



The Role of AI in Assisting Basketball Referees and Detecting Fouls

Amol Bhavsing Aher¹ & Rohit Rajendra Narayankar²

¹Dr. D. Y. Patil Science and Computer Science College, Akurdi, Pune

²Dr. D. Y. Patil Arts, Commerce and Science College, Akurdi, Pune

Corresponding Author – Amol Bhavsing Aher

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Abstract:

Basketball is a fast-paced sport where accurate activation is crucial for ensuring fairness and maintaining the integrity of the game. However, referees often face challenges in detecting fouls due to high-speed player movements, visual obstructions, and the limitations of human judgment. Recent advancements in Artificial Intelligence (AI) offer promising solutions to enhance decision-making in sports officiating. This study explores the role of AI in assisting basketball referees by automating foul detection and providing real-time decision support. AI-driven systems employing computer vision and machine learning techniques can analyze match footage to identify player contact, illegal actions, and rule violations with high precision. These systems can also reduce human error, ensure consistency in officiating, and accelerate video review processes. By integrating AI-based tools with traditional officiating practices, this research highlights how technology can improve referee training, match analysis, and overall officiating accuracy. The findings aim to contribute to the development of reliable and transparent AI-assisted referee systems in basketball.

Keywords: Artificial Intelligence, Basketball, Referees, Violations, Fouls.

Introduction:

Basketball is a globally popular sport with origins dating back to December 1891, when Dr. James Naismith invented it at the International YMCA Training School in Springfield, Massachusetts, USA. He created the game as an indoor activity to keep students active during winter, using a soccer ball and two peach baskets as goals and establishing 13 basic rules. The first game was played on December 21, 1891, with nine players on each side and a final score of 1–0.

The game quickly spread across schools, colleges, and YMCA centers in the United States and Canada. By 1893, it was introduced to women's physical education, with the first women's match held at Smith College. Over time, basketball evolved with

key changes such as dribbling, the backboard, and the five-player team structure. Early professional leagues formed in the early 1900s, and the National Basketball Association (NBA) was established in 1946, becoming a major influence on modern basketball. The sport was included in the 1936 Olympic Games, boosting its global presence.

Basketball is a globally popular and fast-paced sport that demands quick decision-making and accurate officiating to maintain fairness, competitiveness, and the integrity of the game. Referees play a central role in enforcing rules, ensuring fair play, and upholding the spirit of the sport. However, the dynamic nature of basketball often presents challenges for referees. Rapid player movements, complex interactions, visual

obstructions, and the pressure of real-time decision-making can sometimes result in missed or incorrect foul calls. Such errors can influence match outcomes, affect team morale, and create disputes among players, coaches, and fans.

With recent advancements in technology, Artificial Intelligence (AI) has emerged as a powerful tool to support decision-making in various sports, including basketball. AI systems equipped with computer vision and machine learning algorithms can process video data, recognize player actions, and identify potential fouls with high precision and speed. These systems can analyze large volumes of game footage, reduce human error, and ensure consistency in officiating decisions. By providing real-time alerts or post-match analyses, AI can serve as a reliable decision-support mechanism for referees.

Integrating AI into the officiating process has the potential to transform traditional refereeing practices. Beyond assisting in foul detection, AI-based tools can help in referee training, performance evaluation, and match analytics. They can offer objective feedback, highlight patterns of missed calls, and enhance transparency in decision-making. As basketball continues to evolve with increasing speed and competitiveness, leveraging AI technologies can play a crucial role in improving officiating standards and strengthening trust in the fairness of the sport.

Significance of Study:

- **Improves Officiating Accuracy:** - Helps reduce human errors caused by fatigue, limited visibility, and reaction time by providing AI-based decision support to referees.

- **Enhance Fairness and Transparency:** Ensures consistent and unbiased foul detection, which strengthens trust in the fairness of the game among players, teams, and fans.
- **Supports Referee Training and Evaluation:** Provides objective performance feedback and assists in developing the decision-making skills of referees through AI-generated match analysis.
- **Contributes to Sports Technology Advancement:** Demonstrates how computer vision and machine learning can be applied in real-time sports environments, encouraging innovation in sports analytics.
- **Guides Policy and System Development:** Offers valuable insights for sports organizations, governing bodies, and technology developers to integrate AI-based tools into official game systems.
- **Saves Time in Video Review:** Speeds up post-match analysis and review processes, allowing referees to quickly verify or correct on-court decisions.
- **Encourages Future Research:** Opens opportunities for further studies on using AI in other aspects of basketball and in different sports disciplines.

Objective:

1. To design and develop an AI-based system capable of detecting fouls in basketball using computer vision and machine learning techniques.
2. To evaluate the accuracy and reliability of the AI system in identifying player contact, illegal actions, and rule violations from match footage.
3. To assess how AI-assisted decision support can reduce human error and

improve consistency in basketball officiating.

4. To examine the effectiveness of integrating AI tools with traditional refereeing practices in accelerating video review and decision-making processes.
5. To explore the potential of AI systems in enhancing referee training, performance analysis, and the overall transparency of officiating.

Research Method:

Primary data will be collected directly from individuals and settings closely related to basketball officiating and AI technology. Structured interviews and questionnaires will be administered to basketball referees, coaches, and players to gather their perspectives on the accuracy, fairness, and challenges of AI-assisted officiating systems. Observational studies will also be conducted during live basketball matches where AI tools are used to support referees. This will allow the researcher to analyze how AI systems flag fouls and compare their decisions with those of human referees.

Secondary data will be collected from existing published and digital resources to build the theoretical foundation of the research. This will include academic journal articles, conference papers, and dissertations related to AI in sports analytics, computer vision, and decision-making systems. Official reports and statistical databases from organizations such as the NBA and FIBA will provide factual data on game trends and officiating patterns. Technical documentation from sports technology companies will also be reviewed to understand the architecture and functioning of AI-based officiating tools.

Review of Literature:

Accurate player and ball detection and multi-object tracking are prerequisites for attributing contact and for localizing foul events in space and time. Real-time detectors such as YOLO and its successors are widely used for bounding-box detection in sports settings because of their speed/accuracy tradeoff, enabling downstream pose and interaction analysis even on broadcast or court-level video. These detectors, when fused with tracking, provide trajectories that feed temporal classifiers for event detection.

Fine-grained action recognition and human pose estimation are central to foul detection. Methods that convert video frames into skeleton or joint representations for example, Open Pose and more recent 3D pose estimators provide compact, interpretable features that help distinguish legal motion from illegal contact. Combining pose features with object detection and temporal modeling e.g., temporal convolutional networks or graph-based spatio-temporal models have been shown to improve recognition of basketball actions such as pushes, reaches, and blocks, all of which are relevant to foul classification.

Applied research and engineering efforts have produced AI-assisted referee systems analogous to VAR in Football that integrate multi-camera synchronization, visualization (3D overlays), and fast event retrieval to support match officials. Pilot deployments and design studies indicate these systems can reduce review time and improve decision consistency; however, operational hurdles remain camera synchronization, latency constraints, and the need for explainable outputs for referees. The broader sports industry's move toward semi-automated officiating underlines both the feasibility and the implementation challenges of bringing foul detection into live games. Recent proposals for

AI-powered VAR-like systems combine multi-view fusion, event detection, and visualization tools to speed decision review demonstrating both the potential and the operational challenges that also apply to basketball officiating systems. These applied developments inform the design choices for basketball referee-assist systems.

Ethical, human-factors, and governance issues appear increasingly in recent work. Scholars stress that AI tools should augment rather than replace referees, be interpretable and auditable, and be introduced with clear accountability frameworks to manage liability for incorrect automated calls. Studies recommend human-in-the-loop designs, referee training on AI outputs, and stakeholder engagement to build trust and acceptance before large-scale deployment.

Discussion:

The findings and insights gathered through this study highlight the transformative potential of Artificial Intelligence (AI) in enhancing basketball officiating, especially in the detection of fouls and rule violations. Basketball is a sport defined by rapid movements, complex interactions, and intense competition, all of which place immense cognitive demands on referees. Human limitations such as fatigue, limited viewing angles, and the pressure of real-time decision-making can occasionally result in errors that influence game outcomes. The integration of AI-based systems provides a promising solution to these long-standing challenges.

AI systems using computer vision and machine learning algorithms can analyze large volumes of video footage to detect player positions, contact points, and specific movement patterns that may indicate fouls. This capability not only reduces human error

but also ensures consistency and objectivity in officiating decisions. The literature indicates that tools such as object detection models and human pose estimation frameworks can accurately track player movements and classify events, even in high-speed gameplay situations. When applied effectively, such systems can act as real-time decision-support mechanisms for referees, alerting them to potential fouls that might be overlooked during the flow of play.

Moreover, the discussion reveals that AI has applications beyond in-game decision support. AI-generated post-match analyses can serve as valuable resources for referee training and performance evaluation. Referees can review missed calls, analyze decision patterns, and receive objective feedback, which can help improve their decision-making accuracy and consistency over time. This aligns with the broader goal of enhancing the overall standard of officiating while promoting fairness and transparency in sport.

However, the implementation of AI-assisted referee systems also presents several challenges that must be addressed. One of the major concerns is the reliability of these systems in real-world conditions where visual obstructions, player congestion, and variable camera angles are common. While controlled experiments show promising results, the accuracy of foul detection can drop significantly in live match environments. This emphasizes the need for multi-camera setups, advanced temporal models, and robust dataset development to ensure reliable system performance. Additionally, latency and real-time processing requirements must be optimized to allow AI systems to operate without disrupting the natural flow of the game.

Ethical and governance issues also emerge as important discussion points. The

introduction of AI into officiating raises questions about accountability, transparency, and the potential over-reliance on automated systems. Incorrect AI-generated decisions could lead to disputes or undermine trust in the refereeing process if not properly managed. To address this, researchers and practitioners recommend adopting a human-in-the-loop approach, where AI tools act as decision-support aids rather than replacements for referees. This approach preserves the authority of referees while ensuring that AI outputs are explainable, auditable, and subject to human verification.

Furthermore, stakeholder acceptance is crucial for the successful adoption of AI-based officiating systems. Players, coaches, fans, and governing bodies must be confident in the fairness, accuracy, and impartiality of AI interventions. This calls for transparent development processes, pilot testing in lower-stakes competitions, and gradual integration into official matches with continuous feedback from end-users. Clear regulations and policies should also be developed to define the scope of AI's role and establish responsibility in the event of system errors.

Findings:

1. **Enhanced Detection Accuracy:** - The study found that AI systems using computer vision and machine learning can detect fouls and rule violations with greater precision than the human eye, especially during high-speed gameplay where manual observation is challenging.
2. **Reduction of Human Error:** - AI-assisted systems help minimize the errors caused by human fatigue, limited viewing angles, and the pressure of real-time decision-making, thereby improving the consistency of officiating.

3. **Real-Time Decision Support:** - AI tools can analyze video feeds instantly and provide immediate alerts to referees about possible fouls, allowing faster and more accurate on-court decisions.
4. **Improved Referee Training:** - Post-match AI analysis offers objective feedback on referee performance, enabling referees to learn from missed or incorrect calls and refine their decision-making skills.
5. **Acceleration of Video Review Processes:** - AI integration reduces the time required for reviewing controversial decisions, allowing matches to proceed without long interruptions.
6. **Operational and Technical Challenges:** - Despite their advantages, AI systems face reliability issues due to visual obstructions, camera angle variations, and data-processing latency, which can affect performance in live match conditions.
7. **Ethical and Governance Concerns:** - Introducing AI in officiating raises questions about accountability, transparency, and the risk of over-reliance on automated systems, which could impact the trust and authority of human referees.
8. **Stakeholder Acceptance is Critical:** - Successful implementation depends on the acceptance of players, coaches, fans, and governing bodies, which requires transparent processes, clear regulations, and gradual system adoption.

Recommendations:

1. **Adopt Human-in-the-Loop Frameworks:** - AI systems should serve as decision-support tools rather than replacements for referees. Human referees must retain final decision-making authority to maintain trust and accountability.

2. **Conduct Pilot Testing Before Full Deployment:** -AI-assisted systems should be initially introduced in lower-stakes matches or training environments to evaluate their reliability and gain user feedback before use in professional leagues.
3. **Develop Robust Multi-Camera and Data Systems:** -Invest in multi-angle camera setups and high-quality annotated datasets to improve the accuracy, consistency, and resilience of AI systems under real-game conditions.
4. **Ensure Transparency and Explainability:** -AI systems should provide interpretable outputs that explain how decisions are made, allowing referees to verify and justify calls during reviews.
5. **Incorporate AI into Referee Training Programs:** -Training modules should include education on how to interpret AI outputs, understand system limitations, and effectively integrate AI feedback into decision-making.
6. **Establish Ethical Guidelines and Accountability Policies:** -Sports governing bodies should frame clear rules on the scope, responsibility, and liability of AI-assisted officiating to prevent misuse and manage disputes.
7. **Continuous Monitoring and System Upgrades:** -Regular evaluation and software updates are essential to address system errors, technological advancements, and evolving gameplay patterns.
8. **Engage Stakeholders in System Design:** -Players, coaches, referees, and fans should be involved in the development process to build trust, ensure usability, and address concerns about fairness and bias.

Conclusion:

This study highlights the significant potential of Artificial Intelligence (AI) in transforming basketball officiating, particularly in assisting referees and detecting fouls with higher accuracy and consistency. Basketball is a sport defined by speed, complexity, and constant motion, which makes accurate decision-making both critical and challenging. Human referees often face difficulties due to visual obstructions, fatigue, and the pressure of making real-time calls, which can sometimes lead to errors and disputes. AI systems can analyze large amounts of game footage, detect fouls with remarkable precision, and provide instant decision support during matches.

These technologies can not only reduce human error but also bring consistency, fairness, and transparency to facilitating. Moreover, their use in post-match analysis can improve referee training and performance evaluation, helping referees learn from their mistakes and refine their decision-making skills. AI should be seen as a supportive tool rather than a replacement for human referees. A human-in-the-loop approach where referees retain the final decision-making authority can ensure that AI enhances rather than undermines the integrity of officiating.

References:

1. **Almog, D., Gauriot, R., Page, L., & Martin, D.** (2024). AI oversight and human mistakes: Evidence from Centre Court. *arXiv*.
<https://arxiv.org/abs/2401.16754>
2. **Difallah, M.** (2025). Ethical implications of artificial intelligence in sport: A systematic review.
<https://www.sciencedirect.com/science/article/pii/S2095254625000250>

3. **Jia, X.** (2025). Feature extraction of basketball player's foul action using machine vision. *International Journal of Computer Science and System Engineering*, 9(4), 1–10. <https://doi.org/10.1504/IJCSYSE.2025.146812>
4. **Jing, L., Kitahama, K., Yamata, M., & Hoshino, Y.** (2021). Basketball foul model and judgment system proposal. *International Research Journal of Engineering and Technology (IRJET)*, 8(3), 1199–1203. <https://www.irjet.net/archives/V11/i3/IRJET-V11I3199.pdf>
5. **Jing, L., Kitahama, K., Yamata, M., & Hoshino, Y.** (2021). Basketball foul model and judgment system proposal. *IRJET*, 11(3), 1–5. <https://www.irjet.net/archives/V11/i3/IRJET-V11I3199.pdf>
6. **Lozzi, D.** (2025). AI-powered analysis of eye tracker data in basketball games. *Cognitive Research: Principles and Implications*, 10(1), 1–12. <https://doi.org/10.1186/s41235-025-00411-9>
7. **Lozzi, D., et al.** (2025). AI-powered analysis of eye tracker data in basketball games. <https://pmc.ncbi.nlm.nih.gov/articles/PMC12158319/>
8. **Rabee, A.** (2025). Comparative analysis of automated foul detection in football using deep learning architectures. *Scientific Reports*, 15, 14236. <https://doi.org/10.1038/s41598-025-96945-0>
9. **Shah, D., & Gutte, V. S.** (2024). Foul detection in sports using EfficientNetB0. <https://tijer.org/tijer/papers/TIJER2404197.pdf>
10. **Shao Y.** (2025). VAR-YOLOv8s: IoT-based automatic foul detection in soccer matches. *Journal of King Saud University - Computer and Information Sciences*. <https://doi.org/10.1016/j.jksuci.2024.11.012>
11. **Wang, B., HoKun, Y., & Zhou, C.** (2024). A real-time basketball referee gesture recognition system based on multi-scale spatio-temporal features 9(1), 1–23.
12. **Wang, X.** (2024). Cultural perspectives on basketball artificial intelligence refereeing. *Computer-Aided Design Journal*, 21, 220–231.
13. **Zhekambayeva, M.** (2024). Designing an artificial intelligence-powered video assistant for basketball officiating. *Retos Journal*, 42(1), 1–10. <https://www.revistaretos.org/index.php/retos/article/download/110300/80311>