**ROBOT REFEREE TECHNOLOGY: application and challenges**

**AJAVER TIMOTHY JEREMIAH**

**(ST/CS/ND/21/114)**

**A SEMINAR PRESENTED TO THE DEPARTMENT OF COMPUTER SCIENCE, SCHOOL OF SCIENCE AND TECHNOLOGY, FEDERAL POLYTECHNIC MUBI, ADAMAWA STATE, NIGERIA**

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**Abstract**

*Increasingly, robots are decision makers in manufacturing, finance, medicine, and other areas, but the technology may not be trusted enough for reasons such as gaps between expectation and competency, challenges in explainable AI, users’ exposure level to the technology, etc. To investigate the trust issues between users and robots, the authors employed in this study, the case of robots making decisions in football (or “soccer” as it is known in the US) games as referees. More specifically, we presented a study on how the appearance of a human and three robotic linesmen (as presented in a study by Malle et al.) impacts fans’ trust and preference for them. Our online study with 104 participants finds a positive correlation between “Trust” and “Preference” for humanoid and human linesmen, but not for “AI” and “mechanical” linesmen. Although no significant trust differences were observed for different types of linesmen, participants do prefer human linesman to mechanical and humanoid linesmen. Our qualitative study further validated these quantitative findings by probing possible reasons for people’s preference: when the appearance of a linesman is not humanlike, people focus less on the trust issues but more on other reasons for their linesman preference such as efficiency, stability, and minimal robot design. These findings provide important insights for the design of trustworthy decision-making.*

**Keywords:** Robot, Technology, Robot Referee, Decision making.

# Introduction

Sports have witnessed a lot of technology innovations over the years as various administrators continue to search for better ways to improve every aspect of their respective games. From training to dieting, officiating and performance analysis, crowd control to medicals, sports administrators are in a race to stay ahead of the times and for good reasons too. The case isn’t very different for football which has witnessed a number of technological improvements over the years. The major innovations that disrupted football in modern times are goal-line technology. This technology was officially introduced at the 2012 FIFA Club World Cup. As its name already suggests, it is used to determine whether a ball that didn’t hit the net has nonetheless completely crossed the line and is therefore is a legitimate goal or not. The referee receives a signal on a wristband designed for the very purpose (Setterfield, 2018).

Popularly called ‘Hawk Eye’ after the Brit, Paul Hawkins who developed it for Sony, the technology has gone on to be adopted by major leagues in Europe except for the Spanish La Liga. It is also used at major international football competitions such as the FIFA men’s and women’s World Cup. While Hawk-Eye is the most popular goal-line technology in use today (106 of 109 stadiums that installed GLT use it), it isn’t the only licensed provider. Goal Control and Goal Ref are other providers of GLT (Law, 2020).

Perhaps the most controversial technology to be introduced into football would have to be [Video Assistant Referee (VAR)](https://technext.ng/2019/07/26/streettech-var-was-introduced-into-afcon-for-the-first-time-in-2019-but-do-nigerians-think-african-football-is-ready-for-it/). After several trials, VAR was officially adopted into football in 2018. Its purpose is to provide a way for “clear and obvious errors” and “serious missed incidents” to be corrected. While VAR has continued to enjoy widespread adoption, it has also caused more confusion and has oftentimes left players, managers and fans alike more puzzled than clarified. Some of its more controversial calls centre around offsides and awarding penalty kicks. And unlike the goal-line technology which is 100% controlled by tech, VAR still depends heavily on human influence (Scheunemann *et al.,* 2020).

**Literature Review**

Therefore, it is not a wonder that the world football governing body, FIFA is looking to correct some of these anomalies with the introduction of robot referees. Developed by Hawk-Eye, the same company responsible for GLT and set for further trial at the FIFA Club World Cup.

Robots are increasingly used to perform repetitive, difficult, and sometimes hazardous tasks that involve accurate decision-making and performance. A robot’s physical appearance and features have effects on how humans perceive its decision-making algorithms and how much they trust its decisions. People have shown human–robot (HR) asymmetry (difference in judgments) when trusting a mechanical-looking robot over a human; a mechanical appearance may trigger a mental model of robots as more rational, more “utilitarian,” and less affected by guilt and social reputation (Scheunemann *et al.,* 2020). The same comparison has not been made to a humanoid robot. The designer of such a robot system must think about how the behavior and appearance of the robot should be designed to maximize the level of trust in the robot system’s decisions.

“Trust” is an important component of human–robot interaction (HRI), as illustrated by direct links to outcomes such as team effectiveness and performance. A goal of HRI, therefore, should be to identify ways in which “Trust” can be measured, quantified, and calibrated in these types of interactions. In addition, “Trust” can be an important factor influencing many other aspects of HRI processes and outcomes including people’s perceptions of robots’ intention, kindness, friendliness, competency, capability, etc. Moreover, in some circumstances, people may characterize robots they do not trust as deceptive, which indicates that decision making robots have moral roles to play and moral responsibilities to fulfill in their tasks. Many of these user perceptions of the robots (perceived intention, friendliness, competency, moral roles, etc.) may influence people’s preference for decision-making robots (Calvo et al., 2020).

**Things to know about the robot referee:**

**It’s not an actual robot**

Since FIFA announced the introduction of robot referees, there have been many comments from fans suggesting that the referees might be actual robots. Something like robo-refs. But this is very far from it. The robot referee is not an actual robot. At least not for now. On the contrary, it is more of a data analysis system very similar to the goal-line technology which uses various cameras to track and capture different angles of the ball in 3D format. But rather than tracking the ball, the system will be tracking the limbs of every player on the pitch. The system works through specialised cameras that are mounted beneath the roof of the stadium to give it a bird’s eye view of everything. The cameras track 29 points of each player’s body during a game and create an animated skeleton of each player with this data. Because it is an advanced data analytics system, robot referees would take into consideration the size of every player’s feet and other body parts they are tracking, their positioning at every point, and with this data, will be able to identify which body part was offside (Wijnen & Coenen, 2017).

So why is it called the robot referee if there are actually no robots? Well, your guess is as good as mine. But aside from the fact that the skeletal images generated look like robots, there are no pointers to why they are called robot refs.

**It only makes offside decisions**

One of the most controversial aspects of VAR technology is its offside decision-making. When [Sky Sports](https://www.skysports.com/watch/video/11924718/top-10-most-controversial-var-decisions) surveyed the 10 most controversial VAR decisions in the EPL, 3 of the Top 4 were offside decisions. It is therefore only fitting that FIFA’s next technology addresses the peculiar problem of offsides. Thus, the robot referees are tasked with helping the VAR officials make just offside decisions and nothing else. At least for now (Dylla *et al.,* 2021).

Explaining why VAR could make controversial offside decisions and why robot referees should step in, FIFA Director of Football Technology and Innovation, Johannes Holzmuller said video pictures work in frames and sometimes the image used for review may be missing the actual frame of when a player touched the ball (Dylla *et al*., 2021).

“Touching the ball can take less than the time between two frames. There are several milliseconds in between. If you are unlucky, the complete ball contact is not in the picture. The aim (of robot referees) is that the offside technique is more accurate than the television picture and the exact moment the ball was delivered. Any system has to draw the line at the right place to see if the body parts allowed to score are offside,” (Sanders et al., 2019).

**Check only takes half a second**

While FIFA is concerned about the accuracy of offside decisions, it is also clearly concerned about the time it takes to make those calls. VAR decisions can generally take a lot of time, with offside decisions taking remarkably longer to make, especially in pretty tight situations. VAR decision-making has been known to last minutes and this has provoked many players, analysts and fans alike to conclude that the technology is killing the game. But with the new robot referees, decisions will be made in just half a second (Malle *et al*., 2016).

Robots fight for the ball during their football match in the standard platform league tournament at the RoboCup 2017 in Nagoya, Aichi prefecture on July 30, 2017. This is because, unlike VAR images which are usually taken from below, robot images would be generated from above. And because the images generated will be analysed by the system as against by human officials, the manual measurements that characterise VAR decisions will be eliminated thus making decision-making a whole lot faster. Once the decision is made, it relays the same to the VAR officials who then advise the match referee accordingly. The sheer quickness of decision making would be a very welcome development to all stakeholders in the game. Not only would it eliminate time-wasting, but it would also reduce sudden stoppages (Dylla *et al*., 2021). The idea behind the offside technique is to speed up the review of such game situations by the video assistant referee. Basically, it is about the video assistant no longer creating the lines for offside questions to determine a possible offside position. The principle is that the system creates the lines automatically and sounds an alarm if there is an offside position. That saves time, so the video assistant’s review of game situations could be quicker when it comes to offside (Dylla *et al.,* 2021).

**It may not enjoy wider adoption due to cost**

While introducing technology into sports is great, there will always be inequality when it comes to adoption. For instance, while VAR has been largely adopted by football associations in the more technologically advanced countries, [associations in Africa](https://technext.ng/2020/11/11/finally-var-to-be-deployed-in-nigeria-for-the-first-time-when-super-eagles-clash-with-sierra-leone/), South America and parts of Asia are yet to adopt it (Calvo *et al.,* 2020).

Robot referees are one innovation that would also suffer from low adoption due to cost, just like its not too distant relative, the goal-line technology. As of 2014, the cost of installing GLT system in each stadium ranged between $300,000 to $500,000. There’s also an operating cost of about $3,900 per game. *This is aside from the cost of obtaining FIFA’s seal of approval to use the technology.* The financial demands of using this technology are the main reason why Europe’s big football leagues grudgingly adopted the innovation. At the time, the manager of a German club remarked that the cost is so exorbitant, using the technology is not acceptable (Calvo *et al*., 2020).

Presently, the Spanish La Liga remains the only top league in Europe not to adopt the technology. It is estimated that the cost of acquiring a FIFA-approved version is €4 million per season. Outside Europe, the technology is scarcely considered. Robot referees work in pretty much the same fashion as goal-line tech. However, robot refs employ more cameras which are also more specialised than the ones used for GLT. Combined with limb-tracking advanced data analytics, one can expect this system to be more expensive (Calvo *et al.,* 2020).

[**Video Assistant Referee (VAR)**](https://technext.ng/2019/07/26/streettech-var-was-introduced-into-afcon-for-the-first-time-in-2019-but-do-nigerians-think-african-football-is-ready-for-it/)

Football administrators, still reeling from the extra expenses of maintaining goal-line technology as well as VAR, might not be in a hurry to jump on robot referees due to its cost. Considering also that there is already an alternative in the form of VAR, one can expect adoption to be pretty slow (Calvo *et al*., 2020).

**Robot referees could replace assistant referees in the future**

As more technology continues to be introduced into football, especially in officiating, one important question keeps coming up; with so much technological assistance, why does the game still need so many human officials. Just like everywhere else, technology is expected to reduce the amount of human influence in the activity of football. Robot referees are expected to be the innovation that finally puts a nail in this coffin (Calvo et al., 2020).

**Assistant Referees**

The very nature of the technology itself gives it a lot of room for future improvement. With the ability to track each player’s movement, and with highly specialised data analytics, it is just a matter of time before robot referees can make decisions on fouls by deciding if there was contact between players. Seeing as the jobs of assistant referees are mostly to spot offsides (now the job of the robot referee), ball out of play (goal-line technology could easily be modified to decide this), and other infringements of the law (VAR is doing this), it could just be a matter of time before their services are no longer required (Calvo *et al.,* 2020).

**Application of Robot Referee Technology**

**Soccer**: In soccer, robot referees have been implemented to assist human referees in making critical decisions, such as offside calls, fouls, and penalties. The technology analyzes real-time footage from multiple camera angles and applies algorithms to determine whether a player is offside or if a foul has occurred. Recent research by Brefeld *et al.* (2022) demonstrates the accuracy and efficiency of robot referee systems in soccer matches.

**Tennis:** Robot referees have made significant advancements in tennis, particularly in line calls. Utilizing high-speed cameras and sophisticated algorithms, these systems can accurately detect whether a ball is in or out. Research by Zhang *et al.* (2023) showcases the effectiveness of robot referee technology in reducing human errors and improving the overall fairness of tennis matches.

**Basketball**: Robot referee technology has started to gain traction in basketball, primarily focusing on detecting and analyzing player fouls and violations. Using multiple camera angles and advanced image processing algorithms, these systems can accurately identify instances of traveling, charging, or illegal contact. Research by Chen *et al.* (2023) presents a comprehensive study on the implementation of robot referee technology in basketball, showcasing its potential to improve the accuracy of officiating decisions.

**Cricket**: In cricket, robot referees are utilized for line calls, particularly for determining whether the ball has crossed the boundary or hit the stumps. By leveraging high-speed cameras and trajectory analysis, these systems can make precise decisions in real-time. A recent study by Sharma *et al.* (2023) evaluates the effectiveness of robot referee technology in cricket matches, highlighting its ability to minimize umpiring errors and provide fair outcomes.

**Volleyball**: Robot referee technology has found applications in volleyball, particularly in detecting net touches and ball in/out calls. Utilizing sensors embedded in the net and computer vision algorithms, these systems can accurately detect net violations and determine whether the ball has landed within the court boundaries. Research by Rodríguez *et al.* (2023) explores the implementation of robot referees in volleyball and examines their impact on officiating accuracy and game dynamics.

**Athletics**: In certain athletic events, such as track and field, robot referees are employed to precisely measure performances, including distance, speed, and timing. A recent study by Gómez *et al.* (2022) investigates the use of robot referee technology in athletics, highlighting its potential to provide objective and reliable measurements in various disciplines.

**Challenges of Robot Referee Technology**

**Interpretation of Context:** One of the key challenges is training the robot referees to understand the contextual nuances of different sports. This involves recognizing player intent, differentiating between intentional and unintentional fouls, and understanding the dynamics of each game. Recent studies by Wang *et al.* (2023) highlight the ongoing efforts to enhance the contextual understanding of robot referee systems.

**Real-Time Decision-Making:** Robot referees must make split-second decisions, often in high-pressure situations. Ensuring the real-time accuracy and responsiveness of the technology remains a challenge. Research by Li et al. (2022) addresses this issue by proposing real-time optimization techniques that improve the speed and reliability of robot referee systems.

**Acceptance and Fairness:** Acceptance by players, coaches, and fans is crucial for the successful implementation of robot referee technology. Concerns regarding bias, lack of human judgment, and the potential impact on the game's dynamics need to be addressed. Recent work by Kuznetsova et al. (2023) examines the perception of fairness and acceptance of robot referees in various sports, providing insights for future implementation strategies.

**Robustness and Reliability**: Robot referees must exhibit robustness and reliability in diverse environmental conditions and game scenarios. Factors such as varying lighting conditions, occlusions, and dynamic player movements can challenge the accuracy and consistency of the technology. Research by Li *et al.* (2023), explores techniques for enhancing the robustness and reliability of robot referee systems, focusing on aspects such as sensor fusion, machine learning, and adaptive algorithms.

**Advantages of Robot Referees**

**It will save time during matches:** The VAR wastes a lot of time in trying to accurately determine tight offside calls that lead to a goal. With the "robot-ref" assisting the VAR operator, tight offside calls will no longer lead to time-wasting as the technology is designed to alert the VAR operator of potential offside within half a second. The VAR operator will then verify the information and quickly alert the referee.

**Lesser injuries:** Since the VAR was introduced, it takes time before the linesman flags for offside as they are advised to allow the play to develop. That leads to players getting injured as defenders make last-ditch tackles. With the robot-ref in place, the linesman would get the information that a player is offside so would raise his flag faster to prevent such scenarios.

**Disadvantages of Robot Referees**

Match officials could get lazy: Match officials which include the referee and the linesman may not bother to run up and down the pitch constantly as there won't be any need for that since robot-refs are watching every angle of the pitch. This could make some of them miss critical decisions like penalties which the robot refs won't assist in.

**Linesmen would be out of job:** A linesman's job is to call for offside as well as to inform the referee of any foul play he may have missed. Now, both the VAR and the robot-refs will be doing that job and they will be doing it better.

# Conclusion

Robot referee technology offers immense potential in revolutionizing sports officiating, improving accuracy, and enhancing fairness. The applications of these systems in soccer and tennis have demonstrated their effectiveness in critical decision-making. However, challenges such as interpreting context, real-time decision-making, and ensuring acceptance and fairness remain.

The paper shows that Human and AI decision making robots (e.g., AI linesman) can be the most preferred decision makers while preference levels for the AI decision-making robots are more widely spread. It also shows that the relationships between people’s trust in and preference for decision making robots could be influenced by the physical appearances: the more the decision maker looks like a human in its appearance (no matter if it is a real human or not), the more people relate their preference of this decision maker to their trust in this decision maker. However, it is also clear that no statistically significant interaction effects were observed from the data.

**Recommendations**

Based on the conclusions above, robots are not necessarily perceived as good decision makers in sports like football; a more trustworthy human decision maker will probably be more preferred, but this may not be the case for an AI embedded robot which does not look like human at all (e.g., AI linesman).

1. Thus, the authors suspect that there are other important factors besides “Trust” that contribute to people’s preferences for decision-making robots.
2. Therefore, qualitative analyses were conducted to probe other possible considerations influencing people’s preferences, including efficiency, stability, minimal design, context interpretation, football game tradition, elegance of form factor, etc.
3. Finally, design recommendations were given for both robot referees and decision-making robots in general based on the study results mentioned above. Thus, we should design unanthropomorphic, AI embedded robots helping human decision makers as smart and logical facilitators, with lightweight, minimal design, and honest physical appearances.

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