Artificial Intelligence in Gaming: A Bibliometric Analysis of Research Outputs and Trends

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Abstract - This report provides a thorough bibliometric analysis of academic research on artificial intelligence (AI) in gaming, utilizing data obtained from the Scopus database. The analysis reveals noteworthy trends and offers unique insights into the area by analyzing publication numbers, citation impacts, authorship patterns, and geographical distribution. The most notable publication sources are highlighted, with the IEEE Conference on Computational Intelligence and Games (CIG) being the primary venue, followed by CEUR Workshop Proceedings and AAAI Workshop - Technical Report. Documents that have received a significant number of citations, such as those authored by Mnih V (2015) and Vinyals O (2019), are recognized for their pioneering contributions. Renowned writers such as Bulitko V, Togelius J, and Lucas SM are recognized for their significant contributions to the scientific community. The report also shows a significant rise in academic production after 2013, suggesting an increasing fascination and swift progress in the utilization of AI in gaming. The United States has the top position in terms of research contributions, with the United Kingdom and Canada following closely behind, demonstrating a significant global presence. The frequent utilization of terminology such as "artificial intelligence," "human-computer interaction," and "video game" highlights the research's emphasis on technology and user-centeredness. The research also recognizes constraints arising from its sole dependence on the Scopus database, which may result in the exclusion of pertinent papers that are indexed in other prominent databases such as Web of Science and Google Scholar. However, the report provides a comprehensive summary of the present condition and future prospects of AI research in gaming, serving as a basis for further investigation and advancement in this rapidly evolving sector.

Keywords—Artificial Intelligence, A.I., Videogames, Gaming, Video Games.

I. INTRODUCTION

The gaming industry has been radically transformed by Artificial Intelligence (AI), leading to significant changes in game development, gameplay, and user experience. At first, the artificial intelligence (AI) used in video games was simple and relied on basic rule-based systems to manage game dynamics and imitate opponent behaviors. Early examples such as "Pac-Man" and "Space Invaders" demonstrated rudimentary algorithms in which non-player characters (NPCs) adhered to pre-established rules for their movement and decision-making [1][9].

The advancement of artificial intelligence (AI) in gaming has greatly improved the level of player involvement and the authenticity of game experiences [1][12]. With the advancement of processing power and the evolution of AI approaches, new games started utilizing increasingly advanced AI technologies. Currently, artificial intelligence (AI) in gaming incorporates intricate algorithms, which encompass machine learning methods like neural networks and reinforcement learning [10]. These technological breakthroughs allow artificial intelligence (AI) to acquire knowledge from player interactions, adjust games in real-time, and anticipate player behavior in order to provide customized gaming experiences [2]. Procedural content generation (PCG) is a highly impactful development in gaming that has been made possible by AI. AI-powered procedural content generation (PCG) algorithms utilize established rules and player actions to produce dynamic game worlds, levels, and quests. This technique guarantees that every gameplay session provides distinct challenges and experiences, hence strengthening the ability to play the game again and increasing player involvement [3]. Procedural content generation has been utilized in a wide range of game genres, including open-world RPGs and roguelike dungeon crawlers. Games such as "Minecraft" utilize AI-powered algorithms to create vast, voxel-based environments that players may explore and interact with indefinitely. This strategy not only alleviates the workload of developers in manually creating content, but also enables the building of gaming settings that may adapt and scale according to player decisions and actions.

In addition to impacting gameplay mechanics, AI has also brought about a revolution in the realm of interactive storytelling within games. Historically, video game narratives followed a fixed and sequential structure, progressing based on pre-established screenplays and storylines. AI-powered interactive storytelling systems now allow games to dynamically adjust narratives and character interactions based on player decisions and actions. Video games such as "The Witcher 3: Wild Hunt" and "Detroit: Become Human" utilize narrative engines powered by artificial intelligence, which adapt the storyline and character developments based on the decisions made by players [5]. These systems employ machine learning algorithms to examine player preferences and behavior, customizing the

narrative experience for each individual player. This not only intensifies the sense of being fully engaged and the ability of the player to make choices, but also motivates repeated playthroughs in order to investigate various story paths and results [4].

The incorporation of artificial intelligence (AI) in games has generated significant academic research and intellectual investigation [11]. Researchers and game developers are investigating the potential of artificial intelligence (AI) to enhance game design processes, improve gaming mechanics, and revolutionize storytelling tactics. This involves enhancing the capacity of AI to replicate human-like intelligence and decision-making processes, hence enhancing the intricacy and authenticity of virtual environments [2].

Research in this domain encompasses both theoretical investigations of artificial intelligence algorithms in game design and real implementations of gaming mechanics driven by artificial intelligence. The research is centered around improving player experiences by implementing adaptive difficulty algorithms, intelligent non-player character behaviors, and dynamic game settings that react to player activities. In addition, researchers examine the ethical ramifications of artificial intelligence (AI) in gaming, including algorithmic prejudice, worries about data privacy, and the influence of AI on player engagement and satisfaction. This research does a thorough bibliometric analysis to examine the development and influence of artificial intelligence (AI) in gaming from the last twenty years. The objective of this study is to find and analyze patterns in artificial intelligence (AI) research specifically related to gaming. This will be done by evaluating the publication trends, influential works, and collaborative networks in this domain. The investigation yields valuable insights into the impact of AI on game production techniques, the improvement of player experiences, and the overall transformation of the gaming business.

II. METHODOLOGY

Before initiating the search, specific keywords were applied to the Scopus databases, selecting it for its broader coverage. The bibliometric analysis focused exclusively on peer-reviewed journal articles and conference proceedings, excluding non-journal documents like books and reviews. The search was limited to publications in English within a 20-year timeframe (2003-2023). The query used was: (TITLE-ABS-KEY ("video games" "ARTIFICIAL INTELLIGENCE") AND PUBYEAR > 2002 AND PUBYEAR < 2024 AND (LIMIT-TO (SRCTYPE, "p") OR LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")). This query obtained 950 publications from this search which was downloaded and saved in CSV format. Subsequently, we transferred this dataset into R 4.1.1, a prevalent open-source platform for statistical computing [7]. A comprehensive analysis of the dataset was performed using Biblioshiny, an intuitive online interface for Bibliometrix in R. This involved creating matrices for network analysis and examining the conceptual, intellectual, and social frameworks within the research topic.
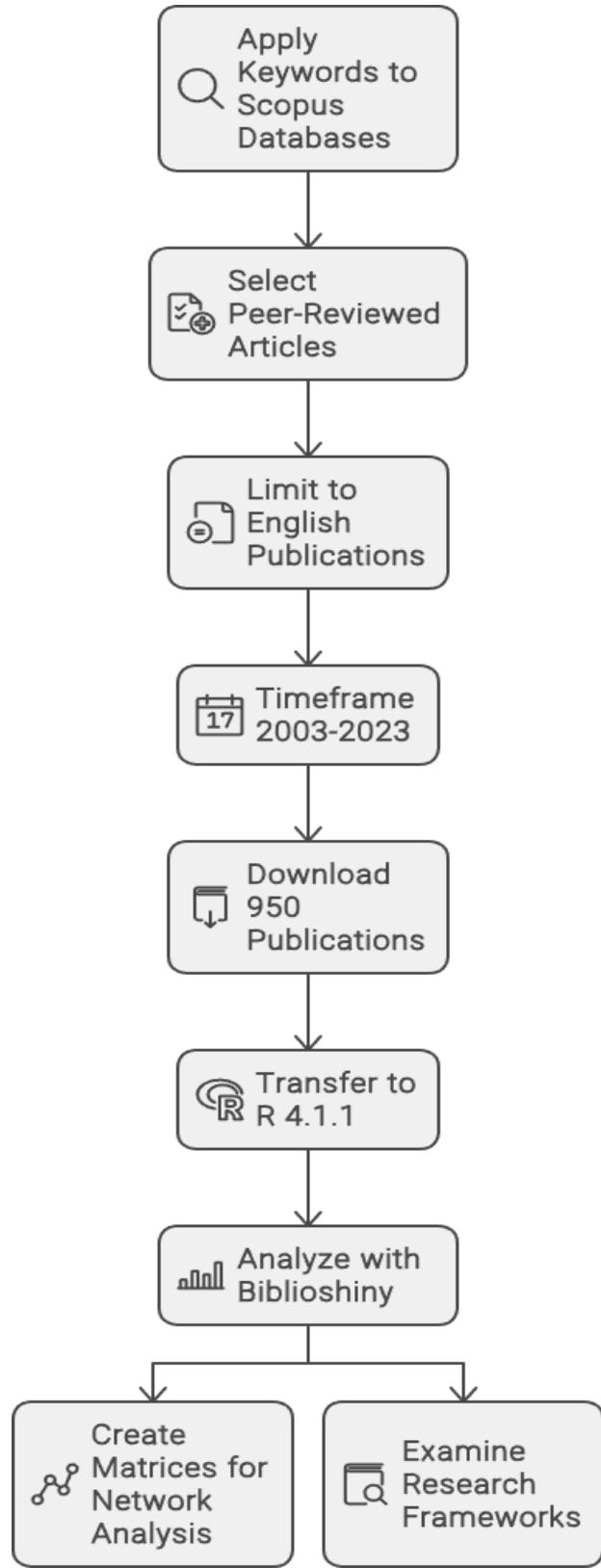

Fig. 1. Flow Chart of Methodology

III. RESULT & DISCUSSION

A. Highly Pertinent Sources

TABLE I

Sr.no.	Sources	Articles
1	IEEE CONFERENCE ON COMPUTATONAL INTELLIGENCE AND GAMES, CIG	58
2	CEUR WORKSHOP PROCEEDINGS	39
3	AAAI WORKSHOP - TECHNICAL REPORT	26
4	ACM INTERNATIONAL CONFERENCE PROCEEDING SERIES	24
5	IEEE TRANSACTIONS ON GAMES	20
6	PROCEEDINGS OF THE NATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE	18
7	IJCAI INTERNATIONAL JOINT CONFERENCE ON ARTIFICIAL INTELLIGENCE	14
8	2015 IEEE CONFERENCE ON COMPUTATIONAL INTELLIGENCE AND GAMES, CIG 2015 - PROCEEDINGS	13
9	2017 IEEE CONFERENCE ON COMPUTATIONAL INTELLIGENCE AND GAMES, CIG 2017	13
10	IEEE TRANSACTIONS ON CYBERNETICS	13

The data provided in table I lists the most relevant sources for publications in the field of artificial intelligence and video games, including their respective publication counts. The IEEE Conference on Computational Intelligence and Games (CIG) is the most prominent, with 58 publications, underscoring its central role in this research area. CEUR Workshop Proceedings follows with 39 publications, highlighting its significance as a venue for disseminating research findings. The AAAI Workshop - Technical Report and ACM International Conference Proceeding Series also feature prominently, with 26 and 24 publications respectively, indicating their importance in the field. The IEEE Transactions on Games has 20 publications, emphasizing its relevance. Other notable sources include the Proceedings of the National Conference on Artificial Intelligence (18 publications), the IJCAI International Joint Conference on Artificial Intelligence (14 publications), and specific editions of the IEEE Conference on Computational Intelligence and Games from 2015 and 2017, each with 13 publications. Additionally, the IEEE Transactions on Cybernetics is listed with 13 publications, reflecting its impact on the research community.

B. Top Referenced Papers

TABLE II

Sr.no.	Document	Citation
1	MNIH V, 2015, NATURE	19730
2	VINYALS O, 2019, NATURE	2294
3	SILVER D, 2018, SCI	2139
4	DEO RC, 2015, CIRCULATION	1878
5	LAKE BM, 2017, BEHAV BRAIN SCI	1264
6	HAN J, 2013, IEEE TRANS CYBERN	1156
7	SCHRITTWIESER J, 2020, NATURE	835
8	MORAVČÍK M, 2017, SCIENCE	626
9	SILVER D, 2005, PROC ARTIF INTELL INTERACT DIGIT ENTERTAIN CONF, AIIDE	535
10	ALBARQOUNI S, 2016, IEEE TRANS MED IMAGING	474

The data provided in table II lists the most globally cited documents in the field of artificial intelligence and video games, along with their DOI and total citation counts. The paper by Mnih V (2015) in Nature is the most highly cited with 19,730 citations, reflecting its groundbreaking impact. Vinyals O (2019) in Nature follows with 2,294 citations, indicating significant influence. Silver D (2018) in Science and Deo RC (2015) in Circulation have 2,139 and 1,878 citations respectively, showing their substantial contributions. Lake BM (2017) in Behavioral and Brain Sciences and Han J (2013) in IEEE Transactions on Cybernetics are also highly cited, with 1,264 and 1,156 citations respectively. Schrittwieser J (2020) in Nature and Moravčík M (2017) in Science have 835 and 626 citations, highlighting their importance. Silver D (2005) in the Proceedings of the Artificial Intelligence and Interactive Digital Entertainment Conference and Albarqouni S (2016) in IEEE Transactions on Medical Imaging have 535 and 474 citations, indicating their relevance in the research community.

C. Top Ten Leading Authors

TABLE III

Sr. no.	Authors	Articles	Articles Fractionalized
1	BULITKO V	27	10.6
2	TOGELIUS J	22	4.8
3	LUCAS SM	20	5.6
4	PEREZ-LIEBANA D	20	5.2
5	SPRONCK P	13	3.5
6	KOENIG S	10	2.9
7	BAKKES S	9	2.4
8	BURO M	9	4
9	STANLEY KO	9	2.2
10	KHALIFA A	8	1.7

The provided data in table III highlights the most relevant authors in the field of artificial intelligence and video games. Bulitko V stands out with the highest number of publications (27) and the highest average citations per publication (10.6), indicating a substantial influence in the field. Togelius J, with 22 publications and an average of 4.89 citations, is also a significant contributor. Lucas SM and Perez-Liebana D both have 20 publications, with average citations of 5.63 and 5.21, respectively, showcasing their impactful work. Spronck P, Koenig S, Bakkes S, Buro M, and Stanley KO, with publication counts ranging from 9 to 13 and varying citation averages, are also notable contributors, reflecting a diverse and active research community focused on integrating AI in video games.

D. Contributions from Leading Ten Countries Over the Years

TABLE IV

Sr.no.	Country	Articles
1	United States	249
2	United Kingdom	113
3	Canada	100
4	Spain	86
5	China	64
6	Australia	41
7	France	39
8	India	37
9	Netherlands	34
10	Italy	31

The data in table IV shows that the United States is the leading contributor to research in artificial intelligence and video games with 249 documents, highlighting its strong research focus and investment in this field. The United Kingdom follows with 113 documents, indicating a significant contribution. Canada and Spain also have notable outputs, with 100 and 86 documents respectively, showcasing their active research communities. China, with 64 documents, reflects its growing involvement in AI and gaming research. Australia (41 documents), France (39 documents), and India (37 documents) also play key roles in the research landscape. The Netherlands and Italy round out the top ten with 34 and 31 documents respectively, demonstrating their active participation in advancing AI and video game technologies. This distribution illustrates a global interest and diverse contributions from multiple regions around the world.

E. Documents Published by Year.
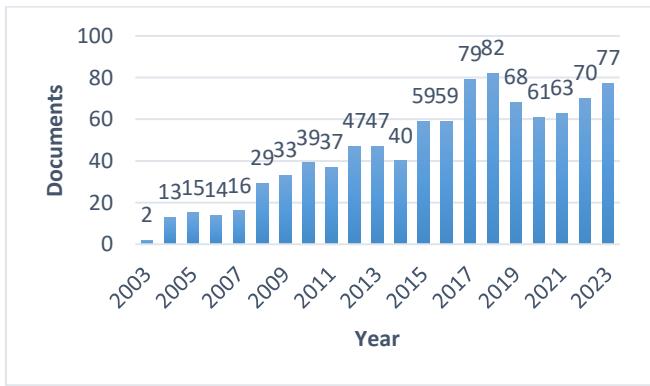
Fig. 2. Documents Published by Year

The provided data in figure 1 reveals the distribution of document production over the years, with a noteworthy upward trend in scholarly output. Starting with 2 documents in 2013, the count has consistently increased each subsequent year, reaching 57 documents in 2023, with the year still ongoing. This progression signifies a positive and sustained growth in research activity. The ascending numbers may indicate heightened academic engagement, potentially influenced by factors such as increased research funding,

evolving research priorities, or advancements in technology. The absence of documents in 2015 and the comparatively lower count in 2016 might suggest variations in research focus during those specific years. Overall, the data portrays a dynamic and progressive landscape, with 2023 expected to contribute further to the ascending trend, highlighting a vibrant and continually evolving scholarly environment.

F. Most Frequently Utilized Words

TABLE V

Sr.no.	Words	Occurrences
1	artificial intelligence	739
2	human computer interaction	555
3	video game	403
4	interactive computer graphics	282
5	video-games	133
6	computer games	127
7	learning systems	103
8	virtual reality	89
9	reinforcement learning	81
10	deep learning	74

Fig. 3. Selected 950 documents word cloud

The data in table V highlights a clear emphasis on artificial intelligence (AI) and its intersection with video games, human-computer interaction (HCI), and interactive computer graphics. "Artificial intelligence" emerges as the most frequent term, appearing 739 times, underscoring its central role in the analysis. HCI, mentioned 555 times, reflects a focus on how users interact with AI systems and video games, while "video game(s)" itself appears 403 times, indicating a significant portion of the study's scope. Terms like "interactive computer graphics" (282 occurrences), "virtual reality" (89 occurrences), and specific AI techniques such as "reinforcement learning" (81 occurrences) and "deep learning" (74 occurrences) further highlight the technological and methodological focus of the research. These findings collectively underscore the study's exploration of AI applications in gaming and interactive systems, encompassing both theoretical frameworks and practical implementations.

G. Publications segmented by Subject Area

TABLE VI

Sr.no.	Subject Area	Articles
1	Computer Science	822

2	Engineering	234
3	Mathematics	102
4	Art and Humanities	88
5	Social Sciences	65
6	Decision Sciences	51
7	Medicine	34
8	Physics and Astronomy	31
9	Materials Science	20
10	Neuroscience	16

The provided data in table VI outlines the distribution of articles by subject area, reflecting the diverse interdisciplinary nature of research output. "Computer Science" stands out as the dominant subject area with 138 articles, underscoring the significant contribution and focus on computational research. "Engineering" follows closely with 96 articles, emphasizing the strong presence of technological and engineering-oriented studies. The intersection of computer science and healthcare applications is explored in 52 articles, placing "Medicine" in a notable position. Meanwhile, "Mathematics" and "Decision Sciences" prioritize the quantitative and decision-making aspects of research, with 36 and 24 articles contributed, respectively. The consideration of societal and health-related aspects is reflected in "Social Sciences" and "Health Professions," each with 23 and 15 articles, embodying a multidisciplinary approach. The interdisciplinary nature of research is evident in the distribution of 14 articles contributed by "Physics and Astronomy," 10 by "Business, Management and Accounting," and 10 by "Materials Science." This cross-disciplinary exploration underscores the integration of scientific and business-oriented themes, emphasizing computer science, engineering, and their applications across diverse domains.

IV. LIMITATIONS

It is important to recognize many underlying constraints in this study. First and foremost, the study is predominantly derived from data obtained from the Scopus database. Although Scopus is a vast and widely-recognized library of academic literature, depending only on it has several limitations. A substantial constraint arises from the omission of several prominent academic databases, like Web of Science, IEEE Xplore, ACM Digital Library, and Google Scholar. Each of these databases possesses distinct indexing rules and may encompass papers that are not encompassed by Scopus. As a result, the study could overlook pertinent articles, conference papers, and other scholarly outputs that are only included in these databases.

Relying just on one database may result in an incomplete portrayal of the total corpus of literature on artificial intelligence and video games. For example, certain specialized journals, local publications, or conference proceedings can be excluded, thereby restricting the comprehensiveness and extent of the findings. Furthermore, it is important to note that various databases might offer different citation measures and coverage periods, which can have an impact on the apparent influence and trends.

Moreover, this analysis specifically encompasses papers that have been published solely in the English language. This linguistic limitation implies that valuable research published in languages other than English is disregarded, possibly excluding major contributions from scholars and places that

do not primarily use English. Excluding non-English literature may result in a skewed comprehension of the worldwide research scene, since it overlooks the many viewpoints and advancements in countries where English is not spoken. In order to have a comprehensive understanding of the quickly growing area, future study should consider integrating numerous datasets. Incorporating papers in different languages will enhance the comprehensiveness and inclusivity of the study, consequently deepening the knowledge of worldwide research trends and developments in artificial intelligence and video games.

V. CONTRIBUTION OF THE STUDY

This study contributes by providing a detailed bibliometric analysis of AI research in gaming, which includes the identification of major publication sources, influential authors, and significant geographic contributors. It highlights the key terms and concepts prevalent in the literature, such as "artificial intelligence" and "human-computer interaction." By focusing on these elements, the study offers insights into the evolving research landscape and underscores the interdisciplinary nature of AI applications in gaming. This comprehensive analysis serves as a valuable resource for researchers, practitioners, and policymakers seeking to understand and advance the field.

VI. CONCLUSION

Based on the comprehensive bibliometric analysis presented, it is evident that artificial intelligence (AI) is profoundly shaping the landscape of gaming research. The study identifies key trends across various dimensions: prominent publication sources such as the IEEE Conference on Computational Intelligence and Games (CIG) and CEUR Workshop Proceedings, which serve as critical platforms for disseminating research findings; highly cited documents by authors like Mnih V (2015) and Vinyals O (2019), underscoring AI's transformative impact; and prolific authors such as Bulitko V, Togelius J, and Lucas SM, whose contributions span diverse aspects of AI integration into gaming. Geographically, the United States leads in research output, followed by the United Kingdom and Canada, reflecting a global interest in advancing AI applications in gaming. Over time, there has been a notable increase in scholarly output since 2013, indicating growing research engagement and technological advancements [8]. The literature emphasizes key terms like "artificial intelligence," "human-computer interaction," and "video game," highlighting the technological focus and user experience within gaming environments. Moreover, the interdisciplinary nature of research, spanning fields from computer science to social sciences, underscores AI's broad impact and collaborative potential across diverse domains. This analysis provides a comprehensive overview of the current state and future directions of AI-driven innovations in gaming, offering insights for researchers, practitioners, and policymakers alike.

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