiating while familiarizing young athletes and referees with modern sports technology. Early AI adoption in community sports can build long-term national expertise in AI-assisted officiating.

3) Strengthening Government and Private Sector Collaboration— Investing in AI sports technology through joint initiatives between the government, private sector, and educational institutions can accelerate AI adoption in officiating. Establishing sports innovation hubs focused on AI-based officiating will enhance domestic sports standards and promote Thailand as a regional leader in sports technology.

By addressing current challenges and leveraging AI's potential, Thailand can develop a robust, internationally recognized AI officiating system, ensuring greater accuracy, efficiency, and credibility in sports competitions.

Conclusion

The integration of artificial intelligence (AI) and challenge rules in volleyball has proven its potential to elevate officiating standards by enhancing accuracy, transparency, and reducing human errors. These advancements have increased trust in officiating decisions among athletes and spectators, contributing to fairer and more credible competitions. However, significant challenges remain, including resource limitations, system complexity, and stakeholder acceptance, particularly in Thailand, where infrastructure and specialized personnel are still lacking. Despite these obstacles, opportunities for AI development in Thai sports remain promising, especially through collaborative efforts between the government, private sector, and international sports organizations. Encouraging research, investing in personnel training, and launching pilot projects at the community level will help establish a strong foundation for AI implementation in a way that aligns with Thailand's unique context. With strategic development and sustained support, AI-driven officiating has the potential to advance Thai volleyball to meet international standards in a sustainable and competitive manner.

References

- Brunnström, K., Djupsjöbacka, A., Ozolins, O., Billingham, J., Wistel, K., & Evans, N. (2023). Quality measurement methods for video assisting refereeing systems. *Sports Engineering*, 26(1), 17.
- Cai, Y., & Dai, J. (2024). Big Data in Volleyball-Present and Future. *Frontiers in Sport Research*, 6(1).
- Çevik, R., Bilgin, M., & Şahin, M. (2023). Evaluation of Video Challenge System in Volleyball from the Points of Classification Referees. *European Journal of Education Studies*, 10(12).
- Chupthaisong, J. & Varothai, V. (2024a). Developing Athletes in the Digital Era: The Role of Human Resources in Enhancing Athletic Capabilities. *Journal of MCU Kanchana Review*, 4(3), 512–525. <https://so05.tci-thaijo.org/index.php/Kanchana-editor/article/view/273471> (In Thai)
- Chupthaisong, J., & Varothai, V. (2024b). Analysis of the Impact and Challenges of Technology Application in Sports Development. *Dusit Thani College Journal*, 18(2), 192–203. <https://so01.tci-thaijo.org/index.php/journaldtc/article/view/274569> (In Thai)
- Conejero Suárez, M., Prado Serenini, A. L., Fernández-Echeverría, C., Collado-Mateo, D., & Moreno Arroyo, M. P. (2020). The effect of decision training, from a cognitive perspective, on decision-making in volleyball: A systematic review and meta-analysis. *International journal of environmental research and public health*, 17(10), 3628.
- Gazvin, I., Rahmani, M., Majedi, N., Hemmatinejad, M., & Jamshidi, A. (2024). Application of Artificial Intelligence in the Sports Industry: A Review Article. *AI and Tech in Sports Management*, 14(2), 34-49.

- Goel, A. (2024). Is technology a complement or substitute to refereeing in sports? A review. *International Journal of Sports Technology and Science*, 2(1), 13-23.
- Gottschalk, C., Tewes, S., Niestroj, B., Drees, J., & Ernst, A. (2022). Innovation in Elite Refereeing Through AI Technologic al Support for DOGSO Decisions. *International Journal of Operations Management*, 2(3), 7-15.
- Guang, X., & Wu, X. C. (2024). Application of Neural Network-based Intelligent Refereeing Technology in Volleyball. *Journal of Computers*, 35(4), 291-301.
- Held, J., Cioppa, A., Giancola, S., Hamdi, A., Devue, C., Ghanem, B., & Van Droogenbroeck, M. (2024). Towards AI -Powered Video Assistant Referee System (VARS) for Association Football. arXiv preprint arXiv:2407.12483.
- Huang, J., & Zou, W. (2023). Artificial Intelligence-based Volleyball Target Detection and Behavior Recognition Method. *International Journal of Advanced Computer Science and Applications*, 14(9).
- Jiang, L., Yang, Z., & Gang, L. (2025). Transformer-Based Multi-Player Tracking and Skill Recognition Framework for Volleyball Analytics. *IEEE Access*.
- Jun, W. U., & Zile, F. A. N. (2024). Portable Referee System for Volleyball Game Based on Pressure Monitoring and Self-Powering Communication. *Mechanics*, 30(1), 91-96.
- Karakaya, A., Ulu, A., & Akleyek, S. (2022). GOALALERT: A novel real-time technical team alert approach using machine learning on an IoT-based system in sports. *Microprocessors and Microsystems*, 93, 104606.
- Kautz, T., Groh, B. H., Hannink, J., Jensen, U., Strubberg, H., & Eskofier, B. M. (2017). Activity recognition in beach volleyball using a Deep Convolutional Neural Network: Leveraging the potential of Deep Learning in sports. *Data Mining and Knowledge Discovery*, 31, 1678-1705.
- Liang, C., & Liang, Z. (2022). The application of deep convolution neural network in volleyball video behavior recognition. *IEEE Access*, 10, 125908-125919.
- Lin, T., Xiang, R., Liu, G., Tiwari, D., Chiang, M. C., Ye, C., ... & Zhu-Tien, C. (2025). SportsBuddy: Designing and Evaluating an AI-Powered Sports Video Storytelling Tool Through Real-World Deployment. arXiv preprint arXiv:2502.08621.
- Liu, C., Ding, Y., & Wang, J. (2023). Study on the importance of computer big data to volleyball match: taking the data analysis and application of women's volleyball video challenge of 2020 Tokyo Olympics as an example. In *Second International Conference on Statistics, Applied Mathematics, and Computing Science (CSAMCS 2022)* (Vol. 12597, pp. 609-616). SPIE.
- Ma, E., & Kabala, Z. J. (2024). Refereeing the Sport of Squash with a Machine Learning System. *Machine Learning and Knowledge Extraction*, 6(1), 506-553.
- Mallen, C. (2019). Artificial intelligence and implications for sport officiating. In *Emerging Technologies in Sport* (pp. 87-104). Routledge.
- O'Brien, K. A., & O'Keeffe, M. (2022). Reimagining the role of technology in sport officiating: How artificial intelligence (AI) supports the design and delivery of ecologically dynamic development processes. *Managing Sport and Leisure*, 1-13.
- Oliveira, L. D. S., Moura, T. B. M. A., Rodacki, A. L. F., Tilp, M., & Okazaki, V. H. A. (2020). A systematic review of volleyball spike kinematics: Implications for practice and research. *International Journal of Sports Science & Coaching*, 15(2), 239-255.
- Petersen, T. S., & Wichmann, S. S. (2021). Fairness, implicit bias testing and sports refereeing: An argument for why professional sports organisations ought to promote fairness in sport through testing referees for implicit biases. *Journal of the Philosophy of Sport*, 48(1), 97-110.
- Piancharoenwong, A., & Sukcharoenpong, S. (2024). Exploring AI Applications in Esports Management: Opportunities for Thailand. *Journal of Management Science Nakhon Pathom Rajabhat University*, 11(2), 55–65. <https://doi.org/10.14456/jmsnpru.2024.27> (In Thai)

- Rangubhet, K. R., Chailert, P., & Pranee, U. (2023). Effect of Volleyball Scoring Performance Analysis on the Women's VNL 2021 Championship Team. In 2023 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON) (pp. 498-501). IEEE.
- Rosani, A., Donadello, I., Calvanese, M., Torcinovich, A., Di Fatta, G., Montali, M., & Lanz, O. (2024). Video Analytics for Volleyball: Preliminary Results and Future Prospects of the 5VREAL Project. In Proceedings of the Ital-IA Intelligenza Artificiale: Thematic Workshops co-located with the 4th CININational Lab AIS Conference on Artificial Intelligence (Ital-IA 2024), Naples, Italy, May 29-30, 2024 (Vol. 3762, pp. 271-276). CEUR-WS.
- Salim, F. A., Postma, D. B., Haider, F., Luz, S., Beijnum, B. J. F. V., & Reidsma, D. (2024). Enhancing volleyball training: empowering athletes and coaches through advanced sensing and analysis. *Frontiers in Sports and Active Living*, 6, 1326807.
- Santi, K., & Rangubhet, K. R. (2023). Attack Performance Model Analysis: Outside Spiker of the Champion Women's Team in Volleyball Nations League 2022. In 2023 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON) (pp. 506-510). IEEE.
- Schrödter, R. (2024). Beyond the Call: Examining Referee Decisions, Competence Development, and Objective Assessment in Sports.
- Shih, C. H., Huang, T. C., & Li, C. (2022). Applying Smart Technology To Volleyball training. In 2022 IEEE 4th Eurasia Conference on IOT, Communication and Engineering (ECICE) (pp. 215-218). IEEE.
- Silva, M., Marcelino, R., Lacerda, D., & João, P. V. (2016). Match Analysis in Volleyball: a systematic review. *Montenegrin Journal of Sports Science and Medicine*, 5(1), 35.
- Sirawattana, C., & Poolsamral, C. (2024). The Use of Artificial Intelligence in Sports Science to Enhance Athlete Performance. *Journal of Arts Management*, 8(4), 700-710. <https://so02.tci-thaijo.org/index.php/jam/article/view/274597> (In Thai)
- Sousa, A. C., Marques, D. L., Marinho, D. A., Neiva, H. P., & Marques, M. C. (2023). Assessing and monitoring physical performance using wearable technologies in volleyball players: a systematic review. *Applied Sciences*, 13(7), 4102.
- Sun, Z., & Zhang, H. (2022). Volleyball Movement Object Detection and Behavior Recognition Method of Artificial Neural Network. *Mobile Information Systems*, 2022(1), 2099204.
- Thomas-Acaro, R., & Meneses-Claudio, B. (2024). Technological assistance in highly competitive sports for referee decision making: A systematic literature review. *Data and Metadata*, 3, 188-188.
- Villarejo-García, D. H., Moreno-Villanueva, A., Soler-López, A., Reche-Soto, P., & Pino-Ortega, J. (2023). Use, validity and reliability of inertial movement units in volleyball: systematic review of the scientific literature. *Sensors*, 23(8), 3960.
- Xu, Z., Yu, C., Zhang, R., Yuan, H., Yi, X., Ji, S., ... & Wang, Y. (2025). VolleyBots: A Testbed for Multi-Drone Volleyball Game Combining Motion Control and Strategic Play. *arXiv preprint arXiv:2502.01932*.
- Zhang, J., & Li, D. (2021). The application of artificial intelligence technology in sports competition. In *Journal of Physics: Conference Series* (Vol. 1992, No. 4, p. 042006). IOP Publishing.
- Zhekambayeva, M., Yerekeshcheva, M., Ramashov, N., Seidakhmetov, Y., & Kulambayev, B. (2024). Designing an artificial intelligence-powered video assistant referee system for team sports using computer vision. *Retos: nuevas tendencias en educación física, deporte y recreación*, (61), 1162-1170.