Million Eyes on the "Robot Umps": The Case for Studying Sports in HRI Through Baseball

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2025 20th ACM/IEEE International Conference on Human-Robot Interaction (HRI) | 979-8-3503-7893-1/25/$31.00 ©2025 IEEE | DOI: 10.1109/HRI61500.2025.10974258

***Abstract*—In this position paper, we argue that baseball—and sports more broadly—provide a unique and under-explored opportunity for researchers to study human-robot interaction (HRI) in real-world settings. Using the rise of robot umpires in baseball as a primary example, we examine emerging themes such as power dynamics among players and umpires, labor implications, and technical challenges. We emphasize the affordances and benefits of studying sports within HRI, including the integration of interdisciplinary perspectives, the large-scale deployment of robots, and the examination of their role in deeply rooted cultural practices.**

***Index Terms*—robots in the wild, baseball, sports**

I. Introduction

In recent years, there has been a growing push in Human-Robot Interaction (HRI) to conduct research "in the wild," studying robot use in diverse contexts outside controlled lab environments. These in-the-wild studies offer a broader understanding of how people respond to robots in complex social settings and how robots affect social dynamics in situ [1], [2]. HRI researchers have explored a wide range of settings—cafes, restaurants, hotels, factories, streets, hospitals, nursing homes, homes, parks, and more—in search of generalizable theories about how robots integrate into the intricate web of daily life [3]–[8].

Despite these advancements, sports remain an underexplored domain in HRI research. Sports offer unique affordances as research sites, with implications for both the content and methodology of HRI studies. The integration of automation and robotic technologies into sports raises interdisciplinary questions, spanning legal frameworks, ethical considerations, social perceptions, and technical advancements. Moreover, sports represent a large-scale, mainstream application of robots rather than niche deployments. The cultural significance of sports further enables the study of robots in contexts imbued with deep emotional and sociocultural meaning, providing a lens to examine how technology integrates into established cultural practices.

Using baseball, a game with a long tradition and rich history, this paper positions sports as a promising site for advancing HRI research. We argue that baseball serves as a powerful context to showcase how HRI can incorporate broader perspectives, including legal and ethical dimensions to study robots in action. We contribute a collection of emerging themes for HRI research in sports. The themes demonstrate how a focus on sports can help HRI research expand methodologically, leveraging a broader set of approaches that address the scale, visibility, and sociocultural depth of sports. Sports is a microcosm of human activities, including norms, strategy, interactions, trust, teamwork and individuality, and so on. Additionally, these themes also demonstrate how recognizing sports as a research site can expand HRI research topically, situating robots in public, culturally significant spaces with millions of spectators. These settings challenge traditional HRI paradigms, offering opportunities to explore new research questions and insights into human-robot integration at scale.

II. Background

***Robots in Sports*—**Robotic technology has permeated various aspects of sports, including training, performance enhancement, broadcasting, entertainment, and rule enforcement. For instance, in broadcasting popular sports events such as the Olympics, FIFA World Cup, and the US Open, robotic cameras are deployed to capture high-definition footage from various angles for the spectators [9], [10]. In training, pitching robots are used in baseball to simulate individual pitchers' styles for

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batter's practices [11], and robotic tackling dummies are used in American football for the safety of tackling drills [12]. Robots also play a role in sports entertainment, as seen in an example of humanoid robot cheerleaders in Japanese professional baseball games during the COVID-19 pandemic [13]. In rule enforcement, robotic systems in tennis have replaced line judges in many tournaments, using high-precision cameras to determine if balls are in or out of bounds, and vocalizing decisions such as "out" or "fault" with pre-recorded voices [14], mimicking the familiarity of linespersons' voices.

The Rise of "Robot Umps" in Baseball—Baseball, originating in late 19th-century post-industrial America, is celebrated as the national pastime of the United States. Sociologists often describe baseball as a window into the "heart and mind of America" [15]. Over time, the game has transcended its American roots, gaining widespread popularity in Latin America and Asia.

Throughout its 150-year history, professional baseball has embraced technology to enhance the game—by making it more accessible (e.g., electronic lights for the night games, broadcast through TVs and radios), improving player performance (e.g., player development and injury prevention with tracking and wearable technology), and making it more entertaining for audiences (e.g., shorter games with pitch clocks, AI-powered visualizations) [16]–[22].

One of the most controversial technologies currently sparking debate is the Automated Ball-Strike System (ABS), commonly referred to as "robot umpires." This system is a combination of pitch-tracking technologies and computer-vision algorithms. It determines whether a pitch passes through the "strike zone," which is one of the most important and frequent calls in baseball. Throughout the history of baseball, this call has been under the sole discretion of the umpires, who make decisions in seconds under the high-pressure setting of a game.

Like any other human decisions, umpires' calls are shaped by personal perspectives, experiences, situational pressures, and subconscious influences [23]–[26]. Misjudgments, biases, and inconsistencies in umpires' calls on whether a pitch is a strike or not thus spur frequent dissatisfaction among fans and incur disputes and arguments from coaches and players, motivating a technology that could enhance the fairness and consistency of the calls. ABS, by combining sensors to track pitches and computer vision algorithms to determine whether a pitch passes through the predefined strike zone, has the promise to introduce accuracy, fairness, and consistency to the game [27].

In the meantime, unlike previous technologies adopted in baseball, ABS has a direct influence on the roles of a key human on the field, the umpire. This has spurred debates and concerns about how it will change people's relationships with the game—both from labor perspectives (umpires' jobs, players' evaluation such as catchers' pitch-framing) [28], [29], as well as ensuring that the game stays entertaining for the audience. After all, baseball is not only a competitive sport, but big business. Preserving the suspense and dramatic arc of the game—including controversial calls!—is important to ensure that audiences (in person and on television) remain engaged in the sport [30], [31], a concern that has sparked several recent rule changes to address games' pacing [32].

In the next section, we outline emerging themes surrounding the use of robot umpires in baseball that are particularly relevant for the HRI audience. These topics were iteratively developed through a combination of referencing relevant literature and engaging in numerous discussions among interdisciplinary authors, including researchers in HRI, Human-Computer Interaction, Natural Language Processing (NLP), Computer Vision, and legal scholarship. While not intended to be exhaustive, this exploration aims to illuminate key themes and underscore the value of studying baseball—and sports more broadly—as a field site for advancing HRI research.

III. EMERGING THEMES

Prism to Larger Societal Issues—Baseball could serve as a prism through which broader societal issues—such as rules, justice, and fairness—are reflected and examined. The sport's structure and its ongoing evolution through technological integration provide valuable insights into how society navigates these fundamental concepts. Machine bias in automated decision-making can have harmful and far-reaching consequences, such as in job screening or prison incarceration [36]–[38]. But it can be difficult for the public to develop well-informed opinions about the use of technology for decision-making in domains in which they lack knowledge or experience; far more of us have debated an umpire's call than have adjudicated a criminal hearing or screened a pool of potential employees, and so our intuitions about the role of technology in supporting (or supplanting) decision-making can be more informed in these "micro-legal" environments [30]. While different situations require tailored strategies, monitoring the role of technology for fairness in baseball can offer valuable lessons for designing and introducing new technologies to the public, fostering equity and trust. Baseball, therefore, mirrors broader conversations about equity, accountability, and the role of technology in upholding or challenging traditional norms.

Culture and Technology—Baseball is an interesting case study in which to observe how cultural norms and technology 'mutually shape' [39] each other. The development of the ABS system reflects societal values around fairness, while the language surrounding it—such as referring to it as "robot umps"—reveals perceptions of technology's place within the game. The introduction of robot umpires, in turn, influences the social roles and identities of human umpires, reshaping their interactions and responsibilities within the sport. Moreover, on a broader scale, the fact that baseball lacks an international governing body and is popular across various countries provides a unique opportunity to study how local cultures influence the adoption and use of technology—and how technology, in turn, shapes cultural practices. For instance, some have argued that South Korea's shifting societal attitude, which increasingly prioritize fairness, have been one of the contributing factors to the country's rapid adoption of robot umpires in its professional baseball league [40].

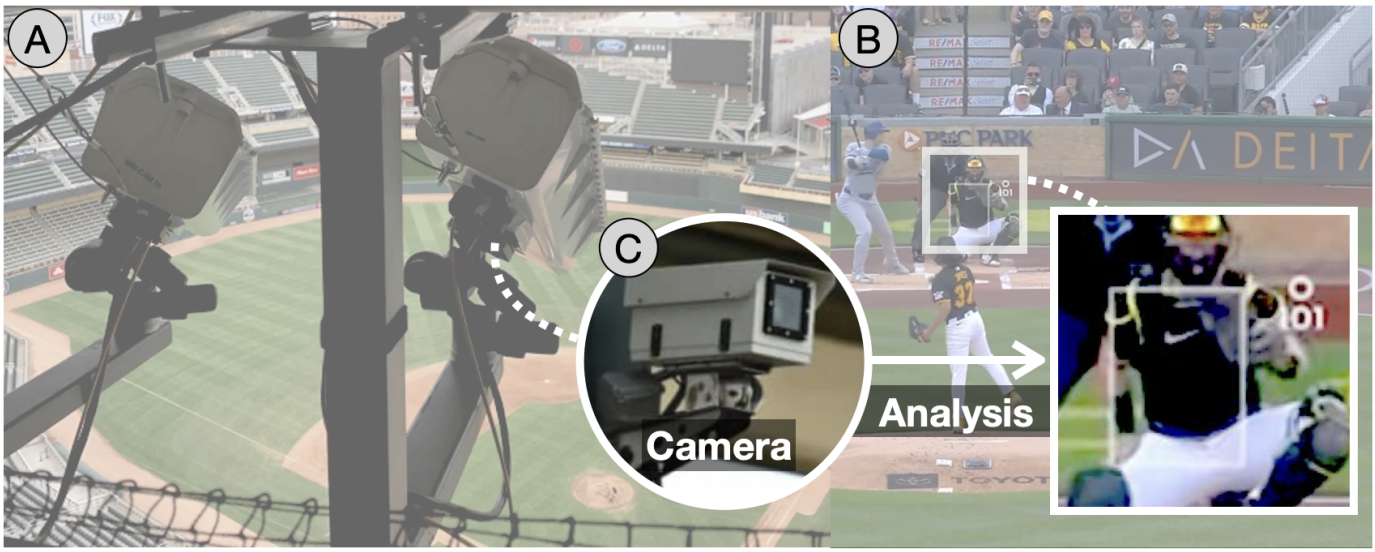

Fig. 1. Automated Ball-Strike System (ABS) utilizes high-speed tracking cameras (C) installed in stadiums (A) with computer vision algorithms to track if each pitch locates in the strike zone (B), as shown in the zoom-in view on the right. Images are from online [33]–[35].

This underscores the dynamic interplay between cultural values and technological advancements, highlighting how cultural values could shape the design, deployment, and adoption of these systems.

Technology and Power—Power is a fundamental dimension in how sports are organized, played, and watched [41], [42]. Power, a central yet often under-explored theme in HRI literature [43], is hence a particularly relevant lens as the integration of robot umpires challenges the traditional authority of human umpires. In the case of the Korean baseball league, the integration of fully automated ABS has transformed the role of the home-plate umpire into a more performative one, focused on announcing decisions made by machines [44], [45]. Players must adapt to machine-defined strike zones to optimize their performance, while coaches take on the responsibility of teaching techniques to help players adjust to the technology. These shifts require all stakeholders to reevaluate and redefine their roles within the game.

The loss of authority for umpires also intersects with their professional identities. For instance, when human umpires act as intermediaries for machine-made calls, they can be perceived as robot-like. This "robomorphism" occurs because human agency, decision-making, and identity are subsumed by the machine. [46], [47] This shift raises important questions about how the erosion of authority affects the identity and perceived role of human umpires within the sport and the profession.

Emotional Experiences of the Game—Baseball is not just about hitting balls and making catches; it is a game of performance and theatrics. One of the manager's unwritten responsibilities—governed by the "unspoken rules" of baseball, a code that shapes the behavior of individuals on the field—is to show dissatisfaction and protest against the umpire when their player is unhappy with strike calls [48]. These moments often escalate into highly emotional disputes, sometimes culminating in the dramatic ejection of the manager [49]. This emotional drama is an important part of baseball's charm, to the point that some journalists express concern that the adoption of robot umpires could lead to fewer disputes like these—and, by extension, fewer compelling stories to write about [50]. The interactions between players, managers, and umpires are hence essential to the character and experience of baseball. This raises an important question: if machine precision replaces human umpires, what happens to the performative aspects of umpiring and the emotions they evoke? Korean baseball league, after using robot umpires to fully automate strike zone calls, found that although robot umpire's calls have confused fans and players, most calls went unchallenged, because "it's hard to argue with a robot" [44]. Perhaps giving these robotic umpires a physical body could provide people with a focal point for their frustrations. However, if they are disembodied and invisible, how might this impact the dynamics of emotional expression and accountability?

Design for Explainability and Trust—Robot umpires make decisions based on computer vision algorithms, an inherent "black box" decision process [51]. How can the decision-making process of robot umpires be made accessible and understandable to audiences? These open questions are essential to materialize the "fairness" enhanced through machine capabilities. For example, when human umpires make mistakes, they can acknowledge and apologize to players and fans [52], [53]. But what happens when robots make mistakes, especially in high-stakes calls? What mechanisms can be designed to acknowledge and explain these errors—for example, would any kind of "natural language interfaces" explaining the logic and confidence of robot calls be helpful?

Adding to the complexity of design is how predisposed attitudes toward technology influence stakeholders' trust in the

robots. For instance, people who believe that human decision-making is superior to that of machines, an attitude also called "algorithm aversion" [54], may have more skepticism and frustration with robot umpires. This could motivate the design of anthropomorphic robots, which could help narrow the trust gap between robot and human referees' decisions [55]. On the other hand, it is equally important to design systems that prevent overtrust in robots [56], [57]. Overreliance on robot umpires can also undermine the human elements of the game, diminishing the dynamic interactions between players, coaches, and referees. After all, the fun is in the messiness of the game, nicely exemplified by the term "jogo bonito" ("the beautiful game") used in soccer to celebrate both the beauty and the contested moments of soccer games [58].

Technical Challenges and the Role of Failure—While the ABS system aims to reduce the significant rate of human error in ball-and-strike calls, technical limitations persist [59]. Issues such as delays in call timing and inconsistencies in strike zone calibration remain problematic. Moreover, discrepancies between the 2D electronic strike zones displayed during broadcasts and the 3D zones assessed by umpires underscore the inherent difficulty of accurately interpreting pitches, particularly those with complex trajectories or late movement [60]. This highlights a critical point: while technology can enhance precision, it is not infallible. However, this opens up an opportunity to explore the role of failure as a means to improve human-robot interaction [61], [62] in scenarios where technology must collaborate with human adaptability to address inevitable imperfections.

Methodological Opportunities for Quantitative Studies—Baseball presents a unique opportunity for HRI researchers to leverage computational social science techniques for large-scale cultural analyses. The discourse surrounding these technologies is extensively documented across publicly available diverse sources, including news articles, books, academic papers, online forums, and broadcaster commentaries. These records capture the perspectives of various stakeholders influenced by technology: players, coaches, team and league personnel, commentators, scholars, and audiences. HRI researchers could utilize NLP techniques, such as topic modeling [63], [64] and sentiment analysis [65], [66], to analyze this rich body of texts. These methods enable HRI researchers to explore questions that small-scale, in-lab qualitative studies may struggle to answer, such as: How do attitudes toward robot umpires differ among stakeholders? How do these attitudes evolve over time? Moreover, sports like baseball often have quantifiable performance metrics, such as those provided by MLB Statcast [1], which are commonly agreed on and easily accessible. These metrics enable data-driven research to address questions such as: How does technology influence player performance and evaluation?

In conclusion, baseball—and sports more broadly—offers a unique opportunity to combine quantitative methodologies with qualitative insights. By leveraging these tools, HRI researchers can uncover deeper understandings of societal attitudes, stakeholder dynamics, and the challenges of integrating new technologies into established cultural practices.

Opportunities for Other Sports in HRI—While we have focused on baseball as an example, these emerging themes are clearly present in other sports as well. Exploring how different sports address these challenges will create new opportunities for comparing the roles and impacts of robots in HRI. For instance, soccer's Video Assistant Referee has been critiqued for disrupting the game's dynamic or "flow" [58], while automated line calling in tennis has already become an established standard practice [67]. Beyond refereeing technologies, surfing practices also grapple with this tension between preserving the "essence of the game" and embracing machine-driven efficiency. Many surfers argue that artificial wave-generating technology diminishes the core essence of surfing [68].

IV. CONCLUSION

This paper positions sports, particularly baseball, as a valuable and understudied site in HRI. An example of Automated Ball-Strike Systems – or "robot umps" – offers a range of both thematic and methodological opportunities for broadening the scope of HRI studies, inviting scholars traditionally underrepresented within the field.

To this end, we would like to highlight that perhaps the most obvious reason to study sports in HRI is their ability to excite and engage a wide audience. This project began as a spontaneous idea to study robots in baseball, yet it quickly gained momentum, and over 20 scholars from across the departments—from legal scholars to NLP researchers—most of whom were not previously involved in HRI, joined us. This enthusiasm reflects the potential of sports to bring scholars together and draw new interest into the HRI field.

ACKNOWLEDGEMENTS

We thank Cheng Zhang, Top Piriyakulkij, and JiHyun Jeong, Luiza Yuan for their support and feedback.

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