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Tracking Scientific Output in Robotic Soccer and AI: A Bibliometric Overview

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A B S T R A C T

This study provides a bibliometric analysis of research related to the topic of robotic soccer and artificial intelligence (AI), mapping the intellectual and thematic landscape of a rapidly evolving interdisciplinary field. Drawing on 79 peer-reviewed articles from the Web of Science database spanning 1997 to 2024, we examine publication trends, citation impact, prolific contributors, institutional output, and core research themes. Utilizing the bibliometrix R package and biblioshiny interface, our analysis reveals that research on robotic soccer has experienced episodic growth, with notable surges linked to global competitions such as RoboCup. Results indicate that topics such as multi-agent collaboration, learning algorithms, autonomous decision-making, and human-robot interaction dominate the field's motor themes. Influential institutions include Islamic Azad University and Sapienza University of Rome, while key authors such as Peter Stone and Hiroaki Kitano shape the domain's scholarly foundation. Despite the dominance of technical publications, there remains a research gap in addressing sociotechnical dimensions and integrative AI strategies. This study not only clarifies the structure of the field but also identifies emerging trajectories, offering a strategic foundation for future research on intelligent autonomous systems in sports contexts.

Keywords: *Artificial Intelligence; Robotic Soccer; Bibliometric Analysis; Multi-Agent Systems; RoboCup Research.*

1. Introduction

In recent decades, remarkable advancements in the fields of artificial intelligence (AI) and robotics, particularly in sports, have led to the emergence of new concepts that challenge human capabilities in complex scenarios (Antonioni et al., 2021; Atasoy et al., 2021; Frias & Triviño, 2017; Hong et al., 2021; Kondratenko, 2014; Rajan & Saffiotti, 2017; Siegel & Morris, 2020). One prominent area of focus is robotic soccer, which attracts a large audience (Baker, 2023) and serves as an effective testing ground for exploring and developing algorithms in AI and robotics (de Boer & Kok, 2002; Reis, 2023; Stone, 2007).

In robotic soccer teams, complex multi-robot systems operate where each unit demonstrates individual skills while collaborating through the exchange of information regarding their local perceptions and intentions (Antonioni et al., 2021). Beyond being an entertaining activity, robotic soccer also provides a valuable platform for testing innovative theories and technologies in AI and robotics

(Ahamed et al., 2025). As robots increasingly permeate our lives, becoming integral to our daily existence (Hägele et al., 2016).

The subject of robotic soccer holds particular significance due to its deep ties to emerging technologies, machine learning software, and decision-making algorithms (de Almeida Martins, 2023; Reis, 2023). This discipline, as a multidimensional challenge, requires a more complex analysis of social, physical, and cognitive interactions, which can lead to significant advancements in AI (Kitano et al., 1998; Rossi et al., 2024; Sheridan, 2016).

In recent years, competitions such as RoboCup have played a pivotal role in advancing AI-driven robotic soccer (Michel et al., 2008; Nardi et al., 2014), fostering international collaboration, and driving technological innovation (Asada & Kitano, 1999; Rossi et al., 2024). Research in this area has also contributed to broader applications, including sports rehabilitation robotics (Ju et al., 2023), field robotics (Hameed et al., 2011), and AI-based educational tools (Budiharto et al., 2017; Eguchi, 2016; Tzagkaraki et al., 2021). These interdisciplinary applications highlight the significance of robotic soccer beyond the competitive arena, positioning it as a cornerstone for AI-driven research and innovation.

Despite the increasing number of studies on AI applications in robotic soccer, there remains a gap in systematically mapping the intellectual landscape of this field. Existing research primarily focuses on technical aspects, such as robot motion planning, learning algorithms, and game strategies (Abreu et al., 2019; Cherubini et al., 2009; Urieli et al., 2011). However, there has been limited effort to consolidate and analyze publication trends, emerging topics, and key contributors shaping this domain.

While AI applications in robotic soccer are increasingly studied, a systematic mapping of the field's intellectual landscape is lacking. Current research predominantly focuses on technical aspects like robot motion planning, learning algorithms, and game strategies (Abreu et al., 2019; Cherubini et al., 2009; Urieli et al., 2011). Consequently, there has been insufficient effort to systematically consolidate and analyze publication trends, emerging themes, and key contributors in the field. To address this shortcoming, the present study utilizes bibliometric analysis to uncover research trajectories, assess scholarly impact, and map collaboration networks in robotic soccer research.

Bibliometric analysis is particularly relevant for understanding the evolution and interdisciplinary nature of AI and robotic soccer research. It enables the identification of influential works, citation patterns, and thematic clusters that define the trajectory of this field (Casadei et al., 2023; Donthu et al., 2021; Zhang et al., 2020). Given the rapid technological advancements and growing interest in AI-driven sports automation (Pashaie et al., 2024), a bibliometric approach provides valuable insights into the intellectual structure and future directions of robotic soccer research.

This study conducts a bibliometric analysis to present a comprehensive overview of robotic soccer and AI research, identifying key trends, influential works, and emerging directions. The article aims to answer the following set of comprehensive research questions:

RQ1. How has the annual scientific production in the field of AI and Robot Soccer evolved over the past decade?

RQ2. Which journals have the highest local impact in AI and Robot Soccer research, as measured by publication count, citation frequency, and H-index?

RQ3. Who are the most influential authors in the field of AI and Robot Soccer based on publication count?

RQ4. Which universities and affiliations contribute the most to scientific production in AI and Robot Soccer based on the number of published articles?

RQ5. Which documents in the field of AI and Robot Soccer have received the highest number of global citations?

RQ6. What are the most frequently used and significant keywords in the titles of scientific publications in AI and Robot Soccer?

RQ7. What are the main motor themes in AI and Robot Soccer research as identified through thematic mapping?

2. Methods and Materials

2.1. Data Collection and Search Procedure

On April 13, 2025, a search was performed in the Web of Science (WoS) database to locate articles pertaining to Artificial Intelligence (AI) and Robot Soccer. The search was specifically focused on article titles, abstracts, and keywords, using the format TS= (("artificial intelligence" OR "AI") AND ("Robot Soccer" OR "Soccer Robot" OR "Robotic Soccer" OR "RoboCup")). The initial search returned a total of 268 documents for preliminary screening.

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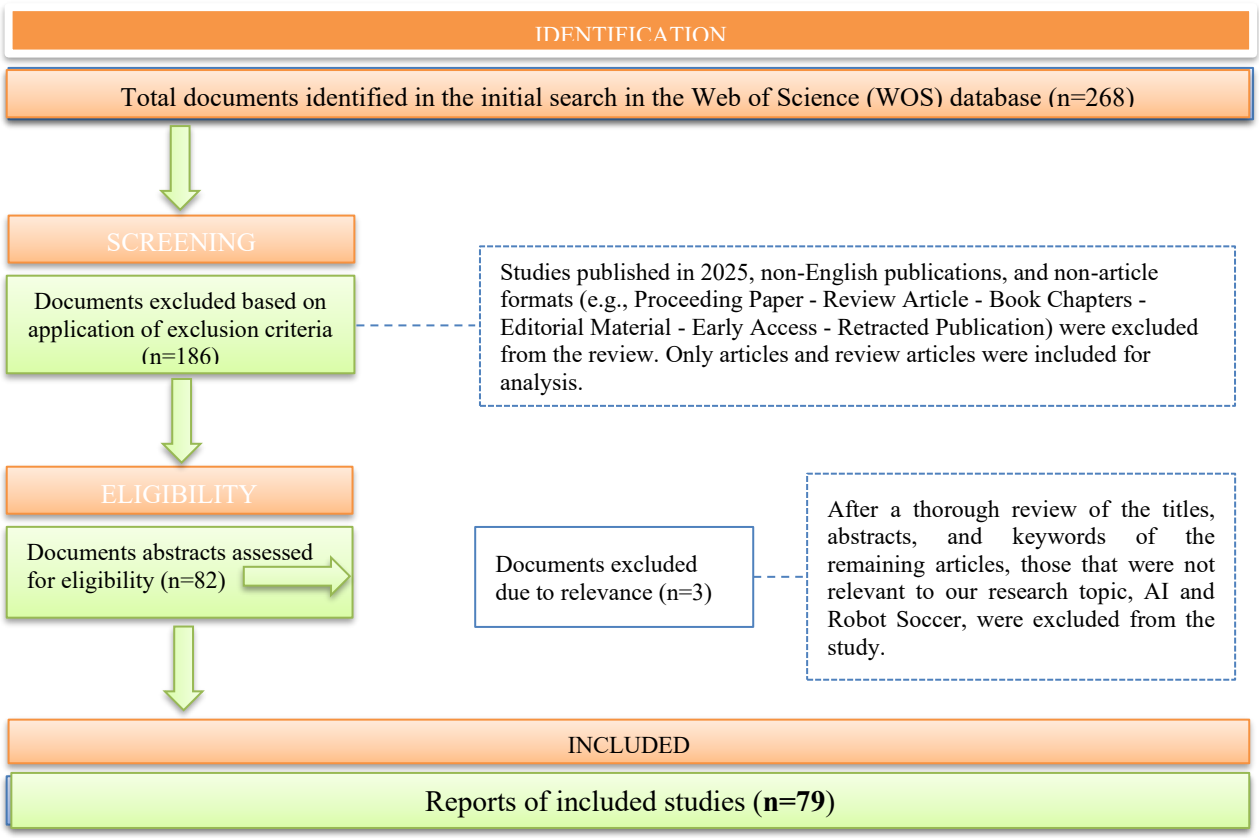
To align with the objective of this study, which was to focus on original research articles and review papers, other types of publications (e.g., proceeding papers, book chapters, editorial materials, early access items, retracted publications) were excluded from consideration. Additionally, articles published up to the end of 2024 were included in the review.

After applying these criteria, a total of 81 articles were downloaded from the WoS for detailed analysis. Following further review, three articles were identified as irrelevant to the study and were excluded from the analysis. The remaining articles (79 articles) were indexed across three main WoS indices: Science Citation Index Expanded (SCI-EXPANDED), Emerging Sources Citation Index (ESCI), Social Sciences Citation Index (SSCI). This careful process helped include only relevant and high-quality articles, which made it possible to carry out a detailed bibliometric analysis. Figure 1 shows the steps and method used in this study.

Figure 1

Research methodology stages



2.2. *Data Analysis*

In the data analysis phase, we used an open source statistical software "R" together with "biblioshiny" (Kalia et al., 2022). The flexible bibliometrix package in R language effectively supports bibliometric analysis (Aria & Cuccurullo, 2017). In recent decades, bibliography has emerged as a crucial tool in scientific management and policy making (Roy & Basak, 2013). Bibliometric approaches are used in many studies worldwide in the fields of scientometrics and research trends analysis to study a particular research topic or special publication (Golmohammadi & Pashaie, 2024). The research strategy employed in bibliometric techniques helps researchers achieve their objectives by utilizing various strategies and methods. According to Niu et al. (2016), bibliometrics can employ quantitative, visual techniques, and statistical methods to identify patterns in scientific production, such as mapping research dynamics and fronts, consolidating ideas, and guiding future studies. Bibliometric methods are applicable across a broad range of research contexts (Merigó & Yang, 2017). Bibliometric analyses can predict

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and map research trajectories and reveal scholars' collaboration networks, illustrating knowledge and expertise flows and convergences (Van Eck & Waltman, 2014). Compared to meta-analyses and systematic literature reviews, it proves to be particularly useful when it comes to broad research areas and extensive data sets that are impractical for manual review (Donthu et al., 2021).

3. Findings and Results

3.1. Overview and Data Description

The provided bibliometric data indicates that the time frame for this analysis spans from 1997 to 2024, covering 53 sources (including journals) and 79 documents. The annual growth rate of these documents is 0%, with an average document age of 12.1 years. Each document, on average, has received 25.39 citations, and the total number of References are 2577. In terms of document content, 69 Plus (ID) keywords and 239 Author (DE) keywords have been identified. The total number of authors is 259, with 14 of them having single-authored papers. The international collaboration rate is 17.72%. In terms of document type, 74 articles and 5 reviews have been presented.

Table 1

Key Information about the Data

Description	Results
Timespan	1997:2024
Sources (Journals)	53
Documents	79
Annual Growth Rate %	0
Document Average Age	12.1
Average citations per doc	25.39
References	2577
Keywords Plus (ID)	69
Author's Keywords (DE)	239
Authors	259
Single-authored docs	14
Co-Authors per Doc	3.8
International co-authorships %	17.72
article	74
review	5

3.2. Annual scientific production (RQ1)

Figure 2 shows annual scientific production from 1997 to 2024, showing fluctuations in the number of papers published each year. The distribution of articles over the years shows noticeable fluctuations. There are periods of low publishing activity, especially in the early years (1997-2009), during which fluctuations in the number of published articles are clearly visible. This is followed by a sharp increase in article production around 2009 and 2010. From 2011 to 2020, there has been a noticeable decline compared to 2011, accompanied by fluctuations. However, compared to the earlier years, a greater number of articles have been published. The most significant spike appears in 2021, indicating a surge in research on the topic of AI and Robot Soccer during that year. After that, from 2021 to 2024, there has been a decrease in the number of published articles. This trend suggests that while the field has seen steady activity over time, there are certain years with more concentrated efforts in publication.

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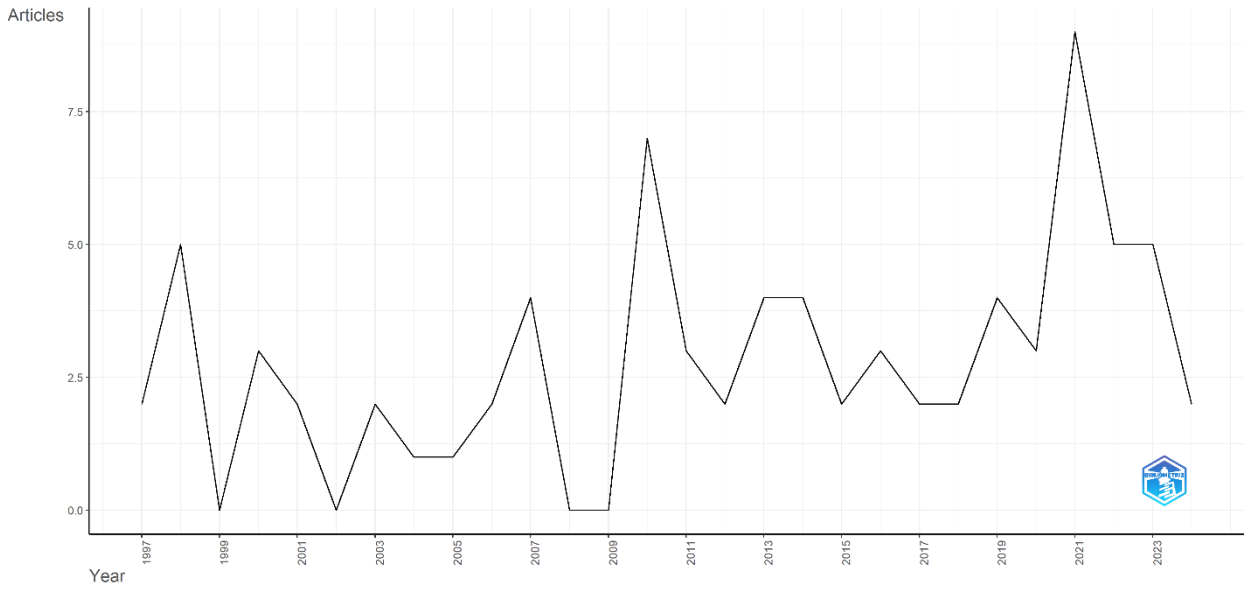
Figure 2

Annual scientific production



3.3. Sources' local impact (RQ2)

Table 2 shows the top four selected journals with the highest number of published articles, each having more than two articles in our research topic. AI Magazine with 6 article and, with an h-index of 4 and a total citation count of 387, has a higher impact than other journals. In contrast, Applied Artificial Intelligence with 5 articles, has an h-index of 4 and citations of 207, indicating its relative start in this field. Also, Autonomous Robots with 3 articles, with an h-index of 2 and total citations of 666 is in the next position. International Journal of Advanced Robotic Systems, with 3 articles, h-index of 2 and total citations of 8, is in the next position and less influential than other above journals. These differences indicate the different impact of these journals in their specialized fields.

Table 2

Sources local impact

Source	NP	H index	G index	M index	TC	PY start
AI Magazine	6	4	6	0.138	387	1997
Applied Artificial Intelligence	5	4	5	0.143	207	1998
Autonomous Robots	3	2	3	0.077	666	2000
International Journal of Advanced Robotic Systems	3	2	2	0.125	8	2010

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3.4. *Analysis of the most influential authors (RQ3)*

Based on the publication count, authors who have published more than two articles on our research topic were selected. Table 3 provides detailed information about these authors. At the top of our list is Stone P, with an h-index of 5, 734 citations, and 7 articles. Following this, the list includes Noda I, Nardi D, Iocchi L, Kasaei SHM with 4 articles, and Kitano H, Veloso M, Kasaei SAM, Kasaei SMM, and Taheri M, with three articles.

Table 3

Authors' Local Impact

Author	NP	H index	G index	M index	TC	PY start
Stone P	7	5	7	0.179	734	1998
Noda I	4	4	4	0.138	399	1997
Nardi D	4	3	4	0.13	80	2003
Iocchi L	4	2	4	0.087	118	2003
Kasaei SHM	4	2	3	0.125	10	2010
Kitano H	3	3	3	0.103	364	1997
Veloso M	3	3	3	0.107	689	1998
Kasaei SAM	3	2	2	0.125	7	2010
Kasaei SMM	3	2	2	0.125	7	2010
Taheri M	3	2	3	0.125	10	2010

3.5. *Most relevant affiliations (RQ4)*

According to our research, the eleven institutions listed in Table 4 each published more than two articles related to our research topic. In the top of these institutions, Islamic Azad University (9 article), Sapienza University Rome (6 articles), Aeronaut Inst Technol (5 articles) are in rank one to three.

Table 4

Top universities by published articles

Affiliation	Articles
Islamic Azad University	9
Sapienza University Rome	6
Aeronaut Inst Technol	5
National Institute of Advanced Industrial Science and Technology (Aist)	4
University of Texas Austin	4
University of Texas System	4
Carnegie Mellon University	3
Korea Advanced Institute of Science and Technology (Kaist)	3
The University of Osaka	3
Universidad Nacional Autonoma de Mexico	3
Zhejiang University	3

3.6. *Most global cited documents (RQ5)*

Table 5 presents the most frequently cited research papers relevant to our study, showcasing key contributions to the field. Notable entries include the highly cited paper by Stone and Veloso (2000) in Autonomous Robot, which leads with 617 total citations. The table provides a detailed view of these top papers, including total citations, annual citation rates, and normalized citation counts. For a comprehensive look at these influential articles and their impact, please refer to the table below.

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Table 5

Top Globally cited research papers: detailed citation metrics

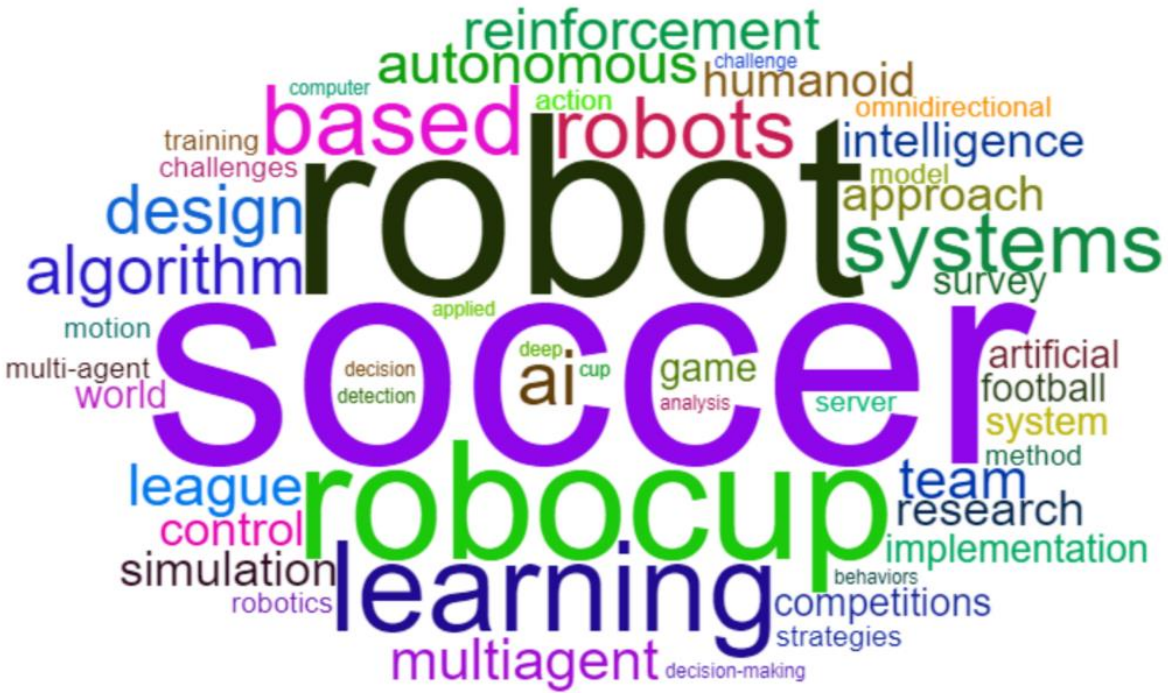
Paper	Total Citations	TC per Year	Normalized TC
Stone and Veloso (2000)	617	23.73	2.78
Kitano et al. (1997)	261	9.00	1.96
Eguchi (2016)	120	12.00	2.75
Noda et al. (1998)	111	3.96	2.89
Kitano and Tadokoro (2001)	99	3.96	1.74
Iocchi et al. (2015)	67	6.09	1.89
Evripidou et al. (2020)	66	11.00	2.15
Stone and and Veloso (1998)	65	2.32	1.69
Bianchi et al. (2014)	49	4.08	3.16
Iocchi et al. (2003)	49	2.13	1.42

3.7. Most important keywords (RQ6)

In the word cloud analysis of title's keywords, figure 3 was created based on the 50 most frequent words.

Figure 3

Word Cloud of Title's Keywords



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According to the data presented in Table 6, the ten most frequently occurring words were: soccer (31 times), robot (26 times), robocup (17 times), learning (13 times), based (10 times), robots and systems (9 times each), AI (8 times), and both algorithm and design (7 times each). These keywords underscore the central themes and prevailing research trends in the field, with a strong emphasis on robotics, artificial intelligence, and their applications in dynamic environments like RoboCup and soccer simulations.

Table 6

The 10 most repeated words

Terms	Frequency
Soccer	31
Robot	26
Robocup	17
Learning	13
Based	10
Robots	9
Systems	9
AI	8
Algorithm	7
Design	7

3.8. Thematic map (RQ7)

Figure 4 presents a thematic map constructed based on title's keywords, organizing research themes into four distinct categories: motor themes, niche themes, emerging or declining themes, and basic themes. This classification provides valuable insights into the evolution of Robotic Soccer and AI research by illustrating which areas are well-established, gaining prominence, or experiencing a decline in scholarly attention.

Figure 4

Thematic mapping analysis

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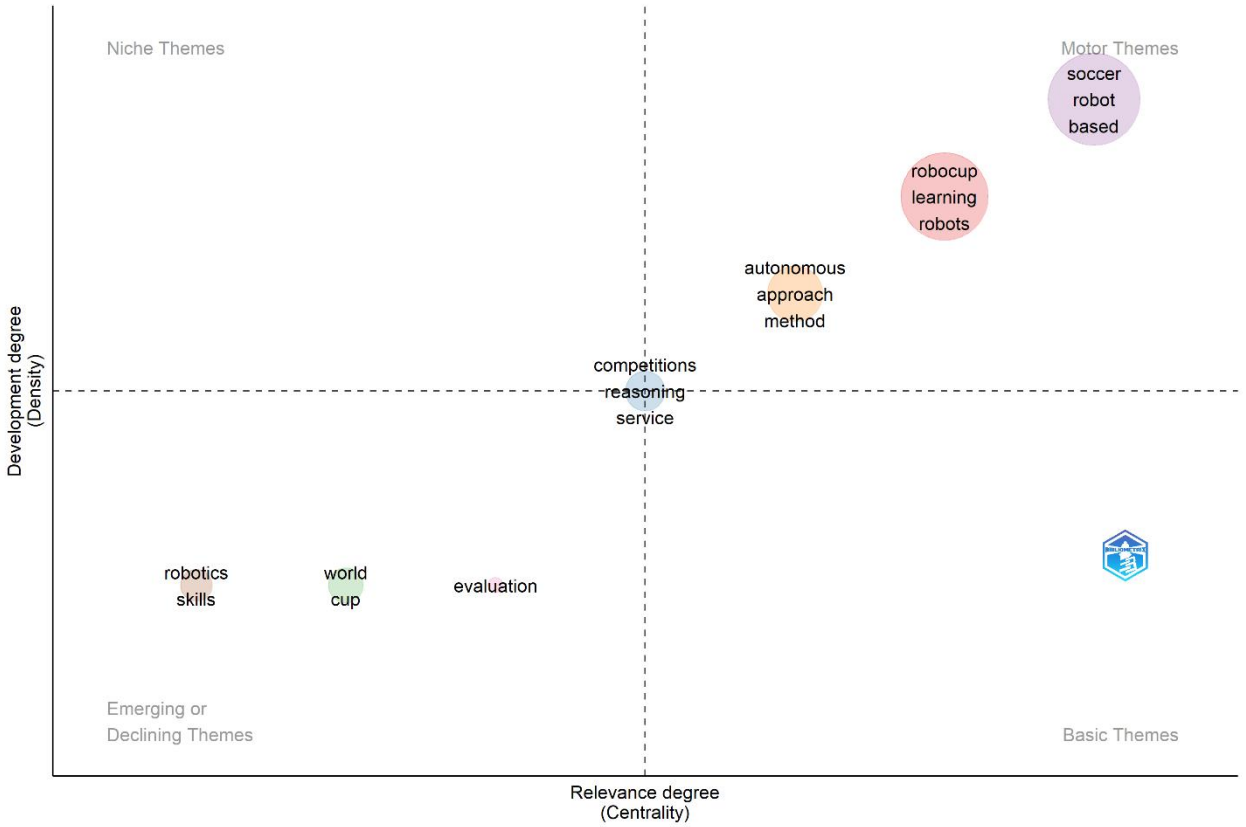

According to motor themes, these clusters exhibit both high centrality and high density, indicating well-developed and influential topics within the field. Key themes such as "Soccer", "Robot", "Robocup", "Learning", "Autonomous", and "Competitions" fall under this category, suggesting they have been consistently studied and play a crucial role in AI and Robot Soccer studies.

4. Discussion and Conclusion

The present bibliometric analysis offers a comprehensive and data-driven perspective on the scientific evolution of robotic soccer within the AI landscape, uncovering trends, thematic priorities, and influential actors across nearly three decades. The findings reflect a fragmented yet steadily maturing research domain, shaped significantly by technological innovation, academic collaboration, and the institutionalization of competitions like RoboCup.

One of the most striking insights is the non-linear growth pattern in scientific production. The 0% growth rate observed in journal publications on robotic soccer and AI may indicate the maturity or stagnation of this niche in AI and robotics. Compared to rapidly expanding areas such as deep learning or general-purpose robots, robot soccer may represent a more specialized research focus. While the overall growth rate remains statistically flat (0%), there are identifiable bursts in publication activity, particularly around 2009–2010 and again in 2021. These surges align with milestones in hardware advancement and the expanding global footprint of RoboCup, suggesting that external technological or institutional stimuli play a catalytic role in driving scholarly output, an observation consistent with prior bibliometric research in AI (Casadei et al., 2023; Donthu et al., 2021).

Furthermore, the analysis of core journals reveals a concentration of high-impact publications in venues like AI Magazine and Autonomous Robots, which not only host the most-cited papers e.g., (Kitano et al., 1997; Stone & Veloso, 2000) but also serve as platforms for agenda, setting discourse. However, the comparatively low H-index of some recurring sources suggests that, despite growing interest, robotic soccer remains a niche specialization within broader AI and robotics research. This points to a need for cross-pollination with adjacent disciplines such as cognitive systems, sports engineering, and human-robot interaction.

The authorial landscape is marked by the repeated presence of pioneering scholars such as Peter Stone, Hiroaki Kitano, and Manuela Veloso, whose early contributions laid the algorithmic and infrastructural foundation for the field. Yet, the relatively low rate of

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international co-authorship (17.72%) highlights a missed opportunity for broader global collaboration. Enhancing transnational research consortia may accelerate innovation, particularly in underrepresented regions that demonstrate emerging interest.

The keyword analysis and thematic mapping offer critical insights into the cognitive structure of the field. Motor themes like "soccer," "robot," "robocup," "autonomous," and "learning" dominate both frequency and centrality metrics, reaffirming the technical focus on multi-agent coordination, real-time decision-making, and reinforcement learning (Ahamed et al., 2025; Antonioni et al., 2021). However, the absence of sociotechnical keywords (e.g., ethics, human-centered AI, inclusivity) reveals a thematic imbalance, underscoring the need for a more holistic research approach that integrates societal, psychological, and policy-oriented perspectives, an increasingly emphasized priority in the broader AI literature (Rossi et al., 2024; Sheridan, 2016).

In terms of research productivity, institutions such as Islamic Azad University and Sapienza University of Rome emerged as prominent contributors, though their visibility in highly cited literature is less pronounced. This discrepancy between quantity and impact invites a closer examination of research quality metrics and raises questions about the dissemination, funding structures, and strategic focus of certain academic ecosystems.

Overall, this study fills a critical gap by systematically mapping the knowledge architecture of AI and robotic soccer research using bibliometric tools. It not only confirms earlier observations about the field's technical sophistication and developmental trajectory (Eguchi, 2016; Reis, 2023) but also contributes new insights into its epistemic limitations, institutional dynamics, and emerging opportunities. Future research should integrate quantitative bibliometric findings with qualitative systematic reviews or meta-analyses to better explore the relationship between technological developments and their practical applications.

Despite the application of a rigorous bibliometric methodology, this study has several limitations that must be considered when interpreting its findings. The analysis was limited to the Web of Science (WoS) database, potentially omitting influential studies from other reputable sources such as Scopus, IEEE Xplore, or arXiv, particularly those from non-English or underrepresented regions. The keyword search strategy, while systematic, may have excluded interdisciplinary or differently phrased research contributions related to AI and robotic soccer. Additionally, the exclusive reliance on quantitative indicators such as citation counts and h-index may overlook qualitative aspects of scholarly impact, such as theoretical innovation or real-world applicability. Finally, the bibliometric tools used do not capture dynamic or alternative metrics (e.g., altmetrics, AI-generated publications), which are increasingly relevant in the rapidly evolving landscape of robotics and AI. It is worth noting that this study excluded conference papers, including those related to artificial intelligence and RoboCup competitions, despite their important role in advancing robotic soccer research. This decision was made to focus on peer-reviewed articles published in WoS-indexed journals to maintain data consistency and reliability in tracking citations. It is suggested that future research expand the scope of sources to include conference papers to provide a more comprehensive view of this field.

Looking forward, future studies should expand their data sources to include a broader range of bibliographic databases and incorporate full-text analysis using natural language processing to uncover deeper thematic structures. There is also a need to investigate emerging research areas such as explainable AI, embodied intelligence, and human-robot collaboration within competitive environments. Scholars should explore the ethical and sociotechnical dimensions of robotic soccer, particularly issues related to fairness, transparency, and algorithmic accountability. Longitudinal analyses of RoboCup data and competition rules could yield insights into the evolution of innovation in autonomous systems. Additionally, integrating altmetrics, funding patterns, and policy impact assessments could help bridge the gap between academic research and its societal relevance, enabling a more comprehensive understanding of the field's development.

The findings of this study offer several practical implications for stakeholders in robotics, artificial intelligence, and educational technology. For AI developers and robotic engineers, the identification of core research clusters, such as multi-agent coordination, reinforcement learning, and real-time decision-making, provides actionable insights into algorithmic priorities and technological bottlenecks in robotic soccer. This can guide the design of more robust, scalable, and adaptive robotic systems applicable not only in sports simulations but also in broader domains like search-and-rescue, autonomous driving, and swarm robotics. For academic institutions and funding agencies, the analysis of author and affiliation productivity can inform strategic investment in high-impact

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research centers and foster cross-institutional collaboration to overcome regional disparities. Furthermore, the dominance of RoboCup as a knowledge production platform underscores the value of competition-based research ecosystems in accelerating innovation; policymakers and educators can leverage this model to design similar AI-driven challenges that stimulate learning and creativity. In the educational context, the thematic link between robotic soccer and STEM learning highlights an opportunity to incorporate simulation-based robotics into school and university curricula, promoting algorithmic thinking and systems engineering from an early stage. Lastly, given the emerging interest in ethical AI and explainability, developers and regulatory bodies should consider embedding transparency and fairness metrics into robotic behavior—particularly in competitive or interactive environments where human expectations intersect with autonomous decision-making. By bridging technical advancement with educational, organizational, and ethical considerations, this study contributes to a more inclusive and application-driven understanding of robotic soccer's role in shaping the next generation of intelligent systems.

Given the results of this bibliometric analysis, several pertinent questions arise that can serve as a structured foundation for future investigations in robotic soccer and AI research. How can explainable artificial intelligence (XAI) models be integrated into robotic soccer strategies to enhance transparency and human-robot trust? To what extent do competition frameworks like RoboCup facilitate long-term innovation in autonomous multi-agent coordination, and how do evolving rule structures influence research focus? What are the impacts of algorithmic bias and data inequality on robot performance and learning outcomes in simulated versus physical soccer environments? Moreover, how can researchers operationalize ethical frameworks in robot behavior, particularly in contexts involving competitive decision-making, human safety, and sportsmanship? Another promising question lies in exploring how reinforcement learning models adapt to unpredictable, non-deterministic environments and what benchmarks best capture such adaptability. From a sociotechnical perspective, how do institutional, geopolitical, and funding dynamics shape knowledge production in robotic soccer, particularly in underrepresented regions? Furthermore, how can educational robotics programs leveraging robotic soccer paradigms bridge the gap between early STEM learning and advanced AI skill acquisition? These research directions call for a more interdisciplinary, ethically grounded, and globally inclusive inquiry into the evolution of robotic soccer. Moreover, future research could expand the scope by incorporating sociotechnical dimensions, such as ethical considerations, stakeholder perspectives, and human-centered design principles. Integrating these aspects through mixed-method approaches can offer a more comprehensive understanding of AI applications in soccer, particularly in contexts where social and ethical implications play a pivotal role. Future studies should consider combining experimental approaches with bibliometric trend analysis to trace how shifts in academic attention correlate with breakthroughs in machine vision, hardware platforms, and multi-agent learning algorithms. A well-designed future research agenda should therefore align technical innovation with human-centered design, educational inclusion, and cross-regional collaboration—ensuring that robotic soccer remains not only a testbed for AI algorithms but also a lens through which the broader societal implications of autonomous systems are critically examined.

This bibliometric study provides a systematic and comprehensive overview of the intellectual landscape of robotic soccer research within the domain of AI, synthesizing publication trends, authorial impact, institutional contributions, and thematic evolution over nearly three decades. By leveraging robust analytical tools such as the bibliometrix package in R and biblioshiny, the study captures both the historical depth and dynamic breadth of the field, revealing a rich tapestry of technical innovation driven by competitions like RoboCup and fueled by global academic networks. The findings indicate that while the field has grown in complexity and sophistication, its development remains episodic, shaped by external technological breakthroughs and localized academic hubs. Core themes such as reinforcement learning, multi-agent systems, real-time strategy optimization, and autonomous decision-making continue to dominate the discourse, yet significant gaps persist in integrating sociotechnical, ethical, and policy-oriented perspectives into the research agenda.

Notably, the relatively low rate of international collaboration and limited representation of institutions from the Global South highlight the asymmetry in knowledge production and dissemination. Moreover, the dominance of a few highly cited authors and journals suggests a centralization of influence, potentially constraining theoretical diversity. Nevertheless, the field exhibits

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conceptual diversification, with growing scholarly attention directed toward explainable AI, human-robot collaboration, and AI-driven robotics education. This review not only clarifies the structural contours of the discipline but also sets a research agenda that encourages methodological pluralism, interdisciplinary integration, and greater attention to real-world deployment. As AI continues to redefine the boundaries of autonomy and cognition, robotic soccer stands as a microcosm of broader transformations in intelligent systems research, offering both a testbed for cutting-edge algorithms and a mirror reflecting the societal, ethical, and collaborative challenges ahead.

Authors' Contributions

Authors equally contribute to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

Not applicable.

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