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BIBLIOMETRIC ANALYSIS OF 3D ANIMATION IN THE CONTEXT OF DIGITAL CULTURE: EVOLUTION, TRENDS AND CONTRIBUTIONS (2000-2024)

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KEYWORDS

3D Animation
Digital Culture
Bibliometric Analysis
Virtual Reality
Artificial Intelligence

ABSTRACT

This study presents a bibliometric analysis of 3D animation research in digital culture from 2000 to 2024. It shows a steady growth in scientific output until 2021, driven by technological advances applied to fields such as education, medicine and entertainment. China, the United States and Canada are the main contributors, despite the limited international collaboration, China presents an opportunity to strengthen research in this area. The keyword analysis highlights the increase of topics related to virtual reality, augmented reality and e-learning, which broadens the applications and efficiencies of 3D animation in education and professional fields. The main limitations are the reliance on a single database and the exclusion of documents in other languages, which could underestimate relevant contributions. Therefore, it is recommended to expand the coverage of sources and encourage international collaboration to enhance innovation and academic impact in this field.

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1. Introduction

3D animation has experienced exponential growth in the last two decades, consolidating it as an essential tool in contemporary digital culture. Its versatility and transformative potential are evident in sectors as varied as video games, cinema, virtual reality, medicine and digital art (Kerlow, 2009; Purves, 2013). In the field of video games, 3D animation has enabled the creation of more complex and realistic virtual worlds, favoring the immersion and interaction of players (Wolf & Perron, 2013). Likewise, the use of advanced technologies -such as motion capture and real-time rendering- has led to more dynamic and immersive experiences (Schell, 2019).

In the film industry, the incorporation of special effects generated through 3D animation has revolutionized production and post-production processes. Lin (2022) highlights the relevance of these techniques in films such as Avatar, where advanced animation methods are applied to conceive worlds and characters with a high level of detail, expanding both narrative possibilities and visual resources in contemporary cinema.

Virtual reality (VR) and augmented reality (AR) have found in 3D animation a fundamental tool for delivering immersive and interactive experiences. Zhang (2022) explores the design of VR-based three-dimensional animation spaces, emphasizing how these technologies enable the creation of virtual environments that enrich the user experience and open up new opportunities in digital design.

In education, 3D animation and related technologies have proven to be effective tools for improving students' understanding and motivation. Ho et al. (2019) investigated how 3D painting within VR environments can enhance students' motivation in learning 3D animation. Their findings indicate that the use of these technologies increases students' interest and active participation, facilitating more meaningful learning. Similarly, Hiranyachattada and Kusirirat (2020) used mobile augmented reality to improve students' conceptual understanding of physics-based rendering in 3D animation, demonstrating that these tools can facilitate the assimilation of complex and abstract concepts.

The application of 3D animation in specialized fields, such as human medicine, has also shown promising results. Kumar et al. (2022) investigate how the integration of artificial intelligence, 3D animation, and VR is transforming medical education. Their study demonstrates that these technologies enable simulation of complex medical procedures, facilitating hands-on learning without risk to patients. In addition, Guo et al. (2023) conducted a review on the use of 3D video in medical education, highlighting that 3D animation improves understanding of anatomical and physiological concepts, and can increase information retention in medical students.

In parallel, in veterinary medicine, 3D animation has been used to enhance the teaching and understanding of complex biological processes. Scherzer et al. (2010) implemented 3D animation technology to teach veterinary obstetrics, allowing students to better visualize and understand anatomical structures and clinical procedures that would be difficult to observe directly.

In digital art, 3D animation has opened up new creative possibilities. Morgan (2020) discusses how digital media practice is pushing the frontiers of cultural communication in Nigeria, using 3D animation to express cultural identities and narratives in innovative ways. In addition, 3D animation is influencing the visual design of corporate packaging. Ma (2024) proposes a deep learning-based method to assess the quality of visual packaging design, demonstrating how 3D animation and artificial intelligence technologies are applied in the business domain to improve visual aesthetics and consumer engagement.

Digital media animation control technology has also advanced significantly. Zhang and Tsai (2021) propose a corpus-based digital media system and complex computation for 3D animation, highlighting the importance of integrating advanced data processing techniques in producing more efficient and high-quality animations.

Integrating 3D animation into educational programs is essential to prepare young people for careers in STEAM (Science, Technology, Engineering, Art, and Mathematics) fields. Bass et al. (2016) describe how a project-based media production program can address career preparation in STEAM for underrepresented young adults. They highlight the importance of attending not only to technical skills, but also to non-cognitive elements of learning, such as creativity and critical thinking, and how 3D animation can be a key tool in this process.

Despite significant advances, there is still a need to understand the evolution of academic research in 3D animation, as well as to identify its current and future trends. Therefore, the general objective of

this study is to conduct a comprehensive bibliometric analysis of the academic production on 3D animation in the context of digital culture between the years 2000 and 2024.

Specifically, the aim is to describe the evolution of scientific production, identify the most influential authors and institutions, explore the key and emerging thematic areas, and analyze the collaboration and co-authorship networks that emerged during this period (Donthu et al., 2021). This approach is essential for mapping the research landscape, understanding the dynamics of collaboration between authors and institutions, and directing future research toward areas of greater relevance and impact.

In doing so, the study aims to provide a comprehensive overview of the current state and trends in 3D animation research, while contributing to the understanding of the impact of this technology on contemporary culture. The findings will serve as a valuable resource for both the academic community and industry professionals by facilitating the identification of opportunities for new research and collaborations.

2. Methodology

To examine the evolution of 3D animation research in the context of digital culture between 2000 and 2024, a quantitative and systematic methodology based on bibliometric analysis was adopted. This approach made it possible to detect patterns in scientific production, as well as to identify collaborative networks and emerging thematic trends in the field of study.

First, the specific objectives of the bibliometric research were defined: (a) to describe the evolution of academic production in 3D animation, (b) to identify the most influential authors and institutions, (c) to explore key and emerging thematic areas, and (d) to analyze collaboration and co-authorship networks.

The Scopus database was selected as the main source of information, thanks to its extensive coverage of academic publications and its high recognition in bibliometric studies. Scopus offers advanced tools for bibliographic and citation data analysis, which made it possible to carry out a detailed and rigorous investigation.

To search for relevant publications, specific search terms were established using Boolean operators. The terms used were: ("3D animation" OR "three-dimensional animation") AND ("digital culture" OR "interactive media" OR 2digital media" OR "virtual reality" OR "augmented reality" OR "digital art"). digital culture" OR "digital media" OR "interactive media". ("3D animation" AND ("real-time rendering" OR "post-production" OR "motion capture")) AND (") AND ("digital culture" OR "digital media" OR "interactive media") ("3D animation" AND ("virtual reality" OR "augmented reality" OR "immersive experiences")) AND ("digital culture" OR "cultural trends" OR "interactive media").

These terms made it possible to cover a wide range of research related to 3D animation and its interaction with different aspects of digital culture and interactive media. The initial search in Scopus with these terms yielded a total of 2,156 documents. To refine the selection and ensure the relevance and quality of the publications, a series of filters and inclusion and exclusion criteria were applied.

Publications between 2000 and 2024 were included. All types of documents indexed in Scopus were considered, including articles, reviews, book chapters, books and conference papers, in order to have a broad view of the scientific production in the area. Likewise, publications in English were included, excluding documents in other languages to ensure the comprehension and detailed analysis of the content.

As for the thematic areas, priority was given to those related to Computer Science, Engineering, Social Sciences, Arts and Humanities and Media, since they are directly linked to 3D animation and digital culture. No specific thematic area was excluded, thus allowing the inclusion of interdisciplinary research that could bring novel perspectives to the study.

Publications in journals classified in quartiles Q1, Q2, Q3 and Q4 according to the SCImago Journal Rank (SJR) were considered, in order to cover the totality of contributionsscientific without being limited by the impact level of the journals. This made it possible to include emerging research and research at different levels of dissemination, enriching the bibliometric analysis.

After applying the aforementioned criteria, duplicate documents were eliminated and titles and abstracts were reviewed to ensure the relevance of the publications in relation to the topic of study. Documents that, despite meeting the initial criteria, did not directly address 3D animation in the context of digital culture were excluded.

The filtering and refinement process progressively reduced the number of documents. From the initial search of 2,156 documents, duplicates and publications in other languages were eliminated, reducing the total to 526 documents. Subsequently, by reviewing titles and abstracts to ensure thematic relevance, the number was reduced to 194 documents. After a final refinement and detailed review, 177 documents were selected and formed the final corpus for the bibliometric analysis.

Bibliographic and citation data were extracted from the 177 selected papers, including information on authors and co-authors, titles and abstracts, year of publication, journal of publication and its SCImago Journal Rank (SJR), authors' institutional affiliations and countries of origin, keywords provided by the authors, and number of citations received.

Standard bibliometric techniques were applied for data analysis. An analysis of scientific productivity was performed to evaluate the temporal evolution of publications and to detect trends and patterns in scientific production. The most prolific authors and leading institutions were identified, as well as their geographical distribution. In addition, a citation analysis was carried out to determine the most influential articles according to the number of citations received.

Co-authorship analysis made it possible to explore the relationships between authors and visualize collaborative networks, using social network analysis techniques. Keyword co-occurrence was also analyzed to identify key and emerging thematic areas by analyzing the most frequent keywords and their interrelationship.

For data analysis and visualization, specialized tools such as Bibliometrix in R Studio were used, which facilitated advanced bibliometric analysis and the generation of scientific maps representing the relationships between authors, institutions and topics (Aria & Cuccurullo, 2017; Sierra, 2012). Initial data management and organization was performed with Microsoft Excel.

The results were interpreted according to the objectives set, identifying trends in scientific production, highlighting periods of increased research activity and analyzing the contributions of the most influential authors and institutions. The predominant and emerging thematic areas in the field of 3D animation and digital culture were explored, and collaboration and co-authorship networks were studied, highlighting the dynamics of cooperation between researchers and countries.

3. Results

Figure 1 shows a detailed analysis of the quality of the metadata in the dataset used. It can be seen that the essential fields for bibliometric analysis-title (TI), abstract (AB), authorship (AU), document type (DT), journal (SO), language (LA), year of publication (PY) and total citations (TC)-are 100% complete. This level of completeness contributes to the reliability of the analysis and strengthens the resulting conclusions.

However, occasional absences are detected in fields such as affiliations (C1), with 2.86% of missing data, and in DOI identifiers (DI), with 16% of omissions. Although these gaps are relatively low, they could partially limit the analysis of institutional collaboration networks and the tracking of specific citations. In addition, the total absence of data in fields such as cited references (CR) and scientific categories (WC) makes it difficult to carry out co-citation studies and more detailed thematic classifications, which is a significant limitation. Such absences may be due to editorial policies or to the very nature of the databases consulted. Even so, the overall high quality of the metadata allows for a solid and reliable analysis.

Figure 1. Metadata Quality Analysis for Bibliometric Analysis of 3D Animation (2000-2024). Generated with Bibliometrix (Aria & Cuccurullo, 2017).

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
AU	Author	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
C1	Affiliation	5	2.86	Good
DI	DOI	28	16.00	Acceptable
DE	Keywords	29	16.57	Acceptable
RP	Corresponding Author	44	25.14	Poor
ID	Keywords Plus	50	28.57	Poor
CR	Cited References	175	100.00	Completely missing
WC	Science Categories	175	100.00	Completely missing

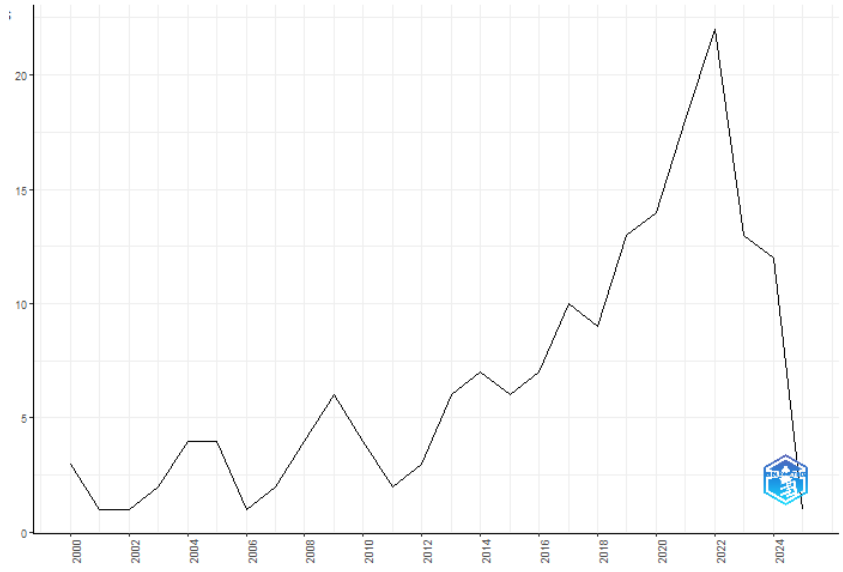
Source: Own elaboration, 2025

Figure 2 illustrates the annual scientific production in the field of 3D animation. A steady growth in the number of publications is evident from 2000 to 2021. During the first decade, the production was modest, with less than five articles per year, suggesting an emerging interest and possibly limited by the technological capabilities of the time. This initial period reflects an exploratory phase where 3D animation was beginning to be integrated into the digital culture.

From 2011, an acceleration in scientific production is observed, reaching a peak in 2021 with more than 20 publications. This increase coincides with significant technological advances, such as the democratization of 3D animation software, improved hardware performance and the rise of applications in various industries, including video games, film and education. The increasing accessibility of tools such as Blender, Maya and Unity has facilitated research and development in this field.

However, a decrease in publications is noted during 2022 and 2023. This decrease could be attributed to various factors, such as changes in research priorities, saturation in certain thematic areas or even global impacts such as the COVID-19 pandemic, which could affect the rate of scientific production. It is possible that this decrease is temporary and that production will recover in the following years.

Figure 2. Annual Evolution of Scientific Production in 3D Animation (2000-2024). Generated with Bibliometrix.

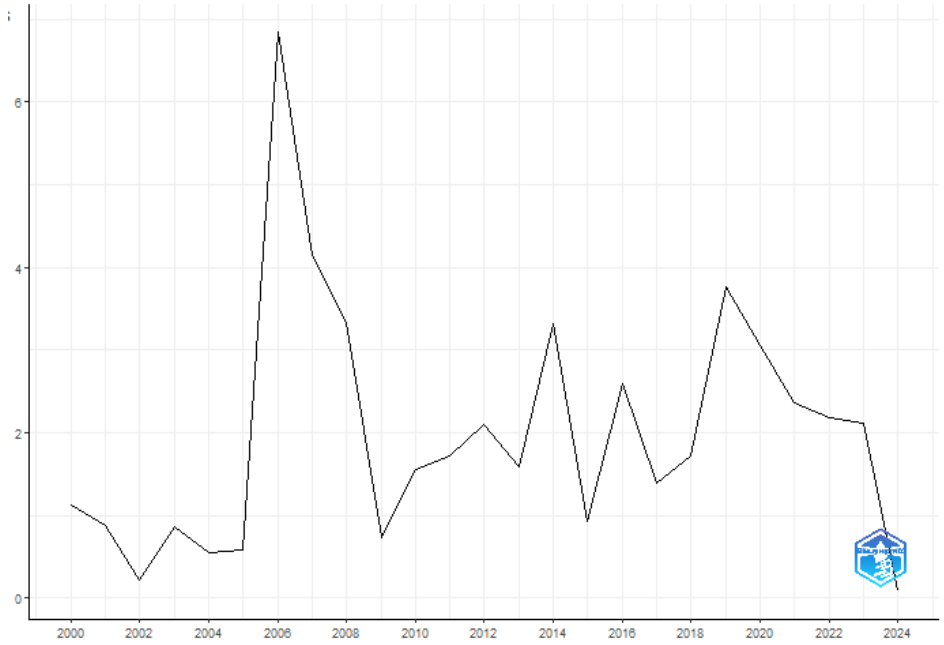


Source: Own elaboration, 2025

Figure 3 presents the average number of citations per year, reflecting the impact of publications over time. A notable peak is observed in 2007, with an average of more than six citations per article. This increase could be associated with the publication of pioneering studies or significant advances that captured the attention of the academic community and established important theoretical foundations.

Subsequently, the average number of citations stabilizes between one and three citations per year, indicating a consolidation of the field and a more uniform dissemination of knowledge. The decrease in average citations in more recent years is to be expected, as articles need time to accumulate citations and become widely recognized. This pattern suggests that the most recent research is still in the process of being assimilated by the scientific community.

Figure 3. Evolution of the Average Number of Citations per Year in 3D Animation Publications (2000-2024). Generated with Bibliometrix.



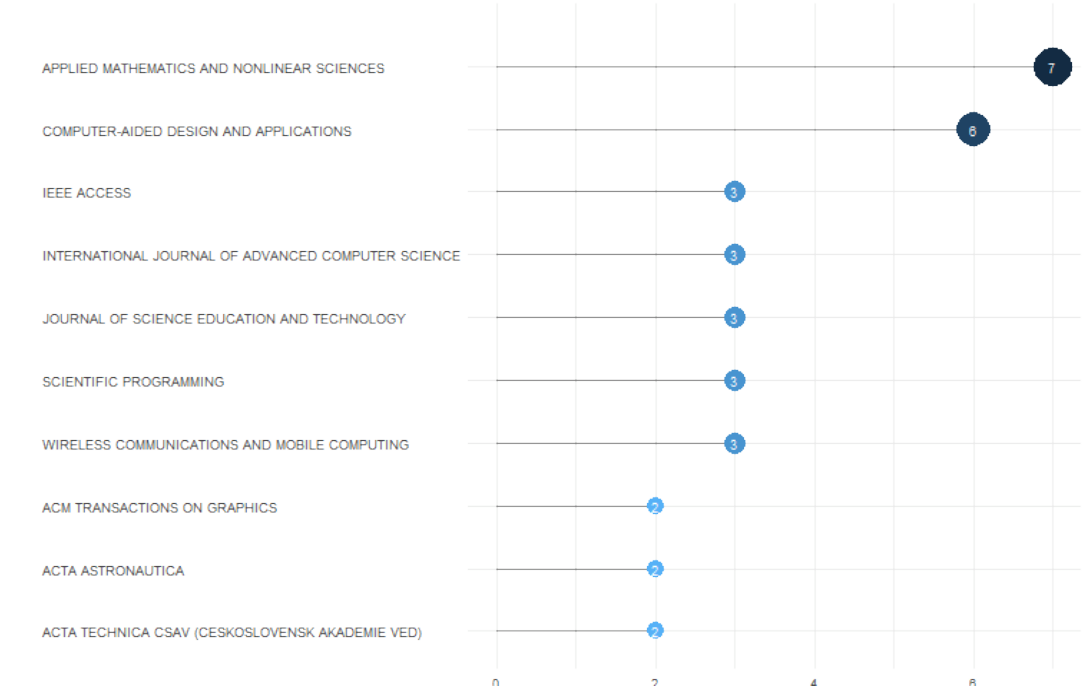
Source: Own elaboration, 2025

As for the most relevant sources, Figure 4 shows that Applied Mathematics and Nonlinear Sciences leads with seven published articles. This journal focuses on mathematical applications and nonlinear sciences, indicating a strong intersection between 3D animation and advanced mathematics, especially in areas such as simulation of physical phenomena and complex modeling.

Computer-Aided Design and Applications, with six articles, highlights the importance of computer-aided design in the creation and development of 3D animations. Journals such as IEEE Access and Journal of Science Education and Technology, with three publications each, reflect the multidisciplinary nature of the field, encompassing aspects of engineering, educational technology and computer science.

These sources provide key platforms for the dissemination of research and demonstrate how 3D animation permeates diverse disciplines, from digital art to industrial and educational applications.

Figure 4. Most Relevant Sources in 3D Animation Research (2000-2024). Generated with Bibliometrix.

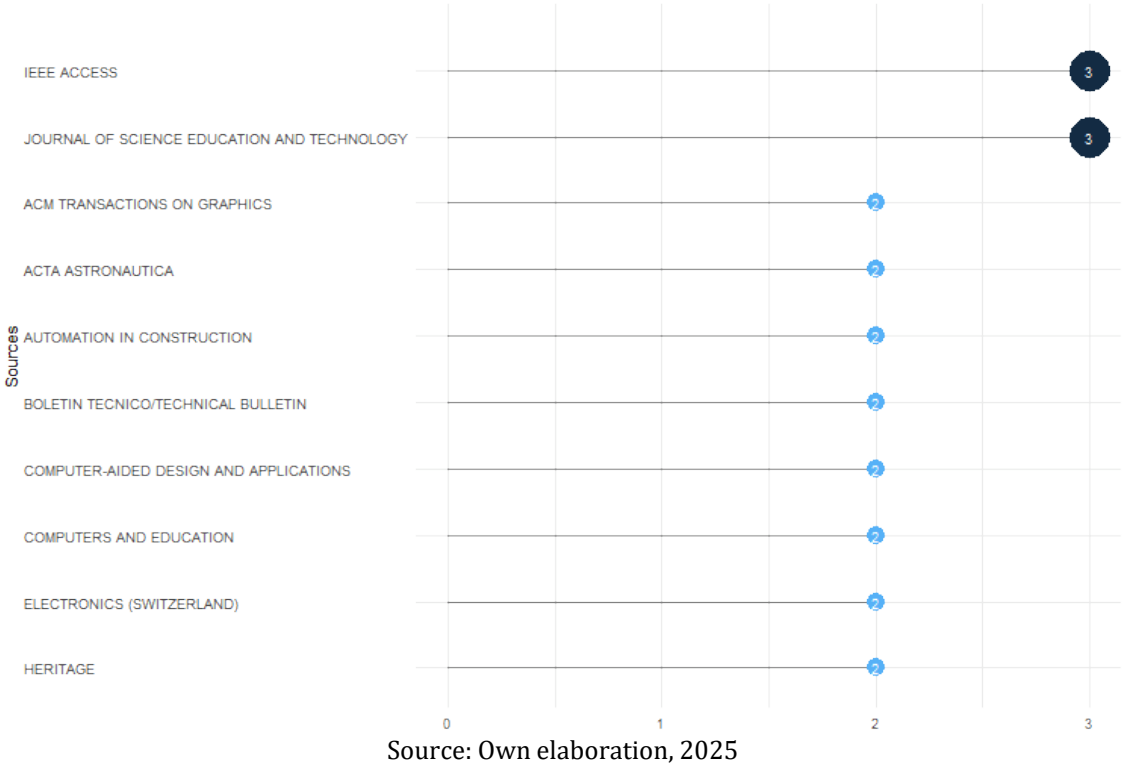


Source: Own elaboration, 2025

The impact of the sources is analyzed in Figure 5 using the h-index. IEEE Access and the Journal of Science Education and Technology present an h-index of 3, indicating a combination of high productivity and strong impact in terms of citations. This suggests that articles published in these journals are widely recognized and referenced, significantly influencing the development of the field.

The presence of Acta Informatica and Communication in Computer and Information Science with an h-index of 2, although lower, shows that these journals also contribute to the advancement of 3D animation, possibly in more specialized or technical areas. The h-index is a valuable measure to assess the influence and relevance of sources in the scientific community.

Figure 5. Sources with Highest Impact Measured by the h-Index on 3D Animation Research (2000-2024). Generated with Bibliometrix.

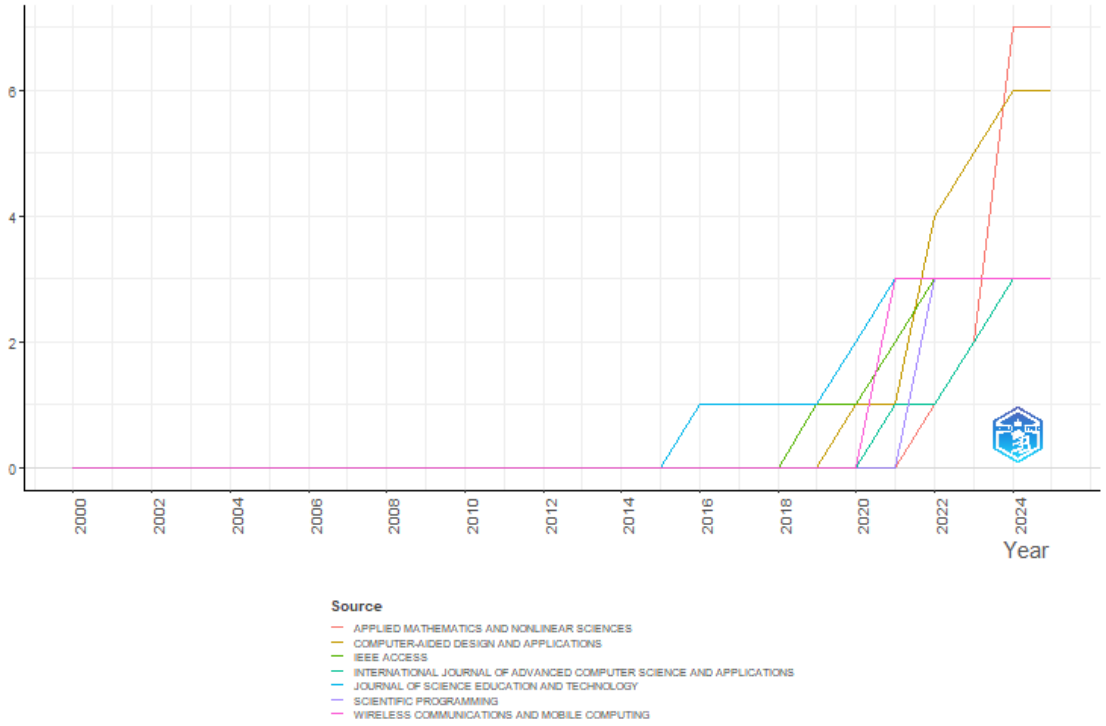


Source: Own elaboration, 2025

Figure 6 shows the evolution of the cumulative production of the sources over time. It can be seen that journals such as Applied Mathematics and Nonlinear Sciences and IEEE Access have significantly increased their production in recent years. This growth may be related to the adoption of new technologies and methodologies in 3D animation, such as machine learning, artificial intelligence and virtual reality.

The increase in the output of these journals suggests a trend towards more interdisciplinary and technologically advanced research. It also reflects the growing importance of 3D animation in practical applications and its relevance in the current scientific landscape.

Figure 6: Cumulative Source Production in 3D Animation Research (2000-2024). Generated with Bibliometrix.



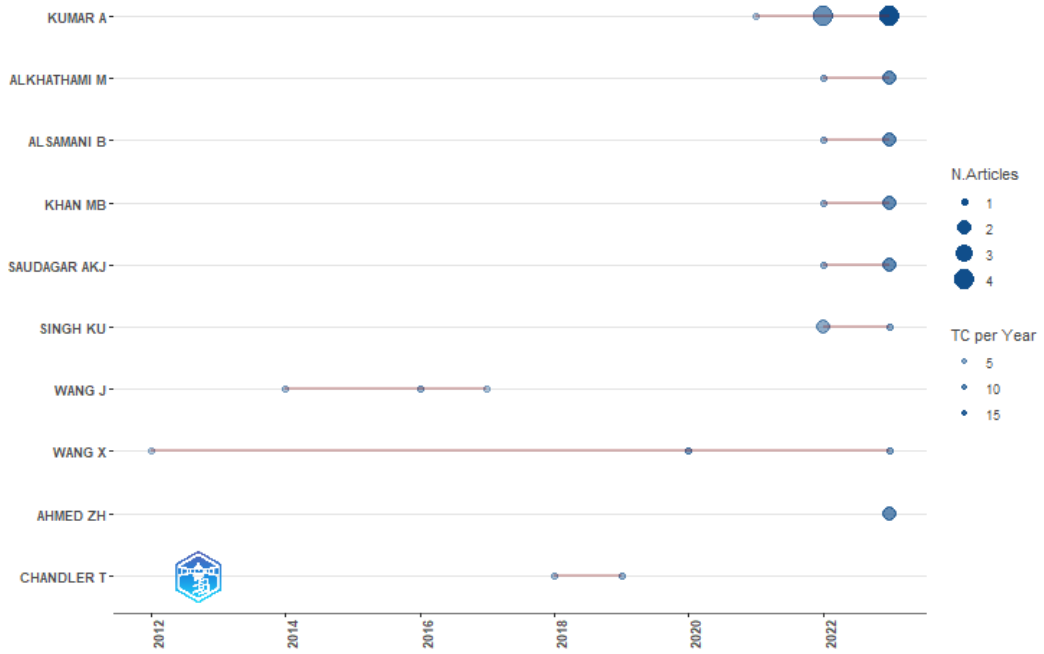
Source: Own elaboration, 2025

Regarding the most prolific authors, Figure 7 highlights Kumar A with four publications and a high citation impact. His contribution to the field could be focused on emerging areas such as the integration of artificial intelligence in 3D animation or innovative educational applications.

Other authors such as Alkhathami M and Al Samani B, with three publications each, are also key figures, possibly collaborating on research on immersive technologies or advanced simulations. The distribution of author output reflects a balance between established researchers and new talent enriching the field with fresh perspectives.

The graph also highlights authors such as Wang X and Wang J, who, despite having fewer publications, have generated a consistent impact over the years, with a considerable average number of citations in their contributions. This suggests that the quality and impact of their research has been valued by the academic community, even though their number of publications is lower compared to other authors. In addition, some authors, such as Singh KU and Ahmed ZH, have started contributing more recently to the field, with publications that are in the process of accumulating citations and recognition.

Figure 7. Author Production in 3D Animation Research (2000-2024). Generated with Bibliometrix.



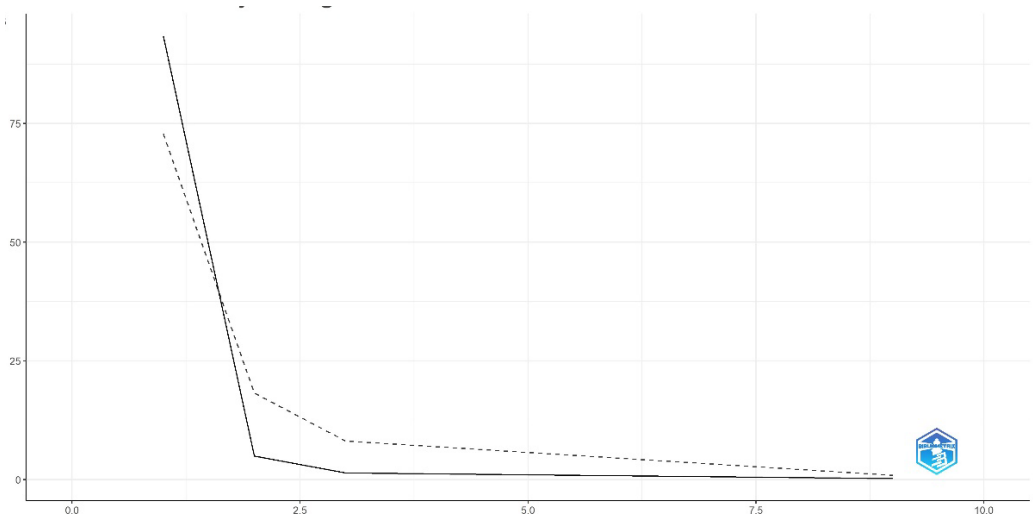
Source: Own elaboration, 2025

The graph presented analyzes the productivity of authors in the field of 3D animation, using Lotka's Law, which is a bibliometric principle commonly used to measure the distribution of author productivity in a research area.

In accordance with Lotka's law, the graph shows a strong concentration of productivity in a small group of authors, while the vast majority of authors contribute a small number of publications. This is clearly reflected in the steep curve at the beginning, where more than 75% of the authors have written only one or two papers. As the number of papers increases, the number of contributing authors decreases significantly, which follows a power law.

The observed behavior is characteristic of many areas of science, where a small group of authors tends to be very productive, while the majority of researchers contribute few papers. In this particular case, the graph highlights that only a small number of authors have published more than 5 papers, reflecting that 3D animation research is mainly driven by a core group of highly productive researchers.

Figure 8. Productivity of Authors in 3D Animation Research according to Lotka's Law (2000-2024). Generated with Bibliometrix.

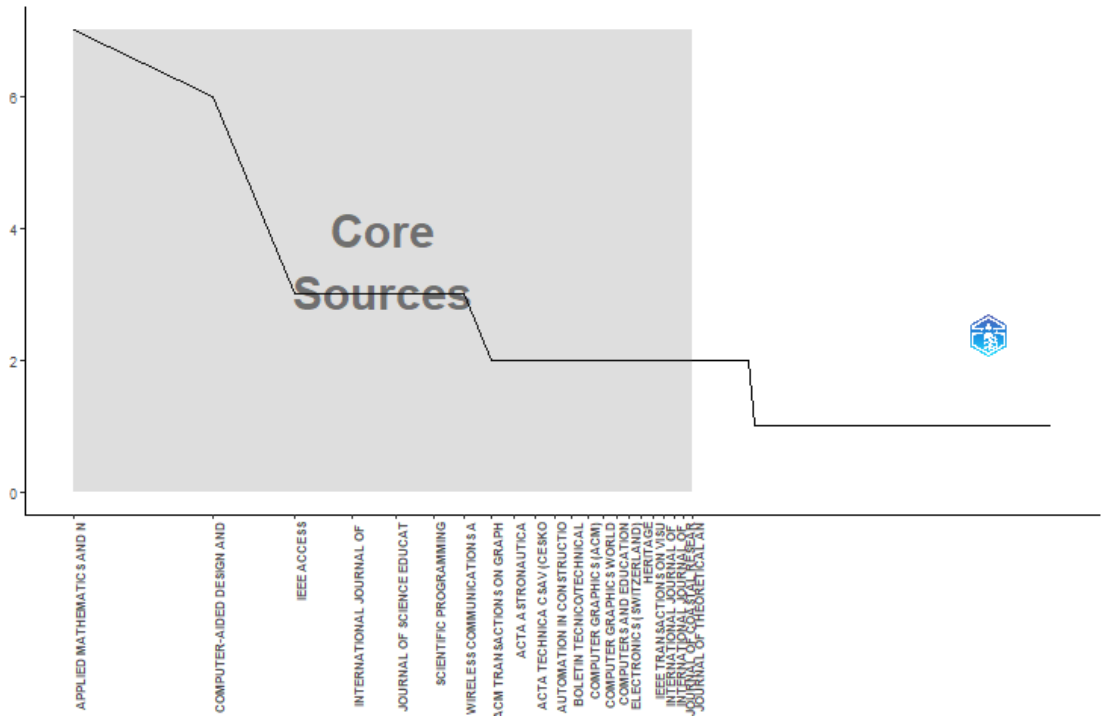


Source: Own elaboration, 2025

The graph presents the analysis of key sources in 3D animation research using Bradford's Law, which classifies journals into three zones according to their productivity. The journals within the core sources are those that concentrate the largest number of articles in the area of study, while the others are distributed in zones with lower relative contribution.*zone*

In this case, the core zone is composed of journals such as Applied Mathematics and Nonlinear Sciences, Computer-Aided Design and Applications, and IEEE Access, which represent the most relevant sources in terms of number of articles published on 3D animation. These journals publish the majority of the articles and are therefore the most influential and frequently consulted by researchers in the field. As one moves down the curve, one sees less productive sources in terms of number of publications, but still contributing to the field, such as the International Journal of Advanced Computer Science and Wireless Communications and Mobile Computing. These journals are still important, albeit with a smaller number of published articles.

Figure 9. Key Sources in 3D Animation Research according to Bradford's Law (2000-2024). Generated with Bibliometrix.

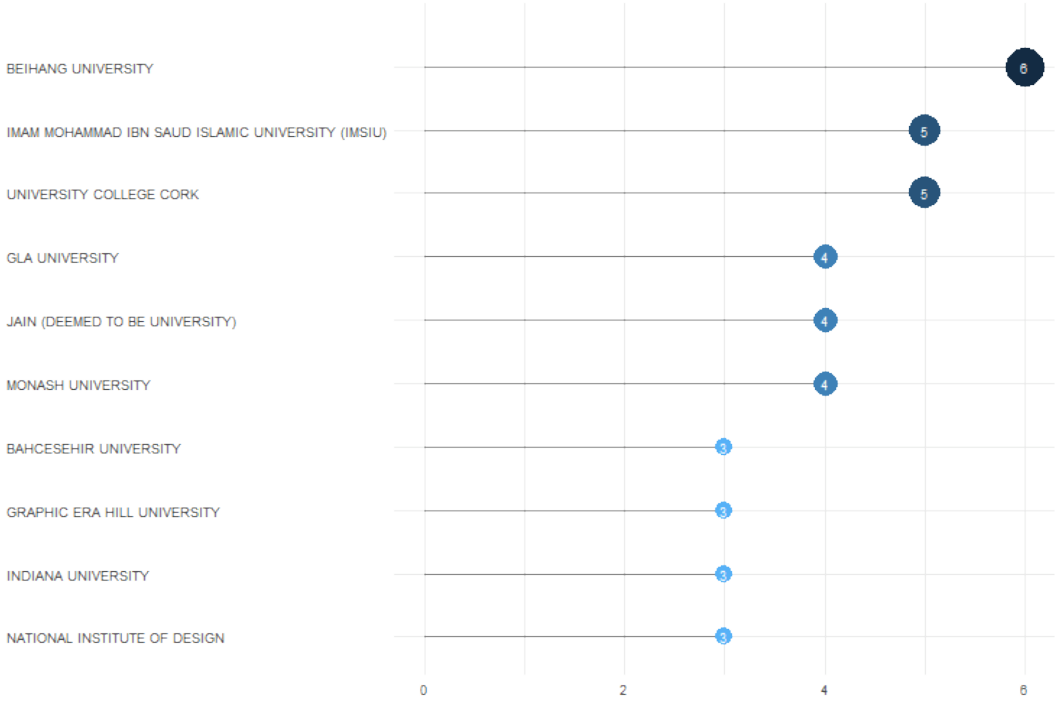


Source: Own elaboration, 2025

In terms of institutional affiliations, Figure 10 shows that Beihang University tops the list with eight publications, followed by Imam Mohammad Ibn Saud Islamic University and University College Cork, with five publications each. This is evidence of the leadership of these institutions in 3D animation research.

Other institutions such as CLA University, Indira Gandhi National Open University, and Monash University, with 4 publications each, are also among the main contributors. Although with fewer articles, these universities play a key role in interdisciplinary research and emerging areas related to the study variables, indicating a diverse geographical distribution and a significant presence of institutions in both Asia and Europe. This reflects the global nature of 3D animation research and international collaboration.

Figure 10. Most Relevant Affiliations in 3D Animation Research (2000-2024). Generated with Bibliometrix.

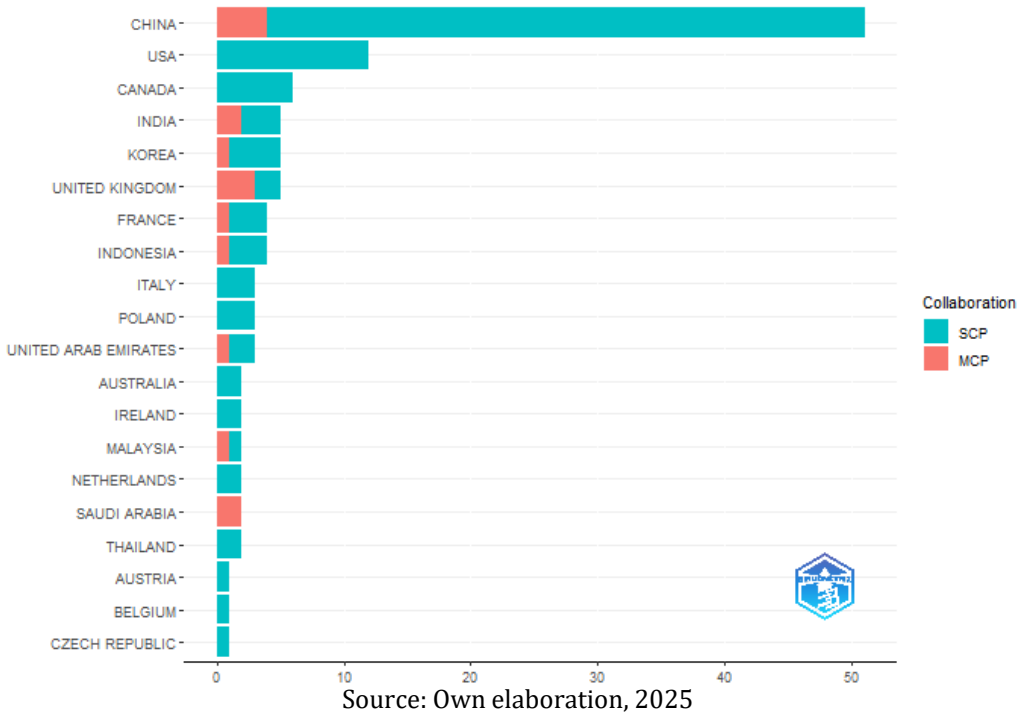


Source: Own elaboration, 2025

Figure 11 analyzes the contribution by country, highlighting China as the main producer with more than 50 publications, mostly of national production. This is evidence of China's investment and interest in advanced technologies and its leadership in the development of 3D animation.

The United States and Canada also have a significant presence, with a higher proportion of international collaborations. This suggests a more collaborative approach and openness to global cooperation in these countries. The participation of other countries such as India, UK and South Korea indicates a growing interest and expansion of 3D animation research worldwide.

Figure 11. Countries of Corresponding Authors in 3D Animation Research (2000-2024). Generated with Bibliometrix.

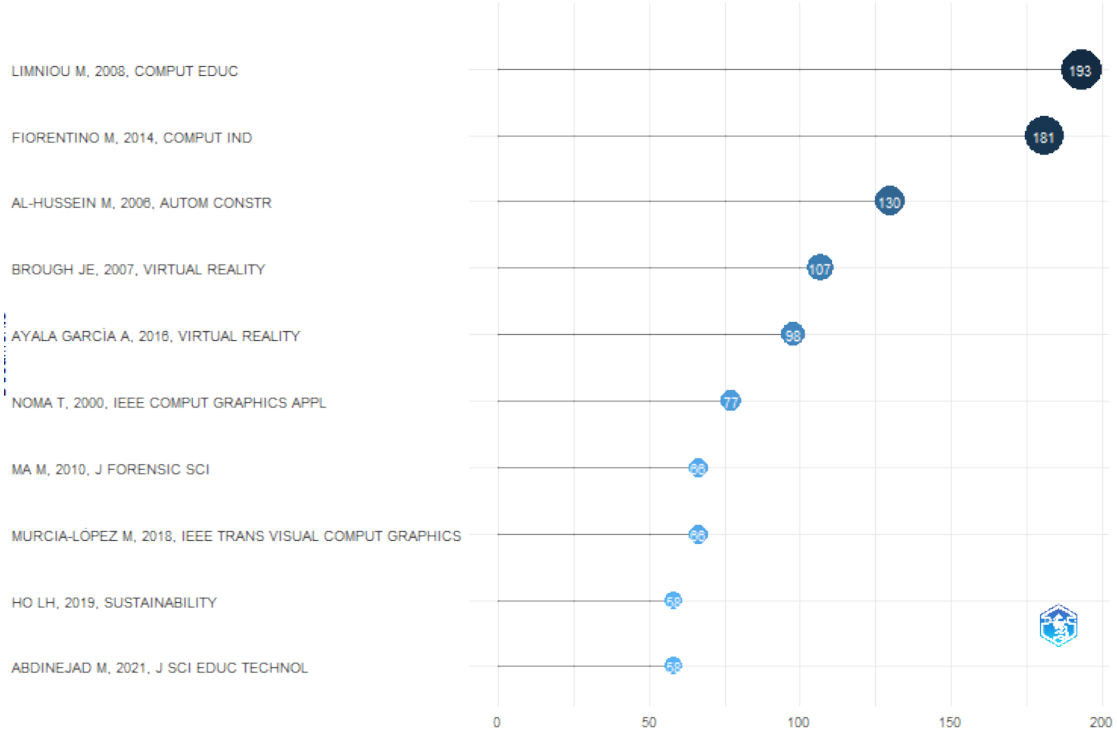


Source: Own elaboration, 2025

The most cited papers globally are presented in Figure 12. The paper by Limniou M. (2008) is the most cited paper with 193 citations, indicating a significant impact in the field, possibly in the application of 3D animation in education or innovative teaching methodologies.

The second most cited paper is by Fredenrich M. (2014) with 181 citations, reinforcing the importance of educational and training applications of 3D animation. These papers have influenced numerous subsequent researches and have established key references for the development of the field.

Figure 12. Most Cited Papers Globally in 3D Animation Research (2000-2024). Generated with Bibliometrix.

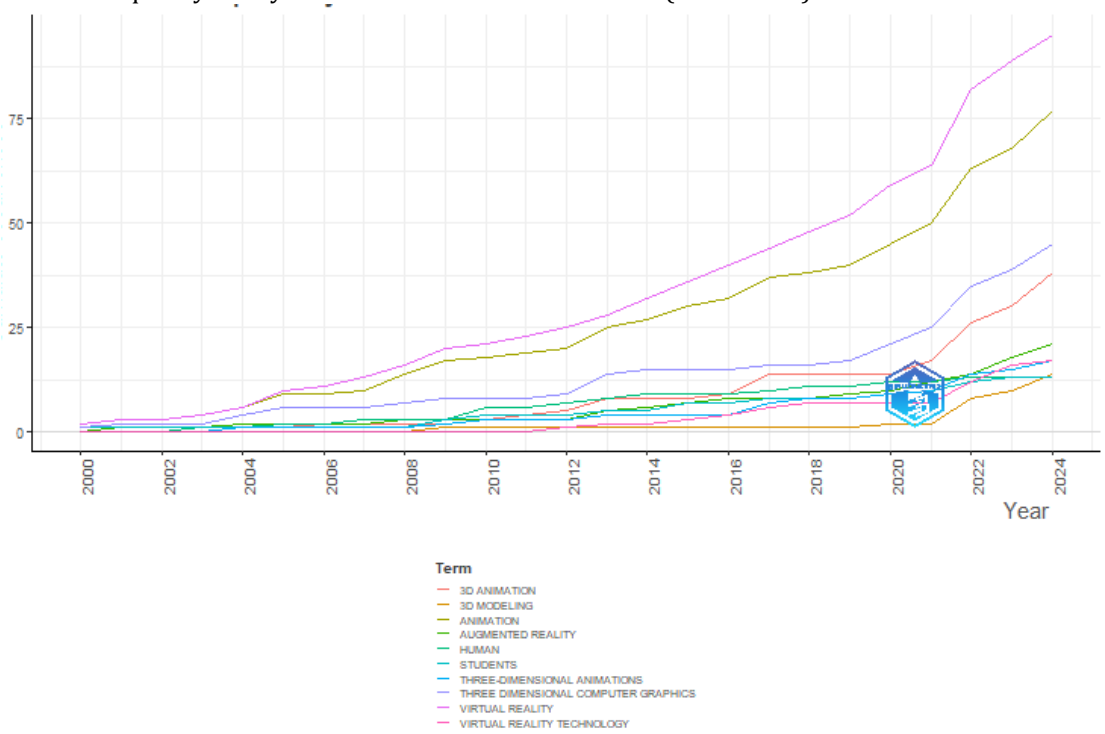


Source: Own elaboration, 2025

The keyword analysis, reflected in Figure 13, identifies terms such as *3D animation*, *virtual reality, augmented reality* and *3D modeling* as the most frequent and growing. This indicates a strong trend towards immersive technologies and applications in virtual and augmented environments.

The increase in terms such as *students*, *e-learning* and *teaching* suggests a growing focus on the application of 3D animation in education, enhancing interaction and engagement in learning environments. In addition, the presence of terms such as *software* and *visualization* reflects the continued development of tools and techniques for the creation and application of 3D animation.

Figure 13. Frequency of Keywords in 3D Animation Research (2000-2024). Generated with Bibliometrix.

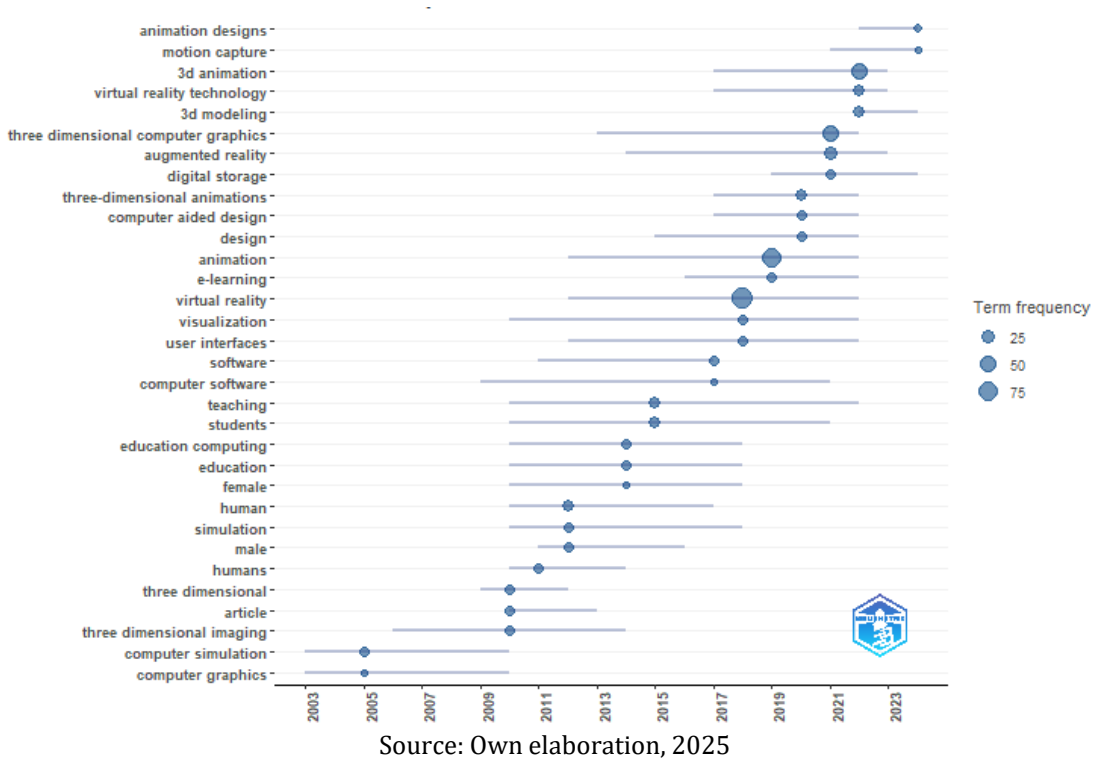


Source: Own elaboration, 2025

Figure 14 elaborates on emerging themes, showing how concepts related to education and immersive technologies have gained prominence in recent years. Terms such as *virtual reality technology* and *augmented reality* indicate that these areas are growing and represent opportunities for new research and applications.

The emergence of these emerging themes suggests that 3D animation is expanding its scope and relevance, integrating with advanced technologies and addressing challenges in diverse fields, from education to medicine to entertainment.

Figure 14. Emerging Themes in 3D Animation Research (2000-2024). Generated with Bibliometrix.

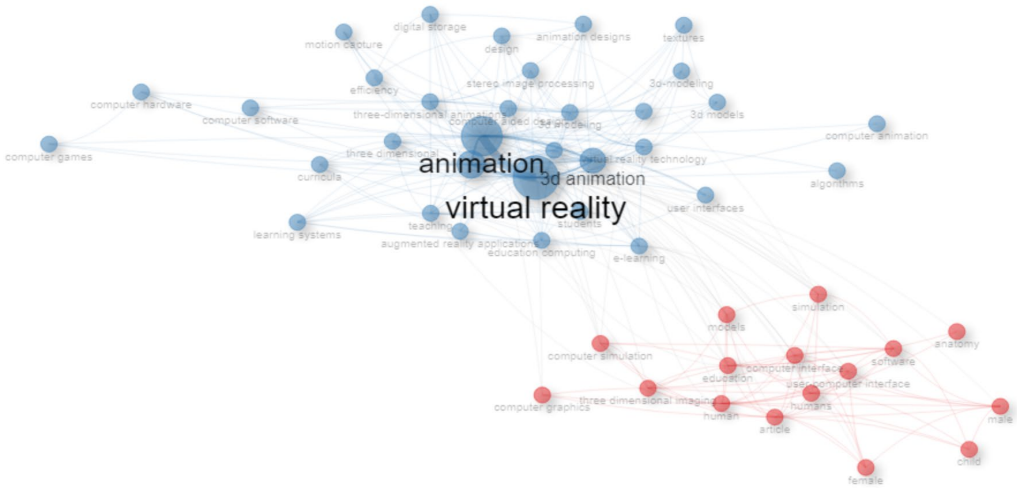


Source: Own elaboration, 2025

The map of co-occurrence of terms, presented in Figure 15, visualizes the interrelationships between the most important keywords. The strong connection between *animation*, *virtual reality* and *augmented reality* is evidence of the convergence of these technologies and their joint importance in current research.

Associations with terms such as *teaching*, *students* and *e-learning* reinforce the central role of 3D animation in the transformation of educational methods. In addition, connections with *human*, *anatomy* and *computer simulation* suggest significant applications in medicine and life sciences, where three-dimensional visualization enhances the understanding of complex structures and processes.

Figure 15. Map of Co-occurrence of Terms in 3D Animation Research (2000-2024). Generated with Bibliometrix.

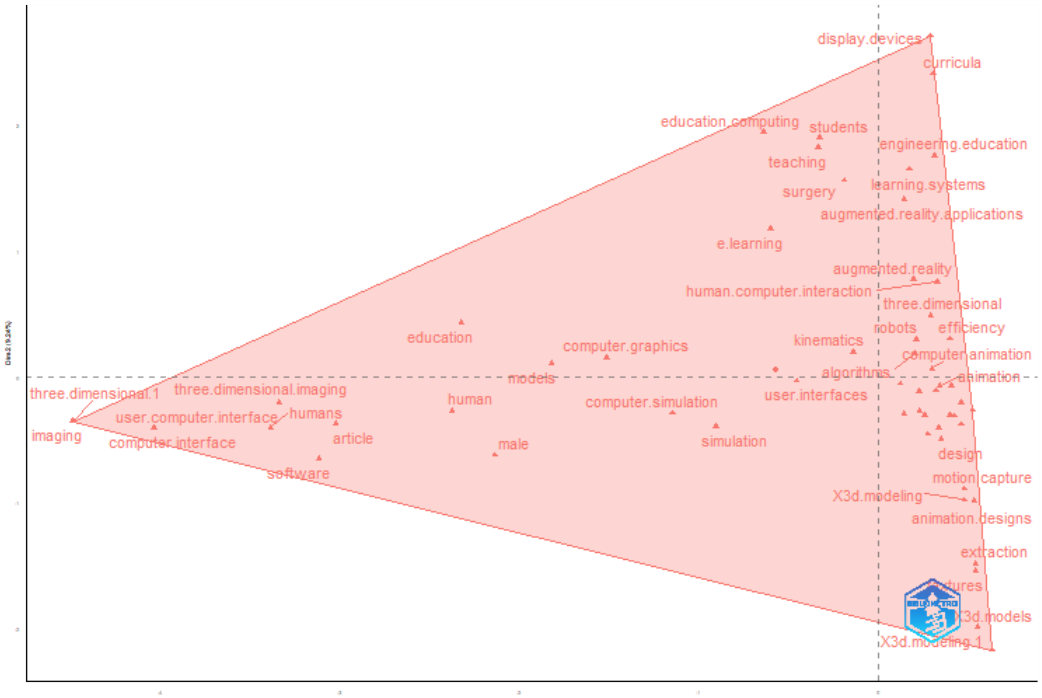


Source: Own elaboration, 2025

The strategic theme diagram, illustrated in Figure 16, classifies keywords according to their relevance and development. Themes such as *human*, *e-learning* and *article* are positioned as drivers of the field, indicating areas of high importance and consolidated development

The positioning of *virtual reality*, *animation* and *three-dimensional computer graphics* as emerging topics or in need of revitalization suggests that, although fundamental, they could benefit from new perspectives and innovative approaches. This presents opportunities for researchers interested in driving significant advances in these key areas.

Figure 16. Diagram of Strategic Themes in 3D Animation Research (2000-2024). Generated with Bibliometrix.

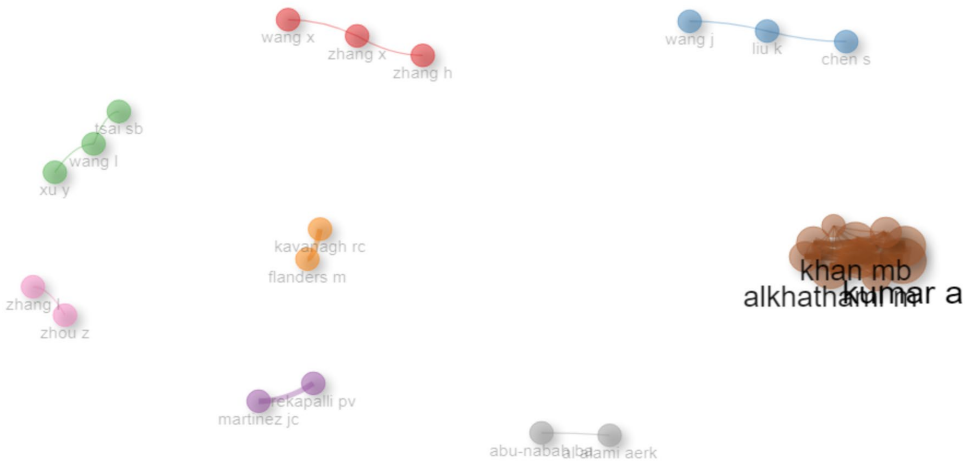


Source: Own elaboration, 2025

Figure 17 shows the network of collaboration between authors. It highlights a central core of researchers such as Khan M.B., Alkhathami M. and Kumar A., who maintain close and frequent collaborations. These co-authorship networks are often indicative of strong research groups and can result in high impact publications and significant advances.

The presence of multiple sub-networks and less dense connections reflects the diversity and multidisciplinarity of the field. This suggests that 3D animation is an area of interest to researchers from diverse disciplines and that opportunities exist to expand collaboration and knowledge sharing internationally

Figure 17, Map of Collaboration among Authors in 3D Animation Research (2000-2024). Generated with Bibliometrix**.**



Source: Own elaboration, 2025

4. Discussion

The results of the bibliometric analysis, carried out between 2000 and 2024, show relevant trends in 3D animation research within digital culture. Consistent with the purpose of describing the evolution of scientific production, a sustained growth is observed until 2021, indicating a consolidated interest in this field, in line with technological advances and increasing accessibility to 3D animation tools (Kerlow, 2009; Purves, 2013). Similarly, the slight decline in 2022 and 2023 could be related to external factors, such as the COVID-19 pandemic, which affected academic productivity globally (Korbel & Stegle, 2020); however, a possible recovery is anticipated in the following years.

Regarding the identification of the most influential authors and institutions, the analysis shows that China, the United States and Canada lead in 3D animation production, although China has less international collaboration, possibly due to policies focused on domestic development (Tang & Shapira, 2011).

For their part, the United States and Canada reflect greater global interaction, a factor recognized as essential for scientific advancement (Gazni et al., 2012). Institutions such as Beihang University, Imam Mohammad Ibn Saud Islamic University and University College Cork have played a prominent role, revealing the presence of centers of excellence dedicated to 3D animation research and training (Wang et al., 2015).

The analysis of keywords and the detection of emerging topics confirm the transition from traditional approaches, focused on 3D animation or animation, to new fields linked to virtual reality, augmented reality and e-learning (Johnson et al., 2016). This finding ratifies the multidisciplinary evolution of 3D animation, especially in areas such as education and medicine, where it enables the understanding of complex concepts and the optimization of training processes (Ho et al., 2019; Hiranyachattada & Kusiririrat, 2020; Guo et al., 2023). Additionally, the adoption of artificial intelligence and machine learning (Ma, 2024; Zhang & Tsai, 2021) underlines the potential of 3D animation to innovate in creative, narrative and technical aspects.

Regarding the analysis of collaboration and co-authorship networks, the presence of a core group of researchers - among whom Khan M.B., Alkhathami M. and Kumar A. stand out - reflects the importance of consolidated teams in the production of knowledge and in the direction of future lines of research (Katz & Martin, 1997). Such collaborative networks favor the integration of diverse perspectives and enhance the quality of scientific results.

Contrasting these findings with bibliometric studies in other emerging technological fields, it is observed that innovation and interdisciplinarity also drive the growth of 3D animation research (Donthu et al., 2021). The rapid incorporation of technologies such as virtual reality and artificial intelligence confirms the dynamism of this field and the need for constant monitoring to identify future opportunities.

On the other hand, 3D animation plays a growing role in cultural dissemination and digital preservation. Research such as that of Morgan (2020) demonstrates how digital media contribute to cultural communication and the expression of identities, while Pertiñez and Alonso (2022) highlight the relevance of hybrid processes that combine analog and digital techniques, reinforcing flexibility and creative diversity in contemporary animation.

5. Conclusions

The present bibliometric analysis has provided a comprehensive overview of the evolution and current state of 3D animation research in the context of digital culture between the years 2000 and 2024. The main findings indicate a steady growth in scientific output until 2021, followed by a slight decline in the most recent years. This pattern suggests that 3D animation has been an area of growing interest, driven by technological advances and its application in diverse fields such as education, medicine and entertainment.

Research has identified China, the United States and Canada as the main contributors in terms of scientific output, with Beihang University standing out as the most prolific institution. However, there is less international collaboration from China compared to the United States and Canada, which points to opportunities for strengthening global research networks.

Keyword analysis reveals a transition in the topics of interest, with an increase in terms related to virtual reality, augmented reality and e-learning. This indicates a trend towards the integration of 3D

animation with immersive technologies and their application in educational and training environments. In addition, the emergence of emerging areas such as the application of artificial intelligence and machine learning in 3D animation opens new perspectives for innovation and development in the field.

3D animation has transcended its traditional use in entertainment to become an essential tool in various sectors of contemporary culture. Its ability to create detailed visual representations and immersive experiences has revolutionized the way we interact with technology and consume information. These studies are crucial to understanding how technology influences society, shaping cultural, educational and professional practices.

In addition, 3D animation plays a significant role in the digitization of culture, enabling the preservation and dissemination of cultural heritage through virtual recreations. It also facilitates inclusion and accessibility by offering new forms of learning and communication that transcend physical and cognitive barriers.

By understanding the impact of 3D animation on digital culture, we can anticipate future trends and prepare for the changes these technologies will bring to society. This is vital for educators, industry professionals, policy makers and academics looking to take full advantage of the opportunities offered by 3D animation, while mitigating potential risks associated with its implementation.

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