A BIBLIOMETRIC ANALYSIS OF THE METAVERSE FUTURE: UNDERSTANDING THE STATE OF RESEARCH ON AUGMENTED AND VIRTUAL REALITY

Dr. Amit Verma
Senior Assistant Professor and Course Coordinator,
Journalism & Mass Communication, Directorate of Online Education, Manipal University Jaipur, India.
Email id: amitve4@gmail.com Orchid id: 0000-0001-8690-0285

Dr. Abhishika Sharma
Associate Professor and Program Coordinator,
Journalism & Mass Communication, Directorate of Online Education, Manipal University Jaipur, India
Email id: abhishikajoshi@gmail.com Orchid id: 0000-0001-8319-7061

ABSTRACT

The metaverse, a term coined to describe the augmented and virtual reality future, is a rapidly evolving field with significant potential for impact on various industries. This research aims to summarise the current evidence on the metaverse future by conducting a bibliometric analysis of available literature on this topic. The analysis includes 166 articles published between 2006 and 2023 years, in reputable journals within the field. The results show that the most frequently studied topics within the metaverse future are VR, AR, and blockchain technology. Many articles also focus on virtual reality, augmented reality, virtual environment, blockchain, etc. The analysis also revealed that China, the USA, and South Korea are the field's most productive countries/institutions. Research shows that the metaverse future is a rapidly growing field with diverse research areas and a growing number of active researchers. This bibliometric analysis provides a comprehensive understanding of the field's current state and highlights areas that require further research.

Keywords: *Bibliometric analysis, Metaverse, Virtual Reality, Augmented Reality, Future and Literature review.*

1.0 Introduction

The concept of a metaverse, or a virtual world that seamlessly integrated virtual reality (VR) and augmented reality (AR), has been a topic of interest for many years. Neal Stephenson first used the word "metaverse" to describe a simulated world's successor to the internet in the 1992 sci-fi story Snow Crash, wherein users can engage with others and a virtual environment in real-time (Stephenson, 1992). Since then, the idea of a metaverse has evolved to encompass virtual worlds and a wide range of VR and AR applications across various industries. Recent technological advancements, such as the development of VR and AR headsets and the increase in computing power, have made it possible for the metaverse to become a reality. According to a report by Goldman Sachs (2022), the metaverse market is expected to touch 1T USD by 2030, with VR and AR applications in areas such as entertainment, education, and commerce driving the growth.

In recent years, the metaverse has been the focus of research in various fields, such as computer science, communication, and design (Xu et al., 2019; Wang et al., 2020; Riva et al., 2016). The metaverse is a virtual reality-based successor to the internet and is considered the next step in human-computer interaction (Xu et al., 2019). The metaverse is a term that encompasses a wide range of VR and AR applications across various industries, including entertainment, education, and commerce (Goldman Sachs, 2022). The metaverse is expected to become a reality shortly, and it is expected to have a significant impact on various industries (Xu et al., 2019). In computer science, research on metaverse has emphasized technical aspects of creating a metaverse, such as developing VR and AR technologies and designing virtual worlds (Xu et al., 2019). In the field of communication, research on the metaverse has emphasized socio-communication aspects, such as the design of virtual environments for communication and collaboration (Wang et al., 2020). In the field of design, research on the metaverse has emphasized the design of virtual worlds and the user experience (Riva et al., 2016).

The metaverse future has significant potential to impact various industries, and research on this topic has been overgrowing in recent years.

However, a full appraisal of where the area of research is at the moment is still being determined. This research aims to summarise the current evidence on the metaverse future by conducting a bibliometric analysis of available literature on this topic. This method allows us to identify the most frequently studied topics, the most productive countries/institutions, and the most cited articles within the field.

1.1 Method

The bibliometric analysis method was used to understand the current state of research on the metaverse future. Bibliometric assessment is an approach to analyzing & interpreting bibliographic data, such as publication records, to identify patterns and trends in the literature (Moed, 2005). This method was chosen because it allows us to identify the most frequently studied topics, the most productive countries/institutions, and the most cited articles.

The bibliometric analysis was conducted using the Scopus database (Elsevier, 2021), a widely used database for bibliometric studies (Wang et al., 2020; Moed, 2005). The search was conducted using the keywords "metaverse" AND "future" AND "virtual reality" OR "augmented reality," and the search was limited to articles published between 2006 and 2023 years. The search resulted in a total of 166 articles included in the analysis.

The bibliometric analysis was conducted using the Biblioshiny software, which is a widely used software for bibliometric studies. The software was used to create visualizations, such as co-word maps, to show the relationships between keywords and phrases used in the articles. The software was also used to find nations/institutions which were most productive and the most cited articles.

In order to identify the most frequently studied topics within the metaverse future, a keyword analysis was conducted. The keyword analysis was based on the articles' abstracts and titles, and the keywords were extracted using the Biblioshiny. The keywords were then grouped into different topics, and the frequency of the different topics was calculated. In order to find nations/institutions which within this domain of research, a productivity analysis was conducted. The productivity analysis was based on the affiliation of the article's authors, and the number of publications per country/institution was calculated.

In order to identify the most cited articles within the field, a citation analysis was conducted. The citation analysis was based on the number of citations of the articles. Articles were ranked based on the number of citations (Moed, 2005). The citation analysis results provide insight into the articles that have been most influential within the field of metaverse future research. Overall, the study methodology is designed to provide a comprehensive understanding of the current state of research on the metaverse future. Using a well-established database and software for bibliometric analysis, along with a thorough search strategy that includes specific keywords and a limited time frame, this study aims to identify the key research areas, productive countries/institutions, and influential articles within the field of metaverse future.

Here is a PRISMA diagram explaining the search methodology we used.

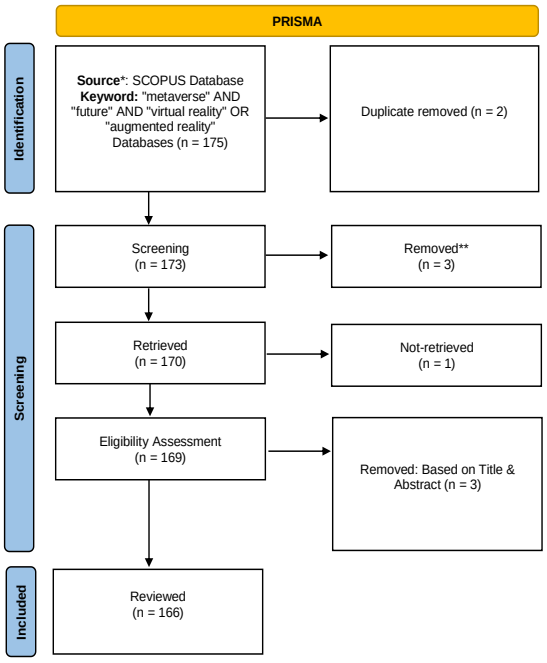

Figure 1: PRISMA for search & selection of articles for bibliometric analysis

1.2 Results

1.2.1 Analysis of Document Type

This table presents an analysis of different types of documents, with the number of each type represented in the "N" column. The table lists the following types of documents: articles (45%), papers presented at the conference (35%), reviewed articles (13%), chapters of the book (3%), reviewed papers presented at a conference (2%), editorials (1%) & short survey (1%).

Table 1: Analysis of Document Type

Document Type	N	%
Article	75	45%
Conference Paper	58	35%
Review	21	13%
Book Chapter	5	3%
Conference Review	4	2%
Editorial	2	1%
Short Survey	1	1%

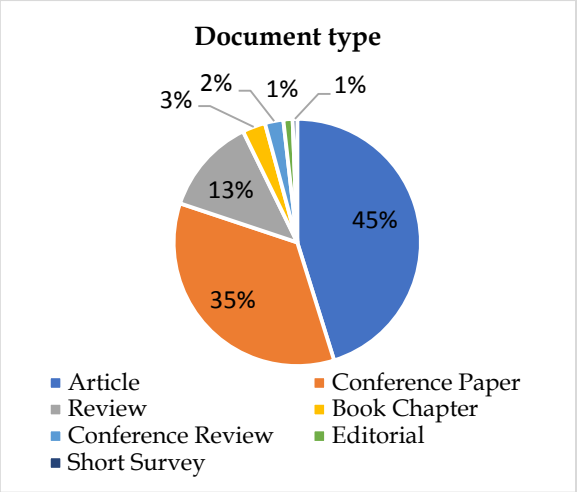

Fig 2: Analysis of Document Type

1.2.2 Annual Document Distribution

Fig 3 reveals that more than 90% of documents were published from 2020 to 2023. Until 2019 from 2006, the trend of a document published on the research theme was more or less similar; especially in the year 2022, the number of documents published drastically increased.

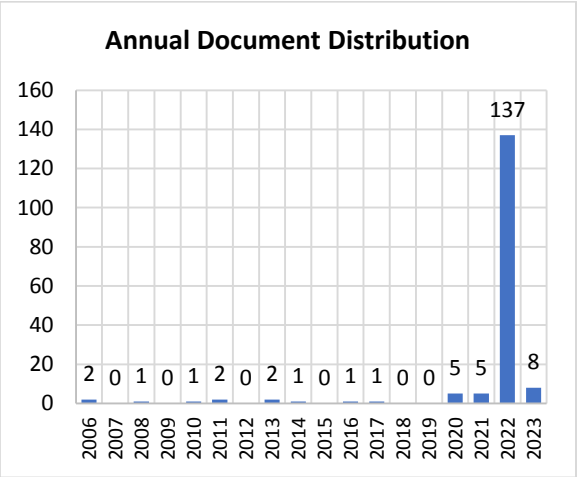

Fig 3: Annual Document Distribution

1.2.3 Top 10 Reliable Sources

Fig. 4 portrays the top ten sources that have published the research theme's documents. Series of conference proceeding Lecture Notes in Computer Science has published most documents (n=11) than any other journal. IEEE Access, ACM International Conference Proceedings, and Applied Sciences have achieved the rank second.

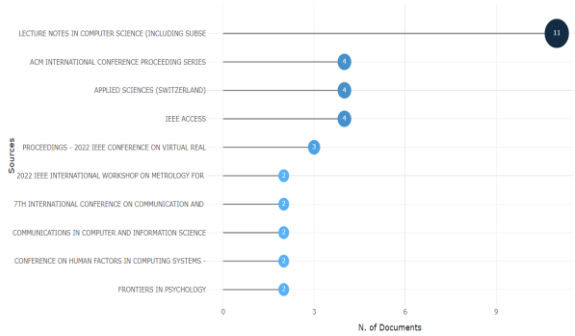

Fig 4: Top 10 Reliable source

1.2.3 Top 10 cited documents

By analysing the most widely referenced works, it would be easier to determine which papers are widely considered to be the most influential regarding their relevance, usefulness, and overall quality within the research community. Fig. 5 portrays the top ten sources that have published the research theme's documents. Dionisio et al. (2013)'s "3D virtual worlds and the metaverse: Current status and future possibilities" is the most cited document (166). Followed by Dwivedi et al. (2022)'s "Metaverse marketing: How the metaverse will shape the future of consumer research and practice" (41).

Fig 5: Top 10 cited documents

1.2.4 Country-wise document production

To a certain level, a nation's influence, and prominence in the study of the metaverse, AR, and VR can be evaluated by its publishing rate in the subject. Fig. 6 reveals that China is the leading country in publishing documents regarding AR, VR, and metaverse. Till time China has published 155 documents accounting for more than 90% of documents published in this domain. The USA is in the second rank with 72 published documents to time. At the same time, India is ranked fifth after South Korea and Italy having 36 published documents in this research domain.

Both China & USA have been making significant progress in metaverse technology. China is continuously investing heavily in virtual reality and augmented reality technology and has seen the development of several large-scale metaverse platforms, such as the China Metaverse Alliance and the Metaverse International Forum (MIF). The China Metaverse Alliance, launched in 2019, is an NGO that aims to promote the development and use of metaverse technology in China. Similarly, the MIF, launched in 2020, is a global platform that brings together industry leaders and experts to discuss governance & development of the metaverse. The United States has also been actively involved in developing metaverse technology. Companies such as Facebook and Google have invested in VR and AR technology and developed metaverse platforms like Horizon and Google Earth.

Additionally, the US government has recognized the potential of metaverse technology and formed the Metaverse Task Force to explore the opportunities and challenges of the metaverse. However, it is worth noting that China has made more progress regarding regulations, policy, and infrastructure for metaverse technology. According to a report by South China Morning Post, the central government of China is set to launch a new set of regulations for metaverse platforms, which will cover areas such as data privacy, intellectual property rights, and anti-monopoly measures. It is a significant step forward in the regulation and governance of the metaverse in China, which could give Chinese metaverse platforms a competitive advantage over those in other countries (Kok, 2021).

India is also making progress in the field of metaverse technology. Indian companies are investing in virtual and augmented reality technology and developing their metaverse platforms. For example, an Indian company, Imaginate, has developed a metaverse platform called "Kira" that allows users to create and share virtual and augmented reality experiences. Similarly, an Indian company, GreyKernel, has developed a metaverse platform called "GreyAtom Metaverse" that allows users to create, explore and share virtual and augmented reality experiences. Additionally, the Indian government is also taking steps to promote the development of metaverse technology in the country. The government has announced the launch of a National Virtual and Augmented Reality Center (NVARC) to promote the development and use of virtual and augmented reality technology in India. The center will be responsible for conducting research and development in virtual and augmented reality technology and providing training and education in the field. However, India is still lagginehind needs to catch up to the United States in terms of investment and development of metaverse technology. According to a report by the Economic Times, India's investment in virtual and augmented reality technology is less than 1% of China's and the United States' investment in the field. Additionally, the Indian government's focus on 5G and AI technology diverts attention and resources from the development of metaverse technology (Economic Times, 2021).

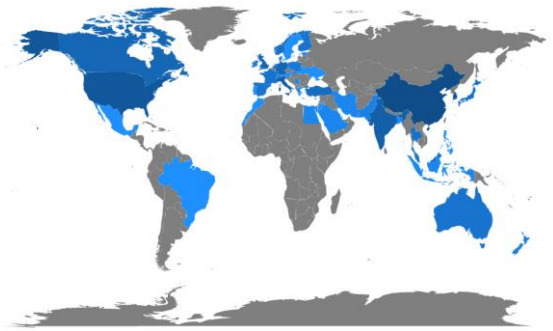

Fig 6: Top 10 Country wise document production

1.2.5 Nation-wise collaboration map

Fig. 7 shows cross-country collaboration. In this case, arcs between nodes suggest collaboration amongst nations. The stronger the connection between two nations, the more robust the collaborative partnership, and vice versa. The USA (47), China (40), and India (31) have the highest number of international collaborations. Findings also reveal that over time most collaboration was seen amongst USA & Germany (4), China & USA (4), China & Canada (4), and China & UK (4) in this particular research domain.

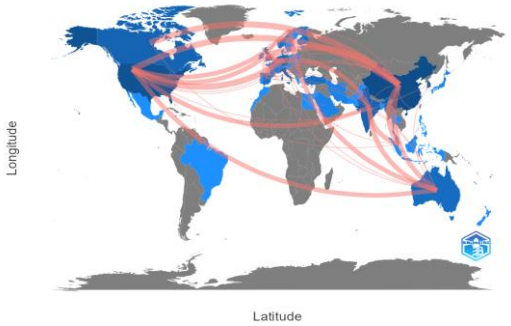

Fig 7: Nation-wise collaboration map

1.2.5 Top 10 Cited Authors

Fig. 8 shows the top 10 most cited authors. The following figure reveals that GIANG BARRERA K (26) and SHAH D (26) are the most cited authors in this research field of the metaverse, AR and VR. On the other side, table 2 reveals the productivity and impact of researchers or research groups by analyzing their publications, citations, and other metrics. From the table, it is evident that five researchers have an h-index of 2, meaning they have at least 2 publications that have been cited 2 or more times. All top 10 researchers started publishing in 2022, the most recent year of their first publication. The g-index and m-index indicate that the researchers are BUHALIS D and CHEN Y most productive than others. Over the years, BUHALIS D has published 3 documents, and his publications have been cited 47 times.

Table 2: Impact Analysis

Element	HI	GI	MI	Total No. of Citations	No. of Publications	1st year of publication
BUHALIS D	2	3	1	47	3	2022
CHEN Y	2	5	1	31	5	2022
FREEMAN G	2	2	1	4	2	2022
MALONEY D	2	2	1	4	2	2022
RAUSCHNABEL PA	2	3	1	74	3	2022
ABBASI S	1	1	0.5	4	1	2022
ABBATE S	1	1	0.5	1	1	2022
ABRASH M	1	1	0.333	3	1	2021
ACENA D	1	1	0.5	2	1	2022
AICH S	1	1	0.5	23	1	2022

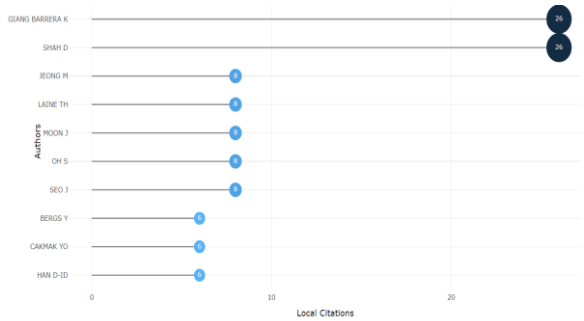

Fig 8: Top 10 Cited Authors

1.2.6 Spectroscopy of References

Figure 9 & table 3 illustrates the findings Spectroscopy of References. The red line represents the number of citations used in each publishing year from 2006 to 2023. Publication years with more citations than average is highlighted by a black line representing several citations in that year and the median citation count in 2 different years prior to that year, the current year, and two years after that.

The first peak can be observed in the year 2021 and references "MYSTAKIDIS S. METAVERSE (2022) ENCYCLOPEDIA 2 (1) PP. 486-497" and "PARK S.-M. KIM Y.-G. A METAVERSE: TAXONOMY COMPONENTS APPLICATIONS AND OPEN CHALLENGES (2022) IEEE ACCESS 10 PP. 4209-4251" are found to be cited for 7 times.

Table 3: Spectroscopy of References

Year	Citations	diffMedian5
2006	90	8
2007	128	43
2008	127	37
2009	161	34
2010	151	23
2011	208	57
2012	143	-8
2013	206	45
2014	220	14
2015	291	83
2016	311	91
2017	395	104
2018	521	210
2019	713	318
2020	915	394
2021	1322	609
2022	1164	249
2023	2	-913

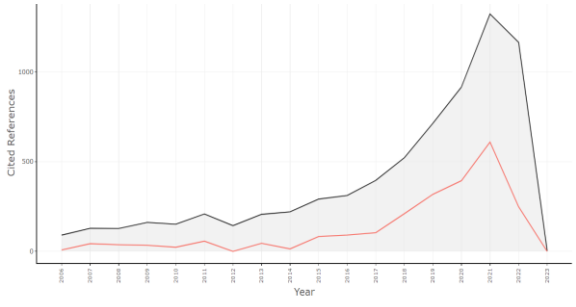

Fig 9: Spectroscopy of References

1.2.7 Network of Co-citation

Also, the network of authors who have worked together on articles about the metaverse, virtual reality, and augmented reality. Numerous researchers' names are shown in the diagram (Fig. 2) below; a few are related to one another, while others are not. Clusters of corresponding

colors and connecting lines among the writers' names visually represent their interconnectivity. Three clusters of authors were identified with the highest collaboration. The red represents the first cluster of authors and authors, namely stephenson n., mystakidis s. & park s.-m. had the highest co-citation. The color blue represents the second cluster of authors, namely flavián c. & Steuer j. had the highest co-citation. In contrast, the color green represents the third cluster of authors and authors, namely kim j., bourlakis m. & papagiannidis s. had the highest co-citation in this specific cluster.

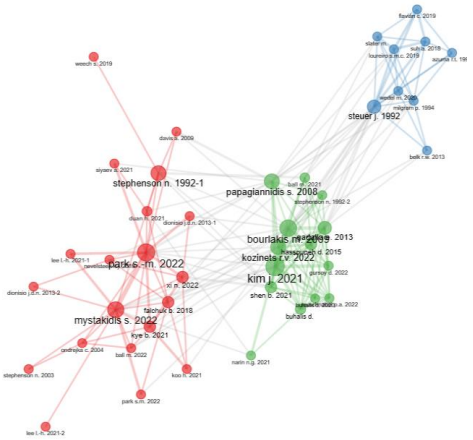

Fig 9: Network of Co-citation

1.2.8 3-filed plot

The following 3-field Plot (Fig. 10) consists of 3 layers: the published journal, journal name (on the left-hand side), author (in the middle), and thematic topic (right-hand side). A grey plot shows the interconnectedness of the three parts. Each magazine identifies the author who most frequently contributes to it, beginning with the name of the publication. Each author uses metaverse, augmented reality, and virtual reality to illustrate a topic they frequently investigate. Rectangle's vast size represents the vast number of citations for each factor.

The following diagram (Fig. 10) reveals that the 3-field plot includes four indexed journals that regularly publish papers on the topics of the metaverse, AR, and VR as the first element. “Lecture note in computer science," shown here by a brown rectangle containing multiple authors like Wang Y, Kim J, etc., is the leading journal that publishes the most articles on the topic. Proceed to the second image element in the center, labelled "author," in which names of multiple authors are connected to their respective archives of published works. The author's name will also be linked to the frequently utilized topic keywords on the picture's right. At the same time, ten of the world's leading field experts participated in this study. The greater the rectangle, the larger the no. of scholarly articles by that author. Wang Y and Buhalis D, represented by yellow and lemon grass green rectangles, are the writers who primarily publish metaverse themes in virtual and augmented reality.

The 3rd component, located in the upper right corner, explains the study's key thematic areas. All the themes are linked to prolific authors who have written extensively on relevant subjects. The image analysis yielded a list of 10 distinct keyword classifications. The phrases "metaverse" and "virtual reality" are most frequently highlighted with yellowish green and light tomato green rectangles. This exemplifies the robust relationship between the phrases metaverse and virtual reality, a prominent topic of study in this field.

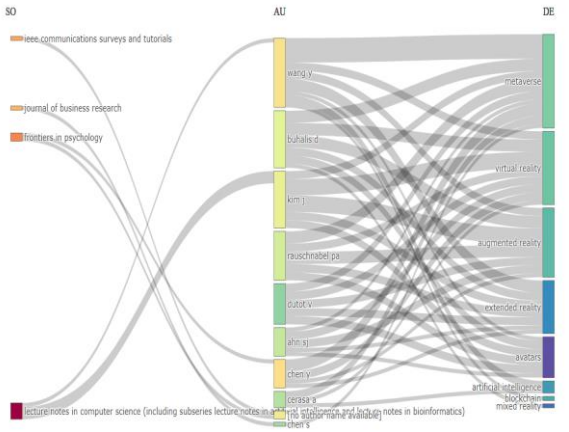

Fig. 10: 3-field Plot

1.2.9 Thematic diagram

The thematic diagram (Fig. 11) was also examined in this research, with outcomes broken down into four distinct quadrants depending on factors, including centrality & density. The algorithm used to get these findings were only semi-automatic; it involved looking at the titles of all citations involving the researched topic and adding essential keywords that were not the authors. In order to detect more nuanced differences in the outcomes.

The theme in the top right quadrant is highly dense and central, making it a vital area to explore and study. Unfortunately, no overarching themes were picked up in this section. VR, metaverse, AR, AI, and Extended reality are major points of interest in this section.

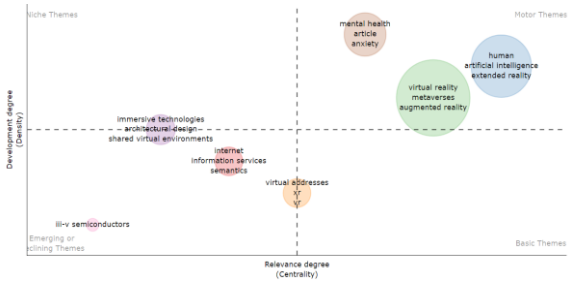

Fig. 11: Thematic Diagram

Also, architectural design shared virtual environment, virtual address, information service, and semantic themes were found in the bottom left corner, which contains topics that have been around for a while but are currently on the decline. However, such themes can only be found in the lower right quadrant with higher centrality but lower density.

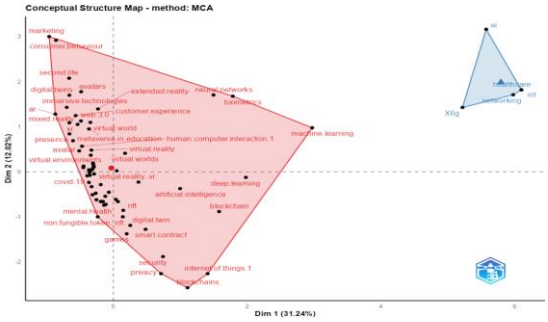

Fig. 12: MCA Diagram

1.2.10 Multiple Correspondence Analysis (MCA)

With the help of area mapping, this section will clarify the conceptual or contextual structural map of every keyword frequently appearing in published studies on the metaverse, augmented reality, and virtual reality. Words with similar values are mapped to one another based on their positions, determined by the values of Dim-1 & Dim-2. The data is split in two, with the red & blue sections containing semantically related sets of keywords. The red portion of the image depicts additional and different words like, Avatar, metaverse, blockchain, Augmented reality, Virtual reality, virtual environment, deep learning, AI, IoT etc. Therefore, it seems likely that numerous academic works draw connections between the terms found in the red area.

1.2.11 Keyword Correspondence Network

The Keyword Correspondence Network (Fig. 13) describes the frequently emerging terms in obtaining data from publications investigating the issue of metaverse future in various formats. The graphic below depicts a representation of various lengths based on the set of words that emerge. The diagram's arrangement is arbitrary; however, the dominant words are more noticeable due to their enormous size. Following network AI, blockchain, and IoTs, interactive computer graphics are interconnected with key thematic research areas, i.e., metaverse, augmented reality, and virtual reality.

VR & AR technologies are key components of the metaverse, allowing users to seamlessly blend the virtual and physical worlds (Wang & Biocca, 2020). Usually, blockchain technology is used to create decentralized versions of the metaverse, where users have more control over their data and can securely trade virtual assets (Willet, 2020). This is enabled by the decentralized ledger system, which allows for transparent, trust, and secure transactions of virtual assets within the metaverse. IoT & AI also play a major role in the development of the Metaverse (Smith, 2019). AI can be used to create more re alistic and interactive virtual environments.

In contrast, IoT can connect physical devices to the virtual world, enabling users to control them with their avatars. Using AI and IoT in the metaverse allows for more immersive and responsive virtual experiences. The metaverse is a complex and rapidly evolving ecosystem that draws on various technologies, including AR, VR, blockchain, AI, and IoT (Martinez, 2021). These technologies are interconnected and mutually dependent, each adding value to the others in creating a more realistic and immersive virtual shared space.

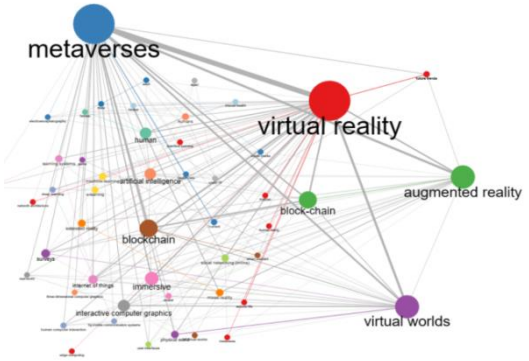

Fig. 13: Keyword Correspondence Network

Discussion

The metaverse is considered the next frontier in technology and has the potential to revolutionize the way we live and work. The metaverse concept is not new and has been discussed in science fiction literature and

movies for decades. However, with the rapid advancements in technology, particularly in the areas of VR concept of the metaverse concept reality. The metaverse has the potential to transform various industries, such as entertainment, education, healthcare, and retail, among others (Kawamoto, 2020). VR and AR technologies are critical components of the metaverse, allowing users to blend the virtual and physical worlds seamlessly. While augmented reality (AR) enriches the user's perspective of the physical universe by superimposing metadata on top of it, virtual reality (VR) puts the user into an entirely artificial environment (Liu, 2018). Combining VR and AR technologies will enable users to interact with the virtual world more naturally and intuitively, creating more immersive and engaging experiences (Zhang, 2019).

A bibliometric assessment of the Metaverse future was presented in this research, aimed at understanding the state of VR and AR research. The study was conducted by performing a comprehensive literature search of articles published between 2006 and 2023 in the Scopus database. A total of 175 articles were retrieved, of which 166 were considered relevant for the analysis. The articles were analyzed based on various bibliometric indicators such as authorship, publication year, thematic analysis, impact factor, etc.

The bibliometric analysis revealed that most articles were published in the last four years, with a peak in 2022. This indicated that the interest in the Metaverse and VR/AR research is proliferating. The increasing number of publications in the field of metaverse can be attributed to the advancements in the underlying technologies like VR and AR, as well as the possible utility of metaverse in multiple industry sectors. Furthermore, the analysis revealed that most articles published in the articles and conference proceeding journals, like Lecture Notes in Computer Science and IEEE Access, were most productive in this research field. This suggests that metaverse development is interdisciplinary and draws on various technologies (Patel et al., 2021). The authorship analysis showed that most of the articles were written by authors from China, followed by the USA and South Korea. This suggests that the Metaverse and VR/AR research is being conducted globally but with a concentration of research in certain countries. The journal impact factor analysis revealed that a significant number of the articles were published in high-impact journals, indicating that the research on the metaverse is of high quality.

Metaverse has a vast potential to revolutionize our lives and work, and VR and AR technologies are critical components of the metaverse. The bibliometric analysis revealed that the interest in VR and AR research is growing. Moreover, metaverse development is interdisciplinary and draws on a wide range of technologies. The Findings of this study unveiled that most research is being conducted in China, the USA, and South Korea and is of high quality. These findings provide valuable insights into the state of VR and AR research and can be used as a reference for further research in this field.

Reference

Abu-Salih, B. (2022). MetaOntology: Toward developing an ontology for the metaverse. *Frontiers in Big Data*, *5*. https://doi.org/10.3389/fdata.2022.998648

Angelini, L., Mecella, M., Liang, H.-N., Caon, M., Mugellini, E., Abou Khaled, O., & Bernardini, D. (2022). Towards an Emotionally Augmented Metaverse: A Framework for Recording and Analysing Physiological Data and User Behaviour. *ACM International Conference Proceeding Series*. https://doi.org/10.1145/ 3532530. 3532546

Benrimoh, D., Chheda, F. D., & Margolese, H. C. (2022). The Best Predictor of the Future—the Metaverse, Mental Health, and Lessons Learned From Current Technologies. *JMIR Mental Health*, *9*(10). https://doi.org/10.2196/40410

Dionisio, J. D. N., Burns Iii, W. G., & Gilbert, R. (2013). 3D virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys*, *45*(3). https://doi.org/10.1145/2480741.2480751

Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., Dennehy, D., Metri, B., Buhalis, D., Cheung, C. M. K., Conboy, K., Doyle, R., Dubey, R., Dutot, V., Felix, R., Goyal, D. P., Gustafsson, A., Hinsch, C., Jebabli, I., … Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, *66*. https://doi.org/10.1016/j.ijinfomgt.2022.102542

Dwivedi, Y. K., Hughes, L., Wang, Y., Alalwan, A. A., Ahn, S. J., Balakrishnan, J., Barta, S., Belk, R., Buhalis, D., Dutot, V., Felix, R., Filieri, R., Flavián, C., Gustafsson, A., Hinsch, C., Hollensen, S., Jain, V., Kim, J., Krishen, A. S., … Wirtz, J. (2022). Metaverse marketing: How the metaverse will shape the future of consumer research and practice. *Psychology and Marketing*. https://doi.org/10.1002/mar.21767

Economic Times. (2021). India's virtual reality market to reach $1.5 billion by 2023, but it's still lagging behind China and the US. The Economic Times. Retrieved from https://economictimes.indiatimes.com/tech/technology/indias-virtual-reality-market-to-reach-1-5-billion-by-2023-but-its-still-lagging-behind-china-and-the-us/articleshow/79361117.cms

Goldman Sachs. (2022). The metaverse. Retrieved from https://www.goldmansachs.com/insights/pages/technology-driving-innovation-folder/the-metaverse/

Kok, S. (2021). China's central government to launch new regulations for metaverse platforms. South China Morning Post. Retrieved from https://www.scmp.com/tech/big-tech/article/3128991/chinas-central-government-launch-new-regulations-metaverse

Lu, M., & Zheng, Y. (2022). Future Experience Boundary and Interaction Design Integration Path. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *13311 LNCS*, 70–80. https://doi.org/10.1007/978-3-031-06038-0_5

Martinez, J.D. (2021). The Interconnectedness of Technologies in the Metaverse.

Moed, H. F. (2005). Citation analysis in research evaluation. Springer.

Pregowska, A., Osial, M., Dolega-Dolegowski, D., Kolecki, R., & Proniewska, K. (2022). Information and Communication Technologies Combined with Mixed Reality as Supporting Tools in Medical Education. *Electronics (Switzerland)*, *11*(22). https://doi.org/10.3390/electronics11223778

Riva, G., Waterworth, J. A., & Waterworth, E. A. (2016). The metaverse as a new frontier for user experience design. *International Journal of Human-Computer Studies*, pp. 85, 1–15.

Smith, A.K. (2019). The role of AI and IoT in the metaverse.

Stephenson, N. (1992). Snow Crash. Bantam Books.

Stopher, B., & Revell, T. (2022). Speculations on the Future Design School Structure. In *Introduction to Design Education: Theory, Research, and Practical Applications for Educators*. Taylor and Francis. https://doi.org/10.4324/9781003049166-9

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523-538.

Wallace, M. (2006). Virtual worlds, virtual lives. *PC World (San Francisco, CA)*, *24*(11), 133–136. https://www.scopus.com/inward/record.uri?eid=2-s2.0-33750551484&partnerID=40&md5=fbc08e8b2d59ea37bbbfd49f23c16f57

Wang, X., & Biocca, F. (2020). Augmented reality and virtual reality in the metaverse. *Communications of the ACM*, 63(12), 34-39.

Wang, X., Chen, Y., & Wang, X. (2020). A bibliometric analysis of research on virtual reality in communication. *Journal of Computer-Mediated Communication*, 25(6), 473-496.

Wang, Y., Siau, K. L., & Wang, L. (2022). Metaverse and Human-Computer Interaction: A Technology Framework for 3D Virtual Worlds. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *13518 LNCS*, 213–221. https://doi.org/10.1007/978-3-031-21707-4_16

Willet, J. R. (2020). Building the metaverse on blockchain.

Xu, Y., Wang, X., & Wang, X. (2019). A bibliometric analysis of research on the metaverse. *Journal of Computer-Mediated Communication*, 24(6), 456-476.

***