Research Article

Bibliometric Analysis of Virtual Reality (VR) Technology in Architecture

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Keywords	Abstract
Architecture, Architecture Design, Bibliometric analysis, Virtual Realty.	The increasing accessibility to Virtual Reality (VR) systems has led to innovative efforts within the field of architecture, aiming to bring new perspectives and generate novel and creative ideas to address existing challenges. Various studies related to the discipline of architecture are being conducted based on this new production process. The primary objective of this article is to conduct a bibliometric analysis of publications related to VR in the field of architecture and architectural design available in the Scopus database. This analysis aims to explore the applications of VR in architectural advancements. Publications spanning the years 2004 to 2023 were analyzed based on keywords, authors, countries, citations, affiliations, and sources. The VOSviewer software was employed to present the analysis results graphically. The outcomes of this study reveal not only the inadequacy of VR research within architecture but also underscore the need for further research. Furthermore, a noticeable increase in the utilization of VR in Building Information Modeling (BIM) and architectural education has been observed in recent years between 36 keywords in the field. Additionally, more than 65% of publications in this field come from countries with easier access to technology. This study can assist in identifying general trends from previous research endeavors and provide deeper insights into the scope of future investigations concerning VR utilization in architecture.

1. Introduction

This article is based on a bibliometric analysis of the studies conducted for architecture and Virtual Reality (VR). In architecture, the design process, ranging from concept and development to implementation, relies heavily on graphic representations for those engaged in visualization, irrespective of the design scale, spanning from urban to architectural and interior design [1]. In order to facilitate successful communication, various drawing methods are employed to define the proposed design's conceptual configuration and perceptual quality. Through a few strategically positioned drawings, multiple image drawings of plans, sections, and elevations can clearly depict a specific configuration in a two-dimensional form and also illustrate comprehensive three-dimensional spatial connections. Axonometric views and oblique plan views use three sets of two-dimensional drawings to provide a more intuitive understanding of how voids are organized in terms of dimensions and proportions. Perspective drawing can transform conceptual drawings into perceptual ones, allowing us to visualize how the proposed design will appear when constructed and enabling us to envision the experiential aspect of architectural arrangement as an architectural space [2]. Over time, drawing tools have evolved to serve as a means of expressing architectural representations. With the integration of computer technology into architecture, drawings have been transitioned into

virtual environments, allowing for the utilization of not only 2D expressions but also 3D forms of representation. In the computer-generated world, visual experiences are fundamentally created and categorized by human visual intelligence, allowing for a deeper understanding of architectural concepts through various perspectives [3]. User experience and the effectiveness of virtual environments are determined by sensory processes and perceptual criteria [4, 5]. The use of digital tools that allow for the representation and visualization of how an architectural space can be perceived by mastering the three-dimensional arrangement of an architectural structure and utilizing freehand drawing techniques is increasingly expanding its influence in architecture and engineering [6]. Furthermore, the technology of Virtual Reality (VR), with its capability to represent scale, depth, and volume, is contributing to the growing popularity of VR in the Architecture, Engineering, Construction, Operations, and Facility Management (AECO/FM) sector. This increasing popularity is attributed to its potential in visualizing and understanding architectural spaces and structures [7]. Additionally buildings must have designs that are technologically advanced, energy-efficient, ecological, flexible, and pleasant in addition to best meeting human requirements [8] . According to Sherman and Craig'e (2018), VR) is a term that describes the technology that immerses a user in a computer-generated, three-dimensional simulated environment [9]. One of the most significant contributions of VR technology to the fields of architecture and engineering is realism. However, VR technology enables users to create the environment, like exploring physical space, rather than merely generating a realistic experience [10].

The evolving virtual reality landscape significantly impacts architectural practice, and numerous research endeavors are being conducted in this field. Due to the relevance of the topic, an increasing number of studies are emerging in this area daily. Analyzing the studies in Virtual Reality (VR) and Architecture can shed light on the current state and facilitate the understanding of shifts and evolution over time. Moreover, there are several disadvantages when conducting analytical research using conventional techniques [11]. Glaser and Strauss (1967) argue that traditional approaches perceive phenomena as always being within the same framework and static [12]. Hence, they fail to explain continuously changing phenomena adequately [13]. Analytical research, on the other hand, assists researchers from various angles when demands such as expanding or modernizing the scope of study arise [14].

The scope of previous studies conducted in the relevant field is expanded based on findings obtained from research areas. In this context, bibliometric analysis is a commonly used examination system, especially in recent times. Bibliometric analysis is widely employed to understand worldwide publications in a single database, encompassing publication year, country, author, and journal in which the research is published. It is extensively utilized to acquire detailed quantitative and statistical information related to the studies [15]. The breadth of a research study can be explored from numerous perspectives using bibliometric analyses, and the results can have a wide range of scholarly connections [16]. Furthermore, bibliometric analyses assist in uncovering hidden patterns and connections among examples and instances within the existing literature based on the mentioned data. These analyses can reduce researcher bias and other factors that might adversely affect the literature review process [17]. The bibliometric analysis aids in generating visual maps from large datasets in research topics [18]. These visual maps are employed as innovative methods in analyzing studies, particularly in cases where research topics are extensive and require frequent updates, compared to the limited research methods available. Various visualization tools such as VOSviewer, Cite-Space, and Bib-Excel are available for data visualization and creating visual maps [19]. VOSviewer is a commonly used graphical visualization software in bibliometric studies due to its user-friendly interface and free availability. It is utilized for reviewing literature and is often employed in bibliometric research to create visual representations of data [20]. Compared to other similar software, VOSviewer excels in network mapping and visualization [21]. This article presents a bibliometric analysis of publications related to the discipline of architecture and virtual reality (VR). The study examines the evolution of research topics and identifies future research trends by analyzing the development of research areas.

2. Research and Methodology

In this study, a bibliometric analysis of publications related to virtual reality in the field of architecture has been conducted using keywords representing research topics. A quantitative examination of books, papers, or other publications is what is meant by the term "bibliographic technique." The bibliometric analysis has been used recently in a number of professional domains to display the state, components, development, and developing trends of knowledge. This can assist curious researchers who lack specialized knowledge in those subjects and ensure a thorough grasp [22, 23]. The research explores the scope of studies by analyzing the connections between authors, publications, citations, and keywords from the Scopus online database. The network system and VOSviewer software (Version 1.6.19) are employed to display bibliometric analyses graphically and visually. Large bibliometric datasets may be objectively analyzed and mapped using the bibliometric technique to identify a scientific domain's structural dynamics [18]. Bibliometric analysis provides insights into a field's emerging regions and aids in illuminating the evolutionary complexities of a scientific subject. It may be used for a variety of things, such as spotting new research trends, patterns of collaboration, research elements, and examining the intellectual hierarchy of a scientific field [24-26]. The performance of many fields may be clearly shown based on bibliometric methodologies. Nees Jan van Eck and Ludo Waltman (Leiden University) published VOSviewer in 2010 [27]. A software program for producing and perusing maps based on network data is called VOSviewer. Although initially designed for the analysis of academic records, it may be used for any kind of network data (such as social networks) in one of three alternative representations—network, overlay, or density visualization—VOSviewer investigates linkages, including co-authorship, co-occurrence, citation, bibliographic

coupling, and co-citation [28]. The bibliometric data of search results between 2004 and 2023 using keywords "Architecture," "VR," and "Architectural Design" in the Scopus database are analyzed. Mapping methods in the VOSviewer software are used to visualize the analyses. By highlighting the present and future development areas for the continuous growth of the ethics-innovation debate, it is intended that a paradigm shift from traditions to future trends will be introduced. These visualizations utilize network, temporal, and density maps. The relationships between studies, their information, and common characteristics are examined using visual maps extracted from the program. The study is based on original sources, specifically scholarly articles indexed in significant bibliographic indexes. Figure 1 illustrates the methodology employed in the study.
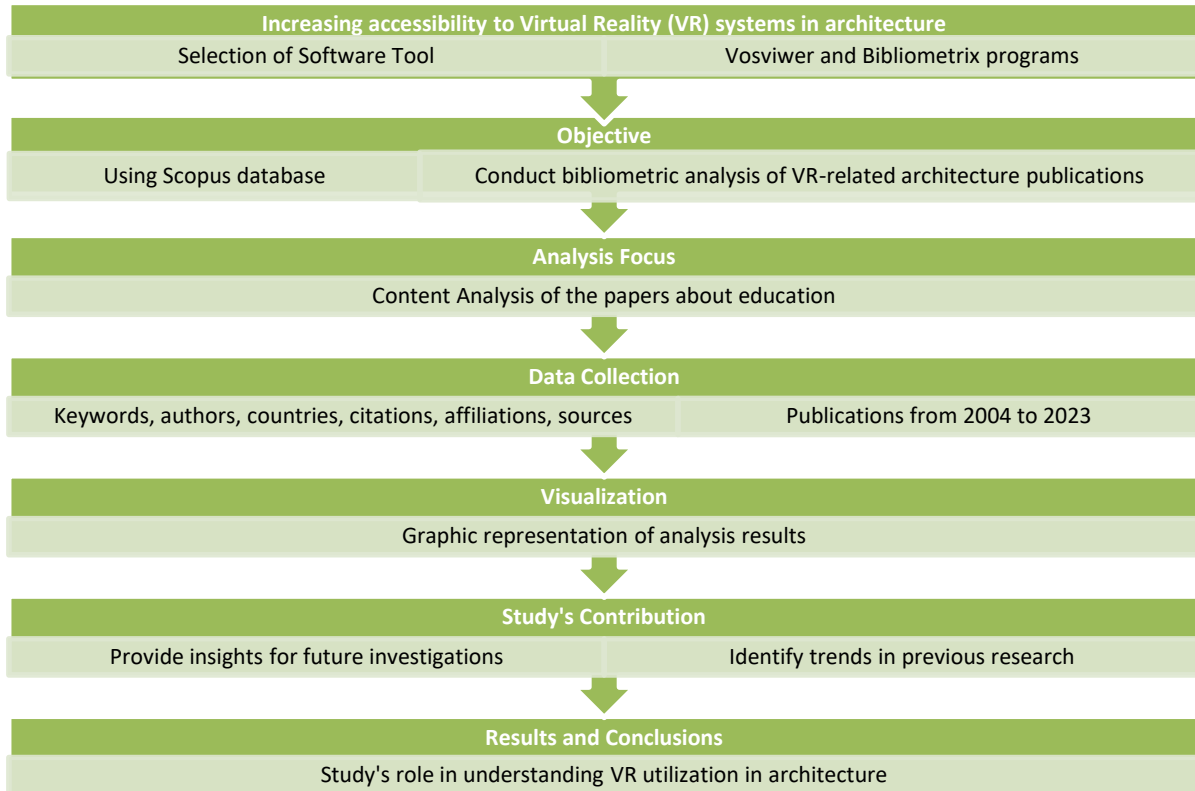
Increasing accessibility to Virtual Reality (VR) systems in architecture	
Selection of Software Tool	Vosviwer and Bibliometrix programs

Objective	
Using Scopus database	Conduct bibliometric analysis of VR-related architecture publications

Analysis Focus
Content Analysis of the papers about education

Data Collection	
Keywords, authors, countries, citations, affiliations, sources	Publications from 2004 to 2023

Visualization
Graphic representation of analysis results

Study's Contribution	
Provide insights for future investigations	Identify trends in previous research

Results and Conclusions
Study's role in understanding VR utilization in architecture

Figure 1. Methodology of the study

The Scopus database includes 75 publications between the years 2004 and 2023. The literature between architecture, architectural design, and virtual reality (VR) has been investigated to address the following fundamental questions:

What are the developments in the Virtual Reality (VR) usage process?

How is Virtual Reality (VR) utilized in the field of architecture?

What are the results of the bibliometric analysis regarding Virtual Reality (VR)?

What are the studies related to Virtual Reality (VR) conducted in the field of architecture?

3. Results and Discussion

The studies in the literature were examined using bibliometric analysis, which is considered one of the quantitative research methodologies. The analysis included keywords, publication years, countries, and citations. Moreover, previous research approaches, objectives, and outcomes were also investigated. The literature studies were obtained from Scopus, and the data obtained were analyzed and visualized using the VOSviewer program. The Scopus database encompasses all works until 2023, regardless of their commencement dates. However, upon further investigation of the database, it can be deduced that the first recorded publication in the database was in 2004, suggesting that the study should be conducted between 2004 and 2023. In order to clarify the publications in the field, a "keyword" search was performed. Publications categorized under the titles "Architecture," "VR," and "Architectural Design" in the database were utilized. A total of 240 studies were conducted. These studies included journal articles (75), conference papers (138), book chapters (25), and other types of publications (2). Out of the 240 studies, 75 journal articles were used for visualization and bibliometric analysis in VOSviewer, incorporating references and relevant keywords of the authors.

3.1. Annual Publication Analysis

Figure 2 illustrates the distribution of publications by year. It can be observed that in the last five years, both the volume of articles and the density of relevant research have increased. The maximum number of articles meeting the

necessary criteria, reaching 39 articles, was published in 2021. Based on the results, there is a need for more comprehensive studies in the field of architecture and VR.

Furthermore, the continuous increase in publications indicates a growing interest in this field in recent years.
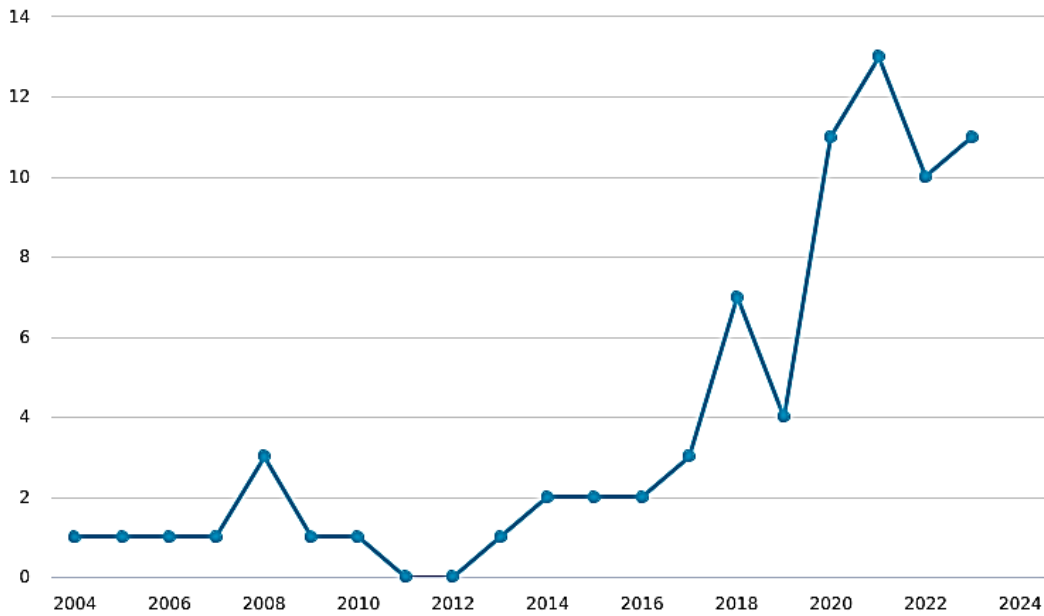

Figure 2. Annual Publication Count in the Field of Architecture Related to VR

3.2. Geographical Area Evaluation

Figure 3 displays the countries contributing to publications in the relevant field. Although 32 countries contributed to the 75 articles examined, only six countries published more than five articles. This indicates that many countries do not have sufficient research in this area (Table 1). Regarding publication count, the United States, China, and the United Kingdom are at the forefront in the architecture-related VR field, followed by Australia, Canada, and Turkey. More than 65% of publications in this field come from these six countries. The countries at the top positions indicate that developed economies and technologically advanced nations are more engaged in this area. Some countries appear with only one publication, implying their inclination towards limited collaboration with other countries. Collaborative networks of authors benefiting from the accessible infrastructure of their affiliated institutions and nations show that growth occurs

on a multi-institutional and global scale. In visual maps, node sizes change based on the strength of positive connections, and larger nodes represent stronger connections (Figure 3). Upon analyzing the visual map, it is evident that countries like Hong Kong, Portugal, Brazil, and Japan have recently joined the research field, as indicated by the visual map's inclusion of new countries.

Scientific studies can progress based on previous research. Hence, citations play a crucial role in the literature. Figure 3 illustrates the bibliometric relationship between countries and their citation numbers. Figure 4 depicts the relationship between countries and citations. It can be observed that Australia has the highest number of citations, with a total of 591. The other countries with the highest citations are the United States (577), Israel (242), Portugal (98), and South Korea (86), in that order. Upon examining citation numbers, it becomes evident that the studies are associated with various research domains.

Table 1. Distribution of Publications by Country Top Ten Countries

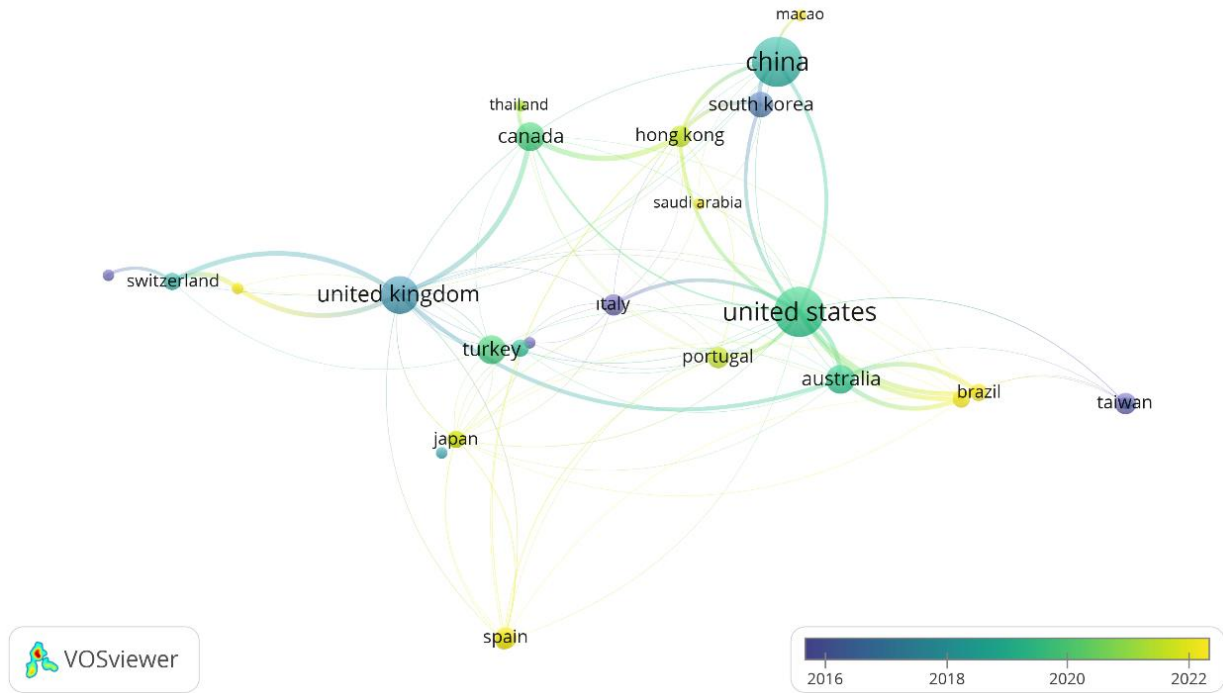| Rank	Country	Publication
1	USA	13
2	China	13
3	UK	8
4	Australia	8
5	Canada	5
6	Türkiye	5
7	South Korea	5
8	Hong Kong	4
9	Spain	4
10	Italy	4

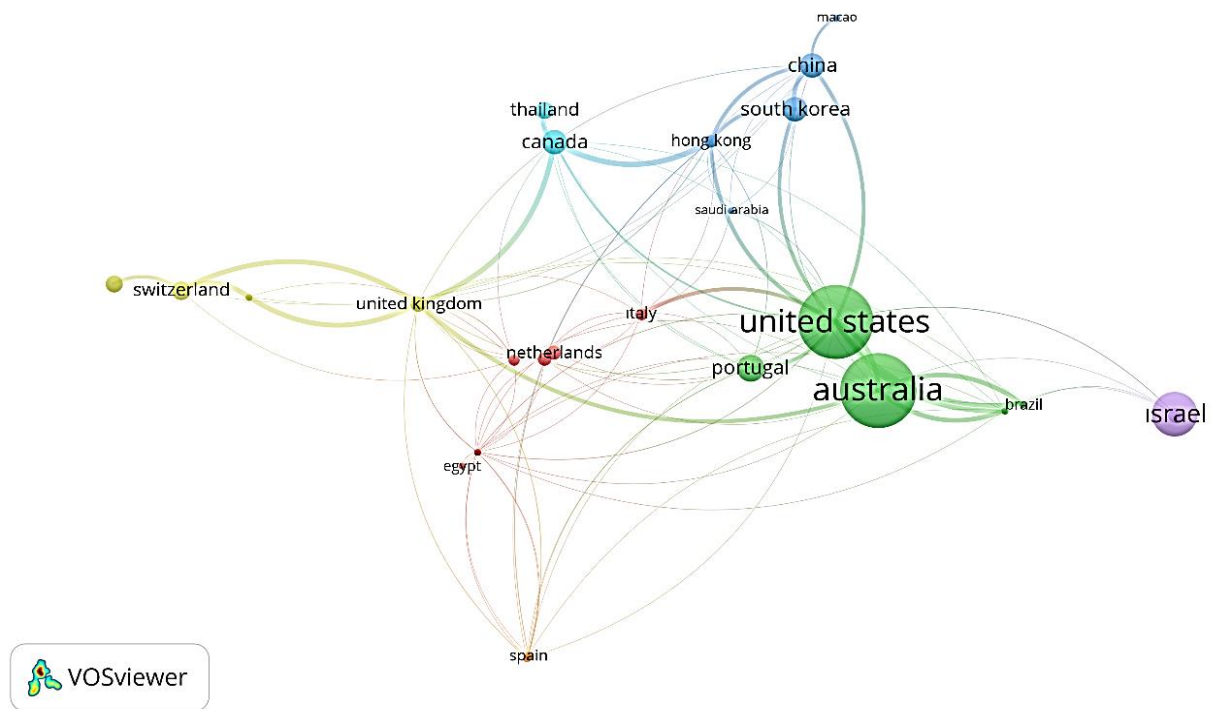**Figure 3.** Bibliographic Coupling of Countries

Figure 4. The network connection between citations and countries.

3.2. *Analysis of Authorship*

In this section, the most influential authors have been discussed. The collaborative authorship network is an exceptionally effective and practical analytical tool to assess and identify trends among co-authors, scientific collaborations, top institutions, countries, or individual researchers themselves [16]. In this section of the study, the

top contributors among researchers to the research topic have been examined, and the top ten are illustrated in Table 2. Research impact was calculated based on publication count, citation scores, and link strength. No authors have multiple publications in the research field, which reaffirms the need for collaborative efforts among experts in the subject area. According to the results obtained from the cluster network, the highest link strength (15) and a total

citation count of 20 belong to "Balali Vahid." The articles with the highest link strength and citation counts present various ideas and processes related to the use of VR in the field of architecture.

Among the authors, the total link strength of collaborative authorship connections defines a writer's relationship with other authors. In the network visualization shown in Figure 5, which includes 75 items, 43 authors with a single publication each are graphically represented as interconnected. These connections are color-grouped based on their relationship level among researchers. This allows for the evaluation of researchers' relationships with each other. Symbolically, the node sizes are directly proportional to the number of citations in the publications. The distance between nodes indicates the proximity relationships of studies. The colors of the nodes change based on the years.

Table 2. Publication and citation weights of the authors

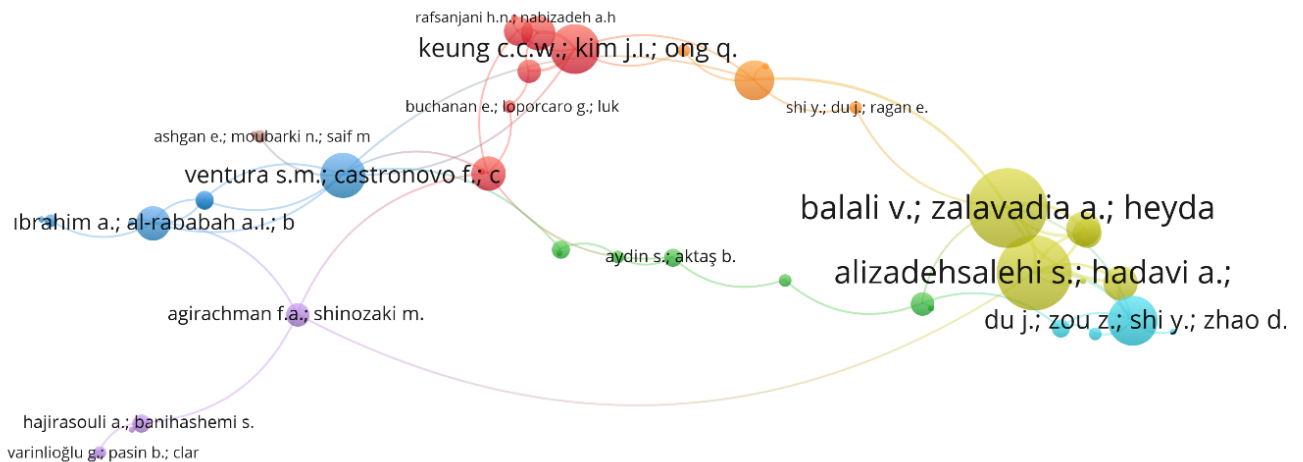| Author	Publication	Citation	Total Link Strength
Balali V.	1	20	15
Alizadehsalehi S.	1	181	14
Du J.	1	185	9
Keung CC	1	9	9
Venture SM	1	18	8
Dinis FM	1	31	7
Noghabaei M.	1	82	6
Khalili A.	1	20	5
Mobach M.P	1	35	3
Portman ME.	1	242	2
Gu N.	1	589	0

Figure 5. Author Total Connection Strengths Visual Map

3.3. Analysis of Organizations

The performance of institutions with publications related to VR within the scope of architecture and architectural design is represented by the bar graph in Figure 6. A total of 137 institutions have contributed to the research field. Only one publication is associated with each institution in the research domain. Deakin University and Newcastle University have the highest citations of nearly 57% in the relevant research (Figure 6). These universities are followed in terms of citation counts by the University of Texas, the University of Michigan, and the University of California.

Architecture departments are at the top of the list in the department analysis. The following are, respectively, project management and civil engineering. The list also includes the Department of Computers (Figure 7).

3.4. Citation by Sources

The relationship between publications in journals and citations is presented in the form of a network visualization in Figure 8. In the visual map, the sizes of nodes increase proportionally to the number of publications. Therefore, the more numerous the research studies conducted in the field, the larger the nodes become. The journal with the highest number of publications (8) and citations (1066) is

"Automation in Construction." The journal "Buildings" follows with three publications and six citations. The distribution of articles classified as VR usage in the field of architecture is mainly published in the journals listed in Table 3.

Automation in Construction Journal has more than 30% of article publications and about 80% of citations compared to the rest of the relevant journals.
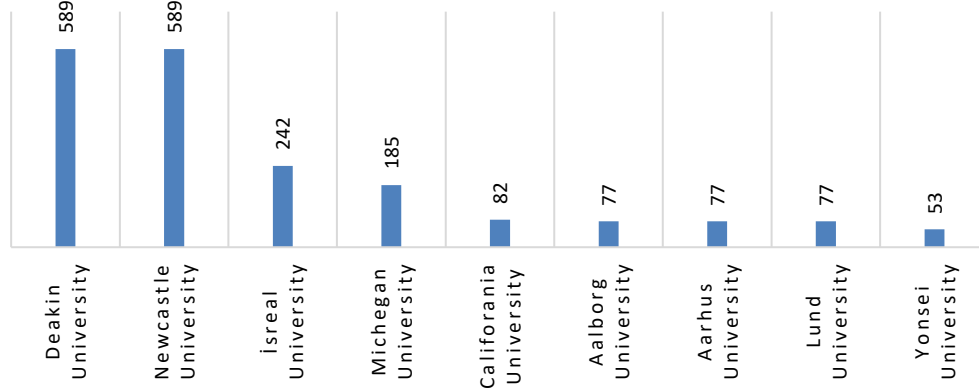

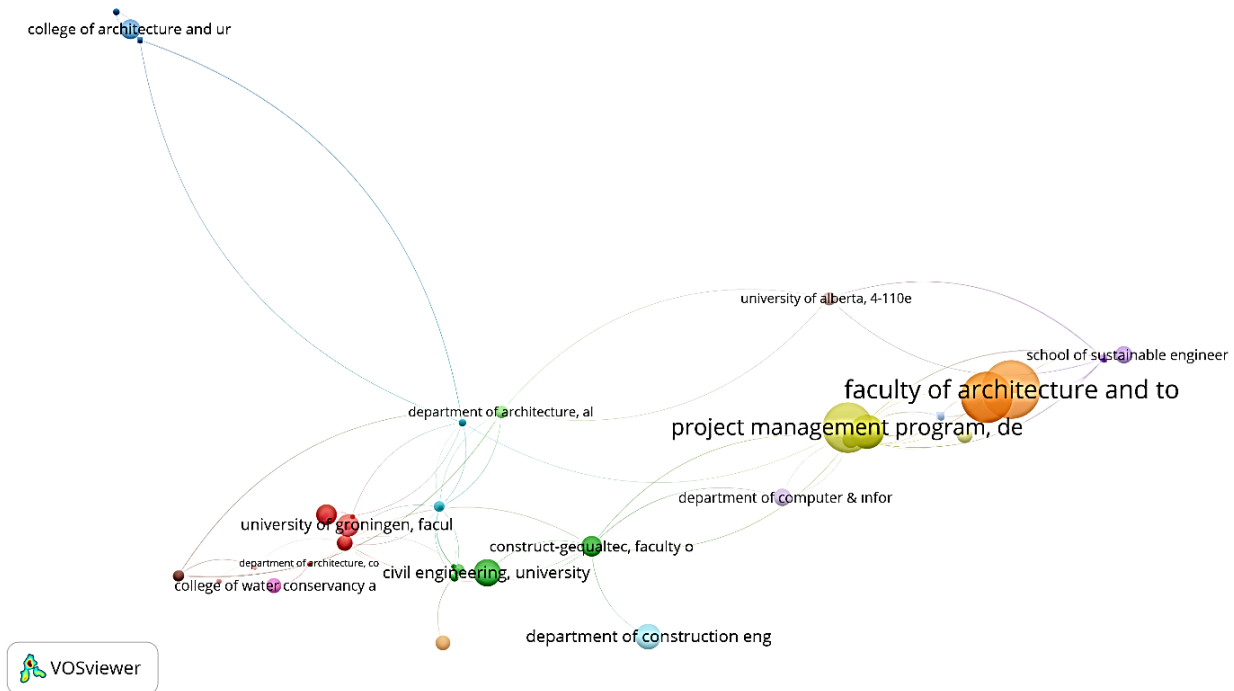**Figure 6.** Institutional publications in the field of Architecture and VR.

Figure 7. Visualization of organizations' citation network.

Table 3. Publication, citation, and total link strength in journals

Journal	Documents	Citation	Total Link Strength
Automation in Construction	8	1066	19
Buildings	3	6	11
Journal of construction engineering and management	2	20	16
Applied Sciences (Switzerland)	2	9	9
Open House International	2	2	6
A|Z ITU Journal of Faculty of Architecture	2	3	3
Journal of Architectural Engineering	2	40	2
Journal of Computational Design and Engineering	2	43	2
Journal of Information Technology in Construction	1	18	8
Journal of Building Engineering	1	31	7
Data	1	82	6

3.7. Co-occurrence of Keywords

In this phase of the study, an analysis of keywords has been conducted. The graphical representation of this analysis is provided in Figure 9. Keywords generally reflect the trajectories of publications in the research domain. Therefore, analyzing the keywords in research studies allows for a more comprehensive perspective on the datasets obtained for the studies [29]. Through keywords, access to information beneath the surface knowledge is enabled, facilitating the tracking and interpretation of transformation stages in the research field. Therefore, the bibliometric analysis of datasets composed of keywords has been conducted to identify trends in the study. In the analyzed keywords, words repeated at least twice were

selected. As a result, 36 keywords were obtained. The most preferred keywords are "virtual reality," " Building Information Modeling (BIM)," and "architectural design." Analyzing these keywords can help researchers explore different themes within the research area for possible future studies.

When examining the changes in keywords over the years within the scope of the research topic, as presented in Figure 9, it is possible to access current research areas. In recent years, it can be observed that this research field has entered the realm of architectural education. Particularly in recent years, the inclusion of VR studies in architectural design studios can be noted.
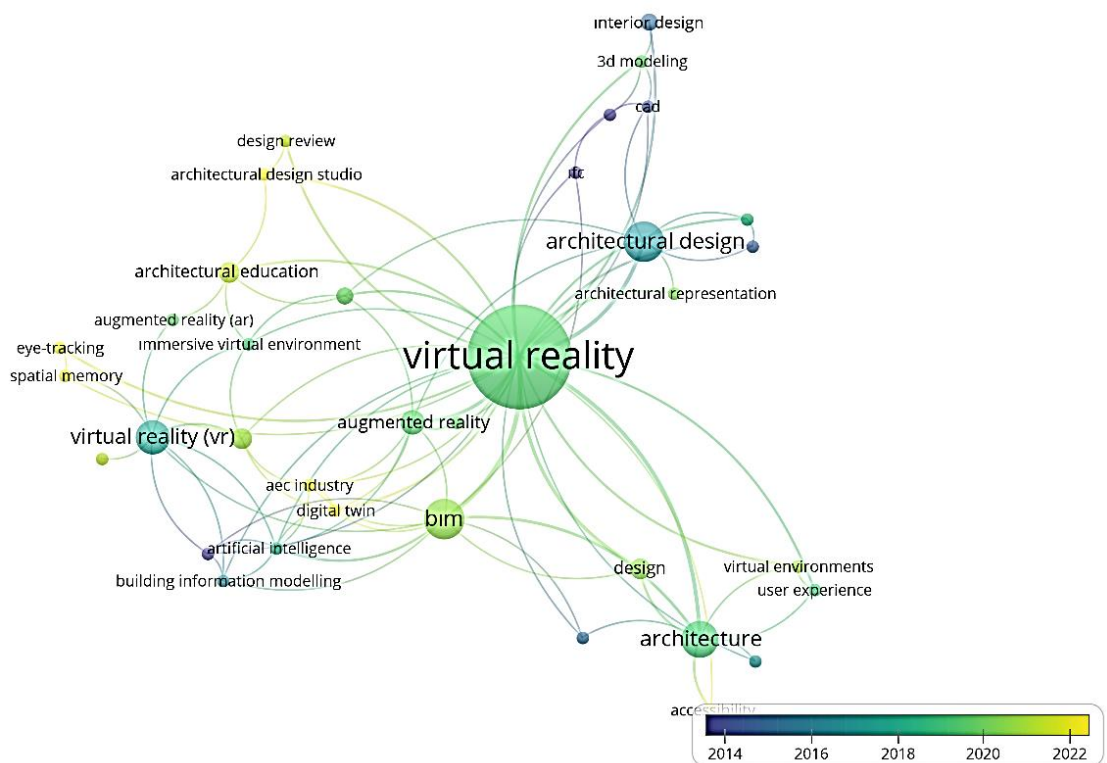

Figure 9. Co-occurrence of keywords

4. Conclusions

The rising usage of Virtual Reality (VR) in architecture is an intriguing topic among students, academics, and practitioners. The increasing number of recent studies indicates the potential research areas in this field. Various institutions are contributing to this field, particularly with the advancement of technology and the widespread adoption of VR devices. Analysis of the Scopus database has shown a notable increase in publications on this topic in recent years. On a country basis, it is observed that the United States, China, and the United Kingdom have a significant impact in this area. Universities in the United States appear to be more active in VR-related research. According to the results, the USA and China are tied for first place with 13 publications in the VR field, followed by the UK and Australia with eight publications each, where

Australia is at the top of the citation list with a total of 591 citations. This suggests that countries with easier access to technology are more active in this field. However, countries and institutions in different geographical locations still have not yet conducted research in this area. Based on these findings, it is clear that more research is needed. In recent years, VR usage in architecture has become education-oriented. It has made its way into architectural studios and is contributing to education. The proliferation of building information systems has positively influenced VR usage. It is effectively used in architectural presentations and has brought changes in expression techniques.

The study offers insightful information about the uses of virtual reality (VR) in the field of architecture. There are, however, a few drawbacks to be aware of. First, the Scopus database-only articles are the only ones included in the

bibliometric study, potentially leaving out research from other sources that could be pertinent. Second, the analysis's time period (2004 to 2023) may not have considered the most recent advancements in VR technology and their effects on design. Furthermore, the emphasis on particular terms, authors, and nations could generate a bias in selection, perhaps excluding significant contributions in adjacent fields. Additionally, although the study recognizes a growth in the use of virtual reality (VR) in BIM and architecture education, the study only briefly explores these developments and their consequences. Despite these drawbacks, the study highlights the shortcomings of VR research in the field of architecture and highlights the necessity for more thorough investigations to fully explore the range and potential of VR applications in architectural improvements.

Nevertheless, there are challenges in the usage of VR systems in architecture. The technology is still in its early stages, and full integration with architecture has not been established, which might hinder its full potential realization. In conclusion, the rising usage of VR systems in architecture brings advantages and challenges. More work is needed to realize the full potential of this technology. Students, academics, and practitioners can work together to test the existing technology and find more efficient and creative ways of utilizing it. In doing so, necessary steps can be taken toward the sustainable and effective utilization of VR systems in architecture.

We may expect virtual reality to play a crucial role in architecture education in the upcoming years. Imagine pupils entering virtual recreations of historical sites, taking in the magnificence of old buildings, and learning about the intricate details of their construction. Through a dynamic and engaging teaching method, experiential learning, students develop a profound understanding of architectural history. It's obvious that the development of virtual reality and architecture are connected as we stand at the beginning of this disruptive age. Architecture is ready to be changed by creativity that knows no boundaries thanks to virtual site visits, AI-driven design simulations, and an increasingly accessible technology landscape. The democratization of VR ushers in an era of inclusion, opening the once-exclusive field of architectural design to a wider range of abilities and voices and enhancing it in previously unthinkable ways. Using VR and Augmented Reality (AR) together might provide architects with a deeper knowledge of spatial interactions. To improve both design and presentation characteristics, research may explore how various technologies can combine to overlay digital information over real-world environments. To improve user experience in virtual architectural environments, further research is required. In order to guarantee that VR fits easily into the design workflow, research can concentrate on improving interaction techniques, easy navigation, and user-friendly interfaces. A potential direction is looking at how VR may help with sustainable design. Architecture may be more ecologically conscientious if VR was used to model environmental conditions, energy use, and lighting optimization. The study of collaborative VR platforms might transform cooperation in architecture. Within the same VR environment, architects from various places might collaborate concurrently, promoting dynamic brainstorming, design debates, and decision-making. In conclusion, there are many opportunities for VR to have an influence on architectural design, building information modeling, and architectural education in the future. These study directions have the potential to improve architectural education, practice, and the built environment as a whole.

Conflict of Interest Statement

The authors declare no conflict of interest.

References

[1] N.-C. Tai, Applications of augmented reality and virtual reality on computer-assisted teaching for analytical sketching of architectural scene and construction, Journal of Asian Architecture and Building Engineering 22(3) (2023) 1664–1681.

[2] F.D. Ching, Architectural graphics, John Wiley & Sons2015.

[3] D.D. Hoffman, Visual intelligence: How we create what we see, WW Norton & Company2000.

[4] J. Wann, M. Mon-Williams, What does virtual reality NEED?: human factors issues in the design of three-dimensional computer environments, International Journal of Human-Computer Studies 44(6) (1996) 829–847.

[5] B.S. Qurraie, Smart Window Design Tool: Daylight Transmission by Using Transparent Color Filters, Computational Research Progress in Applied Science & Engineering 08(01) (2022).

[6] M.B.T. Carreiro, P.d.L. Pinto, The evolution of representation in architecture, Future Traditions. 1st eCAADe Regional International Workshop Proceedings, Association for Education and research in Computer Aided Architectural …, 2013.

[7] F. Castronovo, D. Oprean, Y. Liu, J. Messner, Application of immersive virtual reality systems in an interdisciplinary design studio course, Lean and Computing in Construction Congress (LC3): Volume I Proceedings of the Joint Conference on Computing in Construction (JC3), Heriot-Watt University, UK (2017) 337–345.

[8] B.S. Qurraie, B. Arslan, Investigation of Thermal and Energy Performance of Double Skin Facades in Hot Climate Regions in Turkey, Computational Research Progress in Applied Science & Engineering 08(03) (2022).

[9] W.R. Sherman, A.B. Craig, Understanding virtual reality: Interface, application, and design, Morgan Kaufmann2018.

[10] D. Paes, J. Irizarry, M. Billinghurst, D. Pujoni, Investigating the relationship between three-dimensional perception and presence in virtual reality-reconstructed architecture, Applied Ergonomics 109 (2023) 103953.

[11] Q. He, G. Wang, L. Luo, Q. Shi, J. Xie, X. Meng, Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis, International journal of project management 35(4) (2017) 670–685.

[12] B. Glaser, A. Strauss, The Discovery of Grounded Theory: Strategies for Qualitative Research.,[e-book] Aldine de Gruyter, 1967.

[13] A. Yıldırım, Nitel araştırma yöntemlerinin temel özellikleri ve eğitim araştırmalarındaki yeri ve önemi, Eğitim ve Bilim 23(112) (1999).

[14] M. Oraee, M.R. Hosseini, E. Papadonikolaki, R. Palliyaguru, M. Arashpour, Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review, International Journal of Project Management 35(7) (2017) 1288–1301.

[15] F.H. Arfa, H. Zijlstra, B. Lubelli, W. Quist, Adaptive reuse of heritage buildings: From a literature review to a model of

practice, The Historic Environment: Policy & Practice 13(2) (2022) 148–170.

[16] A. Babalola, S. Musa, M.T. Akinlolu, T.C. Haupt, A bibliometric review of advances in building information modeling (BIM) research, Journal of Engineering, Design and Technology 21(3) (2021) 690–710.

[17] N. Varshabi, S. Arslan Selçuk, G. Mutlu Avinç, Biomimicry for energy-efficient building design: A bibliometric analysis, Biomimetics 7(1) (2022) 21.

[18] M.J. Cobo, A.G. López-Herrera, E. Herrera-Viedma, F. Herrera, Science mapping software tools: Review, analysis, and cooperative study among tools, Journal of the American Society for information Science and Technology 62(7) (2011) 1382–1402.

[19] C. Vigneshkumar, U.R. Salve, A scientometric analysis and review of fall from height research in construction, Construction Economics and Building 20(1) (2020) 17–35.

[20] C. Camarasa, C. Nägeli, Y. Ostermeyer, M. Klippel, S. Botzler, Diffusion of energy efficiency technologies in European residential buildings: A bibliometric analysis, Energy and Buildings 202 (2019) 109339.

[21] N.J. Van Eck, L. Waltman, Measuring scholarly impact, measuring scholarly impact: methods and practice (2014) 285–320.

[22] M. Kamran, H.U. Khan, W. Nisar, M. Farooq, S.-U. Rehman, Blockchain and Internet of Things: A bibliometric study, Computers & Electrical Engineering 81 (2020) 106525.

[23] Y.-M. Guo, Z.-L. Huang, J. Guo, X.-R. Guo, H. Li, M.-Y. Liu, S. Ezzeddine, M.J. Nkeli, A bibliometric analysis and visualization of blockchain, Future Generation Computer Systems 116 (2021) 316–332. https://doi.org/https://doi.org/10.1016/j.future.2020.10.023.

[24] M.R. Hosseini, I. Martek, E.K. Zavadskas, A.A. Aibinu, M. Arashpour, N. Chileshe, Critical evaluation of off-site construction research: A Scientometric analysis, Automation in construction 87 (2018) 235–247.

[25] A. Darko, A.P. Chan, X. Huo, D.-G. Owusu-Manu, A scientometric analysis and visualization of global green building research, Building and Environment 149 (2019) 501-511.

[26] E. Ohene, A.P.C. Chan, A. Darko, Review of global research advances towards net-zero emissions buildings, Energy and Buildings 266 (2022) 112142. https://doi.org/https://doi.org/10.1016/j.enbuild.2022.112142.

[27] N. Van Eck, L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping, scientometrics 84(2) (2010) 523–538.

[28] S.-P. Jun, H.S. Yoo, S. Choi, Ten years of research change using Google Trends: From the perspective of big data utilizations and applications, Technological forecasting and social change 130 (2018) 69–87.

[29] M. Özdemir, S. Arslan Selçuk, Mimarlıkta Makine Öğrenmesi: Bibliyometrik Bir Analiz, Online Journal of Art & Design 9(4) (2021).