An analysis of the current status of metaverse research based on bibliometrics

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Abstract

Purpose – The rise of the metaverse has brought profound changes to the economic and social operation models and injected new vitality into academic research. Although a large number of studies have emerged, there are few quantitative analyses of development frontiers and trends.

Design/methodology/approach – From a bibliometric perspective, this paper selects 183 pieces of metaverse-related literature in the WoS core database since 2000 as the object of analysis. This paper sums up the characteristics of the literature using the methods of descriptive statistical analysis, keywords analysis, thematic evolution analysis and summarizes the core themes and the laws of metaverse development in each stage.

Findings – The digital economy vision brought by the metaverse has led to an increasing number of researchers and achievements in this field. But the depth and breadth of research are still insufficient and unevenly distributed in the region, and the cross-fertilization fields need to be expanded. From the industry's point of view, VR games represented by Second Life and My World have contributed to the popularity of the metaverse. As technology progresses, the research hotspots in the field of metaverse gradually develop from conceptual research to artificial intelligence, blockchain, NFT and other technical applications. However, academic research has not yet caught up with the industry's pace and stays more in the concept discussion and preliminary application stage.

Originality/value – A systematic overview of the current status, knowledge structure and hot issues of metaverse research is shown, which provides a thematic axis for this field, enriches and improves the quantitative analysis of its literature and provides a clear picture for researchers to continuously promote the development of this field. At the same time, it is necessary to warn that technological development is a double-edged sword. The process of metaverse development should return to rationality, respect the laws of its development and guarantee the healthy development of the metaverse by strengthening legal regulation and the ethical review of science and technology.

Keywords Metaverse, Virtual world, Bibliometrics, Knowledge graph, Theme evolution, Research status

Paper type Research paper

1. Introduction

In March 2021, the sandbox game Roblox—the first stock in the metaverse, was successfully launched, and Chinese gaming company Tencent also committed to developing products related to the metaverse. In July of the same year, Zuckerberg said that Facebook would transform itself into a metaverse company within five years and renamed the parent company "Meta" (short for Metaverse). Is this series of moves by Facebook simply to attract attention (Smith and Brooks, 2022), or is it a reflection of the shift to the virtual for social and work, offering new opportunities for learning and working (Kraus *et al.*, 2022)? These developments all suggest that the metaverse is an

important driver of contemporary technology, but they do not tell us what the metaverse is (Fernandez, 2022), as we will discuss in later sections of the article. Whatever the answer, the world's largest social network, Facebook's pioneering placement of the metaverse has accelerated the influx of Internet companies into the metaverse space. At the same time, with the entry of a large amount of capital, the public and academic circles are paying more and more attention to this concept. The Baidu search index for the topic of the metaverse in China has continued to climb since August 2021 and reached a peak of 126,575 in December 2021; for example, in June 2022, the number of academic papers related to the topic of "metaverse" at CNKI exceeded 1,000.

At present, metaverse research is mostly concentrated in the fields of computer software and applications, automation and other scientific and technological fields (Matsubara and Oguchi, 2010), some scholars have also focused on the integration of the metaverse with traditional fields such as journalism and media, library and intelligence, environmental science and education (Kim *et al.*, 2022; Ma, 2022; Rillig *et al.*, 2022). While the metaverse literature is growing and the research hotspots are changing, there is still a paucity of literature analyzing the current state of research in the field of the metaverse, and there is a lack of work to comb through the studies that have been done. To grasp the current development of the field of the metaverse and its evolution trends, this paper selects the existing literature on the Web of Science for analysis and visualizes the thematic evolutionary paths and frontier hotspots of the field by summarizing the characteristics of existing research results in the field of the metaverse to provide insights for the long-term development of metaverse. To help scholars further understand the nature and development of the metaverse, the research questions to be solved in this paper are as follows:

RQ1. Since the concept of metaverse was proposed, what are the characteristics of the results in the field of metaverse?

RQ2. What are the prospects for the metaverse concept itself and its technological achievements in other fields of application?

RQ3. How have the research hotspots in the field of metaverse changed since 2000, and what are the implications for future research?

2. Overview of metaverse

So far, many scholars have elaborated on this concept from different perspectives. From a literal perspective, the metaverse means that humans both live in the natural universe and use the digital universe to cross the limits of the natural universe to exercise human initiative and achieve human freedom (Huang and Cao, 2022). However, if we discuss it from the technical level, the metaverse is a virtual world and survival vision that starts from the game platform is based on digital currency and is supported by the synchronous emergence of a series of integrated digital technologies and hardware technologies, in which human life is deeply involved (Yuan and Yang, 2022). From the perspective of the economic system, the metaverse is a virtual but highly interconnected open-source platform constructed by a closed-loop economy. It has the characteristics of synchronization with the real world, high fidelity, open sources, innovation and creation, sustainable development and closed-loop operation, as well as low cost and high resolution. It can be used in distributed collaboration, 3D data model exploration, scientific visualization and other aspects (Yu, 2021; Shi *et al.*, 2004). From the perspective of social media, the metaverse is a set of virtual spaces that can provide a platform for the common exploration and co-creation of people in different physical spaces (Fernandez, 2022).

At present, it is generally accepted that the concept of "metaverse" originates from the novel avalanche written by Neal Stephenson (Neal, 1992), a famous American science fiction writer. According to statistics, the word "Metaverse" appeared 116 times in the book. This book is known as the cornerstone of the concept of the metaverse. The consensus on the concept of the metaverse cannot be reached without the development of science and technology. Since the mid-20th century, electronic information science and technology have developed rapidly. The new generation of the technological revolution in the 21st century has laid a solid foundation for the development of the metaverse. With the landmark achievements of the core technologies of the metaverse communication technology, interaction technology, computing power and core algorithm (Guo, 2022), the development and popularization of the metaverse have been further accelerated. The materialization of the concept of the metaverse is also inseparable from the promotion of Internet enterprises. At the beginning of 2021, soul app first proposed to build a "social metaverse" in the internet industry; In March of the same year, Roblox, known as the first stock of metaverse, was officially listed on the New York Stock Exchange; since then, Haier, NVIDIA, Facebook, Baidu, Sony and other enterprises have also launched the metaverse platform. The competing layout of the internet and technology enterprises has made the concept of metaverse gradually known to everyone.

The continuous development of the metaverse is also inseparable from the close attention of academia. At the beginning of the concept of "Metaverse", some scholars started to study the emerging business opportunities in the metaverse, the moral influence and its application in the social world from "Second Life" (Papagiannidis *et al.*, 2008; Kaplan and Haenlein, 2009). Recently, Siriborvornratanakul (2019) and other scholars have devoted themselves to AR research and summarized modern AR into five waves, including Marker-Based AR, Spatial AR with Projector, Wearable AR for Corporate, Markerless AR in Smartphone and AR Underneath Artificial Intelligence. They also gave a detailed description of the development process and application status of each wave, which laid a solid theoretical foundation for the development of metaverse-related technologies. Siriborvornratanakul (2016) also proposed two strategies for combining VR headsets and heart rate sensors for research, which provided a new communication channel for VR devices to interact with users. Besides Du *et al.* (2022) conducted a bibliometric analysis of 51 papers that studied the application of AR in retail, which revealed the current status of AR scholarly works in retail. As the research of VR, AR and other technologies get deeper, scholars are increasingly enthusiastic about exploring the metaverse. At the 2022 World Mobile Communication Conference, "Metaverse" made its debut in the "hot search" list of the conference and became the focus of the conference. Metaverse technology itself, the profit model and related ethical issues were hotly discussed (Guo *et al.*, 2022). Metaverse is regarded as the next generation Internet at the world-famous international consumer electronics exhibition (Kesselman and Esquivel, 2022), and its pillars are Virtual Meetings, Simulations, Remote Collaboration, Immersive Design, Marketing and Developing New Skills.

To sum up, this paper argues that the metaverse is a metaphor for the real world, that is, a relatively independent but highly interconnected virtual space with the real world. Metaverse is likely to become an important direction of the next generation of scientific and technological development, bringing great changes to people's lifestyles. However, at this stage, due to the limitations of the technical level and commercialization effect, there is still a long way to go before the ultimate metaverse is built. Promoting the healthy development of the metaverse still requires the joint efforts of industry and academia.

3. Data sources and research methods
3.1 Data sources
The Web of Science database includes the famous three major citation index databases (SCI, SSCI and A&HCI), which include authoritative journals in various subject areas (Wang,

2022b). Its strict selection criteria and citation indexing mechanism make WoS both a tool for literature retrieval and one of the most important sources of bibliographic data for scientometric research. Therefore, the WoS database is used as the data retrieval platform in this study. The first search has yielded 201 papers, and the retrieval strategies are as follows:

(1) Subject = ("Metaverse" OR "Non-Fungible Token").

(2) Publication date = (January 1, 2000–June 6, 2022).

(3) Database = (SCI-EXPANDED, SSCI, CPCI-S, CPCI-SSH, CCR-EXPANDED, IC and A&HCI).

To ensure the quality of literature, letters, book reviews, and news is excluded from the selection process. Finally, a total of 183 articles are included in the study. As shown in Figure 1, 75 papers (35%) are included in the scientific conference database CPCI-S, and 68 papers (31%) are included in SCI-EXPANDED, which shows that conference literature is an important part of the metaverse literature.

3.2 Research methods
Bibliometrix, a scientometric analysis tool, which developed based on R. It has gained the attention of R language development enthusiasts around the world and is continuously updated and maintained due to its full functionality, simplicity of operation, efficiency, open sources and free of charge (Li *et al.*, 2018). Therefore, the Bibliometrix toolkit is chosen to analyze the literature data, and the specific literature data sample collection and research process are shown in Figure 2. Firstly, a visual analysis is conducted to summarize the characteristics of the metaverse literature by analyzing the number of domestic and foreign literature issued, the scientific output of authors and collaborative relationships. High-frequency keywords and research hotspots were summarized by a series of methods such as keywords word frequency statistics, keywords co-occurrence and cluster analysis. This study also sorts out the thematic evolutionary paths of the metaverse and obtains a knowledge network of metaverse-related studies.
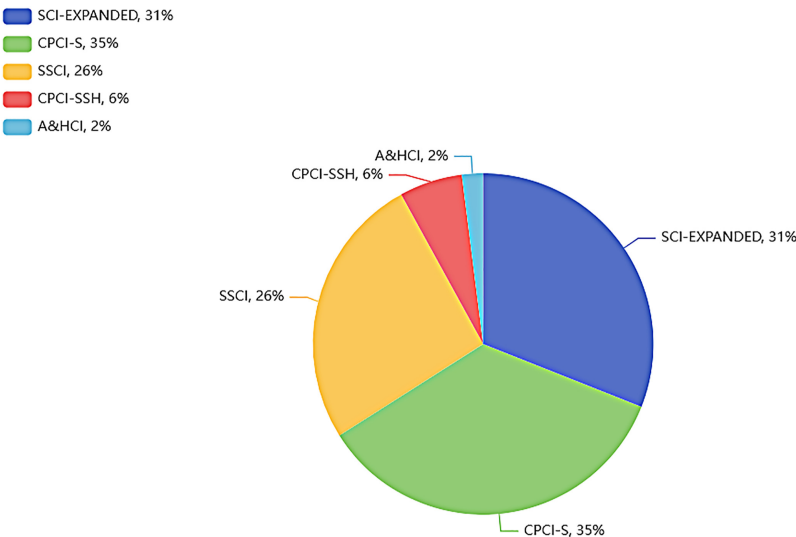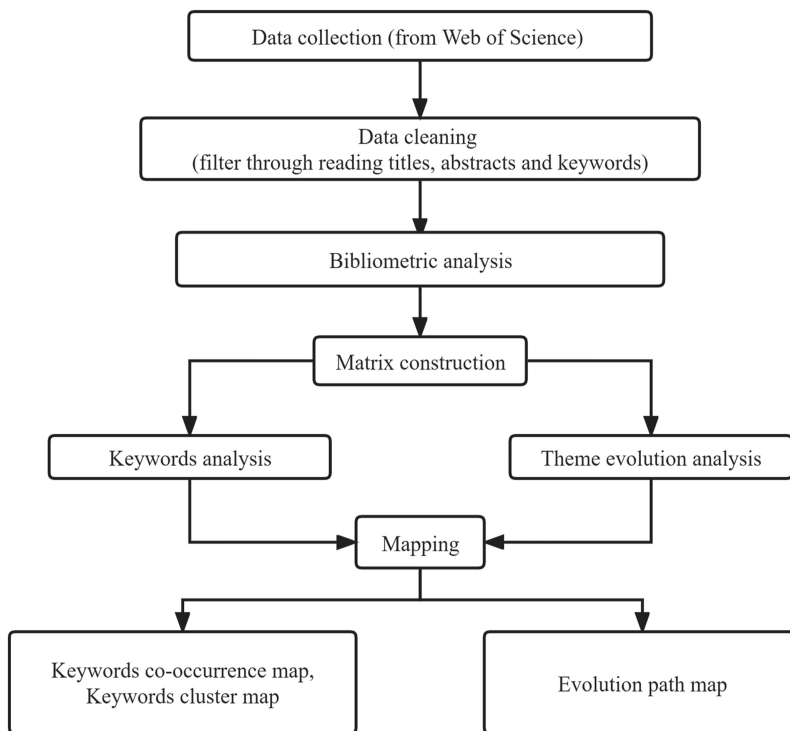

Figure 1.
Source distribution of metaverse literature

Data collection (from Web of Science)

Data cleaning
(filter through reading titles, abstracts and keywords)

Bibliometric analysis

Matrix construction

Keywords analysis

Theme evolution analysis

Mapping

Keywords co-occurrence map,
Keywords cluster map

Evolution path map

4. Research results
4.1 Descriptive statistical analysis of metaverse research
4.1.1 Analysis of the number of articles published. This section and the next two subsections will give a three-fold answer to the first question RQ1 (Since the concept of metaverse was proposed, what are the characteristics of the results in the field of metaverse?). The visualized results of the annual number of 183 articles published are shown in Figure 3. Among the sample literature, the earliest one was Kobryn's "Architectural Patterns for Metamodeling: The Hitchhiker's Guide to The UML Metaverse" published in 2000 (Kobryn, 2000). Two classic games, Second Life (2003) and Roblox (2004) reanimated the metaverse, with an article published every year from 2004 to 2007. In 2009, Bitcoin was officially born, and key technologies such as blockchain, which symbolizes digital asset tokenization, emerged one after another (Hong *et al.*, 2020), providing technical support for the construction of the metaverse. Therefore, from 2008 to 2009, a total of 15 metaverse-related articles were published, which was the first research peak in the metaverse-related field. Since then, the popularity of the metaverse has not decreased. Tron: Legacy released in 2010 is extremely in line with people's longing for the metaverse. Therefore, from 2010 to 2014, the number of publications related to the metaverse has been maintained at a high level, during which a total of 38 relevant pieces of literature were published. In 2015, HTC Vive was officially released on MWC2015, and the first year of VR came. The barrier between the real world and the virtual world was broken so that the heat of the metaverse could continue.

In 2020, with the outbreak of COVID-19, people's demand for online life scenes is getting higher and higher, and the pace of development of the metaverse is further accelerating. In 2021, a large amount of capital is pouring into the metaverse as technologies such as 5G, AI,
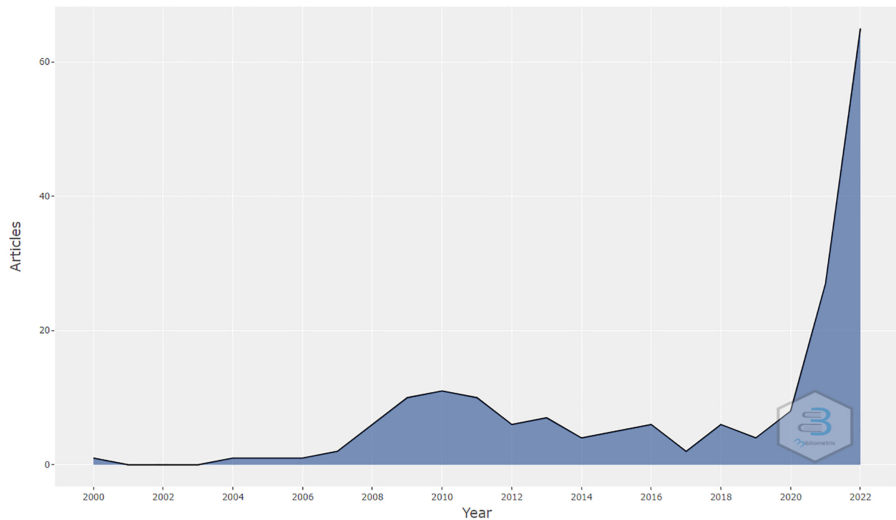
Annual Scientific Production

Figure 3.
The number distribution of papers published in the field of the metaverse

blockchain technology and VR/AR display technology are flourishing. In a short time, the metaverse has attracted great attention. The number of metaverse-related articles published every year has reached 16. The popularity has continued until 2022, with 65 related articles published as of June 6. According to the current development trend, the heat of the metaverse will continue and spread further.

According to the characteristics of the number of papers in the metaverse in each period, this paper divides the development of the metaverse into three stages: The period from 2000 to 2007 was a period of low-yield exploration. At that time, the concept of metaverse had not yet emerged, and the number of pieces of literature grew slowly, which did not attract much attention from scholars. 2008–2019 was the embryonic stage of development. During this period, bitcoin, blockchain and other technologies made breakthroughs. Besides, the number of metaverse literature experienced several fluctuations and gradually showed a trend of steady increase. Since 2020, the concept of "metaverse" has attracted the attention of a large number of scholars, with a total of 92 papers published, accounting for about 50% of the total number of papers published from 2000 to June 2022. The number of papers published in the first three months of 2022 alone has exceeded that of any previous year. This phenomenon shows that although the research on the metaverse is still in the initial development stage, it has shown great potential for development and will become the focus of academic circles in the next few years.

4.1.2 Analysis of authors in the field of the metaverse.

(1) Statistical analysis of the number of papers published by authors

A statistical analysis of the data derived from WOS found that as of March 2022, 451 authors had published 183 papers in the field. Among them, Ayiter, Elif scholar ranked first with 6 articles published. Ayiter mainly studied the influence of the metaverse on architecture and art. Inspired by Second Life, Ayiter recreated El Lissitzky's 1919 building "Proun #5A" in the metaverse (Ayiter, 2014a, b). As a designer and artist (Ayiter, 2010), Ayiter also made various artistic creations in the virtual environment and expounded their understanding of metaverse text and metaverse printing, etc (Ayiter, 2012). In addition, 8 scholars including Barry, Fukumura and

Kanematsu have published more than 3 papers. Meanwhile, Arroyo, Bourlakis and other scholars have also become the top 10 authors in this field by publishing 2 papers.

(2) Authors collaboration analysis

In order to understand the achievements of academic exchanges and the general situation of team cooperation in the field of the metaverse, co-occurrence analysis is also conducted on the cooperative relationship between authors, as shown in Figure 4. The size of nodes represents the number of authors' publications and the same color represents an author cluster. We find that most scholars choose cooperative output, but there are generally fewer internal members in each academic team formed by cooperative output.

Further analysis of author clusters with a large number of publications and members in the cooperative network shows that Barry, Fukumura, Kanematsu and other scholars have jointly published 4 metaverse related articles, which is an important author cluster in this field at present. Their research focuses on the application of the metaverse in the field of education. They find that the emergence of the metaverse virtual world can improve students' imagination and creativity. The combination of a metaverse virtual classroom and a real classroom provides new possibilities for STEM education (Kanematsu et al., 2014). In addition, the author cluster
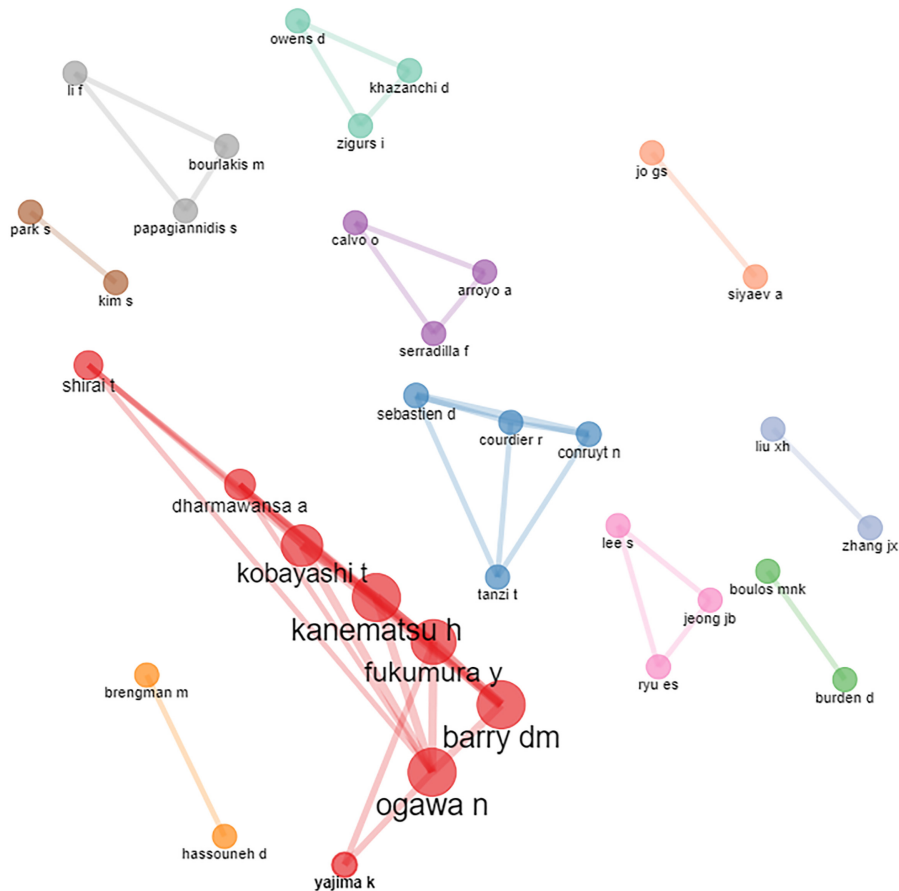

Figure 4.
Author
cooperation map

composed of Conruyt, Noel, Sebastien, Didier and other scholars jointly published 3 metaverse articles, which is the high-yield author cluster second only to Barry, Dana M and other scholars. Its main research direction is the realization of biodiversity systems in the virtual world of the metaverse. This author cluster studies the different possibilities that data representing biodiversity in information systems can present in the metaverse (Sebastien *et al.*, 2009a) and proposes a new management component in biodiversity information systems (Sebastien *et al.*, 2009b). It enhances the public's immersive experience in virtual environments.

4.1.3 Distribution of metaverse articles in space and domain. The distribution of existing results on the metaverse from the spatial dimension is counted. The United States has the largest number of relevant publications, reaching 52 papers, accounting for more than 20% of the total. In addition, Korea and China have more than 30 papers. Japan, the UK, France, Spain and Brazil have more than ten publications. In addition to the above countries, 12 countries, including Italy and Brazil, have published fewer than 10 papers. The total number of papers published in these 12 countries only accounts for 29% of the total, indicating that the research on the metaverse is still shallow in most regions or countries.

Following the analysis of the sources in the metaverse literature from the domain dimension, a total of 73 different domains are covered in the 183 papers, and their distribution conforms to the Pareto principle. Among them, the fields ranked at the top of the paper output are 37 in Engineering, Electrical and Electronic, 42 in Computer Science, Theory and Methods, 35 in Computer Science, Information Systems, 20 in Computer Science, Artificial Intelligence, 19 in Computer Science, Interdisciplinary Application and 18 in Computer Science, Software Engineering. Field distribution characteristics of the metaverse literature indicate that the new generation of computer technology and Internet technology is the basis for building the physical layer of the metaverse (Li, 2022). Current metaverse-related research focuses on computer science.

4.2 Keywords analysis

Keywords are the author's high-level summary of the content of the article, which has an obvious indicating function and is an important analysis index of Scientometrics. Sorting through the keywords of the 183 metaverse-related documents included in the study, the results will answer the second question RQ2: What are the prospects for the metaverse concept itself and its technological achievements in other fields of application?

4.2.1 High-frequency keywords analysis. The word cloud in Figure 5 shows the most frequent keywords in the metaverse paper. The more frequently the keywords appear, the larger the corresponding keyword labels. The frequency occurrence of keywords plays a significant role in meeting the study's objectives. This analysis reveals the hotspot category

Figure 5.
Word cloud analysis

and future developments of a discipline (Borgohain *et al.*, 2022). From the chart, it is clear that in addition to the metaverse, Second Life, Virtual Reality, Blockchain, E-learning and Art are also high-frequency keywords. These themes occupy a crucial place in the field of the metaverse. Second Life is an extremely social virtual environment developed by Linden Lab at the beginning of the 21st century (Godfrey, 2008). The platform was a hit, allowing researchers not only to conduct extensive academic research on it (Gajendra *et al.*, 2012), but also to raise the connection between users to a higher level. But for various reasons, the game gradually faded from the public view. The rise and fall of Second Life have led to more rational thinking about the development of the metaverse (Lee *et al.*, 2022). Scholars hope to further elucidate the concept of the metaverse and its implementation methods based on interactive technologies such as Avatar and XR, Virtual world (Park and Kim, 2022) and further enrich the metaverse by analyzing Blockchain, Smart control and other technologies for settlement and control to further enrich the connotation of metaverse (Duguleana and Girbacia, 2021). At the same time, industry and academia have actively sought creative integration of metaverse with Creative Education, Urban Muralism, Cultural Industrialization, Environmental Education and Language Learning (Yohan and Lee, 2022; Jeon and Won, 2022; Doo, 2022; Kanematsu *et al.*, 2010; Liu *et al.*, 2019).

4.2.2 Keywords co-occurrence analysis. The co-word analysis method is based on the word frequency analysis method, which mainly analyzes the phenomenon of keywords appearing in the same literature to determine the relationship between topics in the subject area (Zhang and Ma, 2007). In this paper, based on the study of posting number in the statistical description of the first section, the metaverse's development history is divided into the following three phases: low-yield development stage (2000–2007), volatility rises phase (2008–2019) and high-yield active phase (2020–2022). On this basis, the high-frequency keywords matrix of each stage was constructed. The keywords matrix is visualized by co-occurrence network analysis in Biblioshiny. The results are shown in Figures 6–8.

(1) Low-yield development stage (2000–2007)

Metaverse research was in its infancy at this time. Metaverse, virtual design teams, etc. are the high-frequency keywords in this stage. During this period, metaverse research is very closely related to games and education (Sidorko, 2009). In terms of conceptual exploration: with the rise of games such as Second Life and World of Warcraft, massively multiplayer online games have long evolved into interactive paradigms for learning, simulation and digital design (Bardzell and
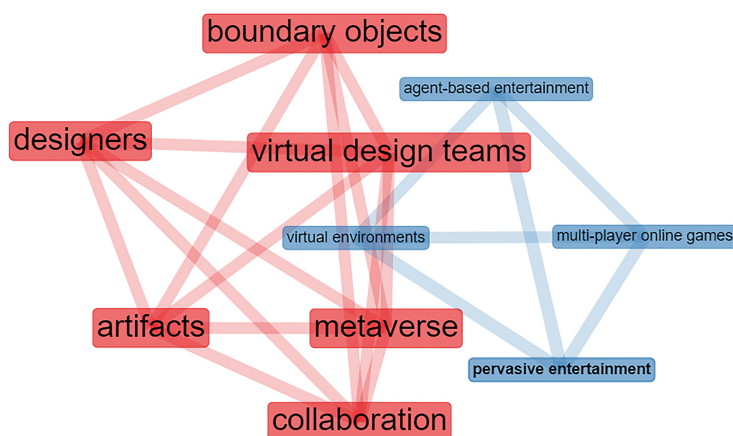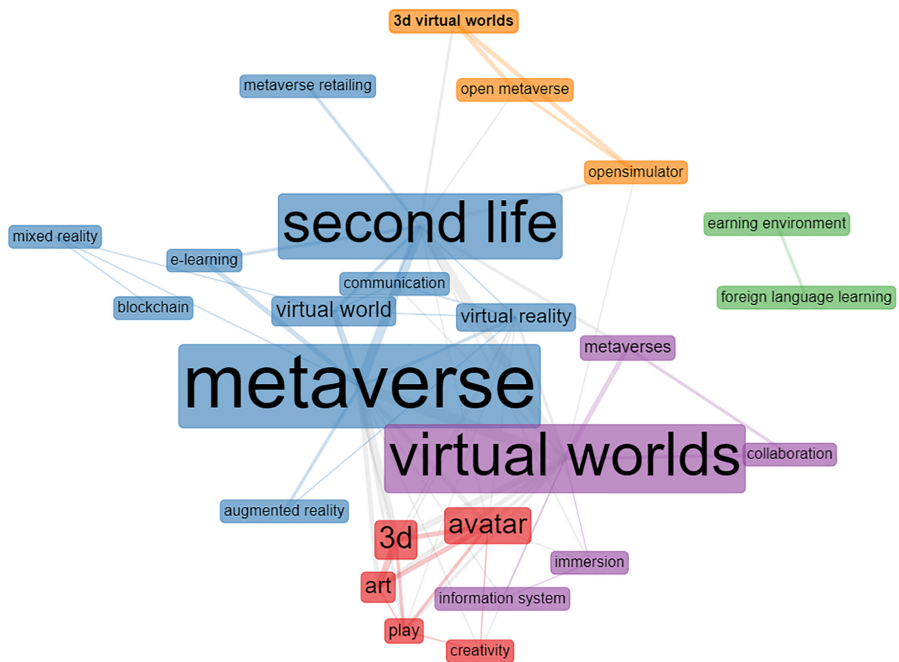

Figure 6.
Keywords co-occurrence network, 2000–2007

Shankar, 2007). Scholars describe platforms such as Second Life as a constructivist learning environment (Antonacci and Modaress, 2005), with the creativity to build immersive learning environments (Hill and Lee, 2009). They were pioneers in the development of the concept of metaverse (McArthur, 2007), prompting the concept of metaverse to enter the public domain. On the implementation path: games such as Second Life have explored approaches to improve the protection of user rights for metaverse (Cacciaguerra, 2006) and have proposed new ideas in terms of the architecture of metaverse (Kobryn, 2000).

(2) Rising stage of fluctuation (2008–2019)

At this time, the research of the metaverse is in the development stage. The metaverse, virtual worlds, augmented reality, 3D and so on are the core keywords of the research at this stage. The successful realization of 3D technology and the successful definition of the concept of the virtual world become a new starting point for researchers to conceive the realization of the metaverse (Dionisio *et al.*, 2013). At the same time, products like Fortnite, Minecraft and Roblox are blurring the line between games and social networks. The science fiction metaverse is slowly becoming reality (Sweeney, 2019), as the metaverse merges with other fields of knowledge. In the field of education: At this stage, metaverse has achieved remarkable application achievements in history education and evaluation of students' learning styles (Hun, 2017; Barry *et al.*, 2015). In the field of retail: The metaverse has promoted virtual retail into reality with stronger fun and more complete product inspection procedures (Hassouneh and Brengman, 2015; Swilley, 2016).

(3) High-yield and active Stage (2020–2022)

During this period, the metaverse received unprecedented attention and the scientific output of the academic circle also showed a blowout rise. The development path brought by
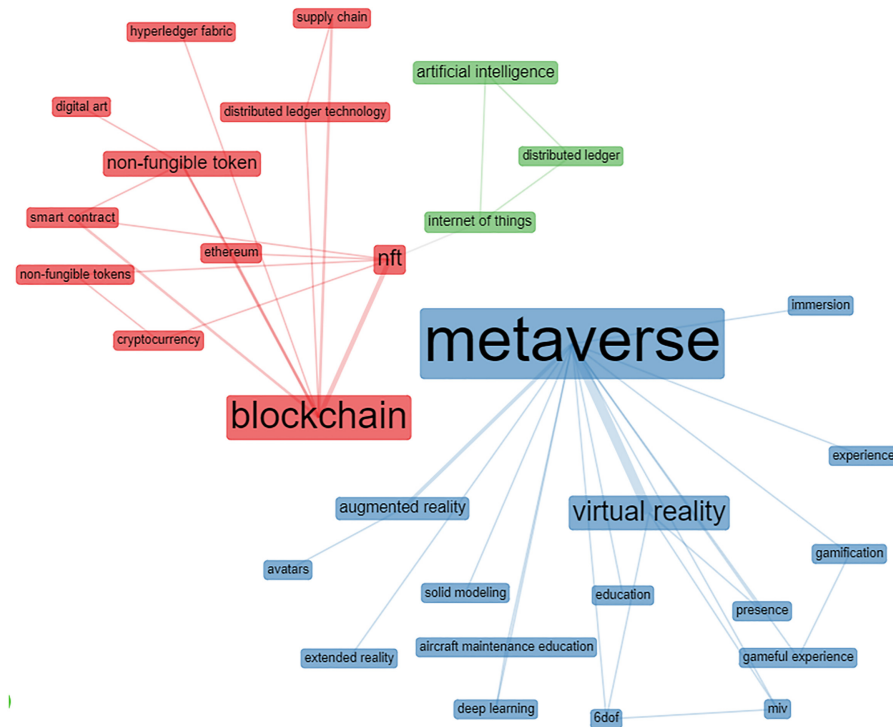
Blockchain, Smart Contract and other technologies and their products to the metaverse technology has become a hot research topic at this stage. At the same time, the application of the metaverse has also been expanded more widely. In the tourism industry, the "metaverse + tourism" has become a new topic in the field of tourism (Noh, 2022; Jun *et al.*, 2021). In addition, the application of the metaverse in urban digital diplomacy, real estate, advertising, product display and other fields has brought new development opportunities for all industries (Mun, 2022; Rae, 2021; Park, 2021; Xin, 2022). At the same time, the challenges brought by the development of the metaverse to human society have also attracted people's great attention. Legal and ethical issues have become the issues that need to be addressed for the sustainable development of the metaverse (Wan, 2022). Humans participate in social activities mainly through avatars on the metaverse platform with a low degree of moral restraint. Therefore, some users damage the legal rights of others through verbal or visual behaviors (Kang, 2022), posing a great challenge to the construction of social moral systems and laws.

To sum up, the co-citation network with the metaverse as the core is obtained by visual analysis of the keywords matrix of the metaverse-related literature from 2000 to 2022, as shown in Figure 9. Nodes that are highly related to the concept of the metaverse are as follows: keywords in interactive technology such as virtual worlds, virtual reality and augmented reality; computing technology such as blockchain and related games such as Second Life. Technological breakthroughs are the basis for the development of the metaverse, which can be either integrated from independent virtual worlds (Dionisio *et al.*, 2013) or implemented in the form of blocks based on a decentralized blockchain point-to-point distribution model (Ryskeldiev *et al.*, 2018). Besides the breakthrough of visible technology, it still continuously provides a new path for the realization of the metaverse and promotes the metaverse from theory to practice.
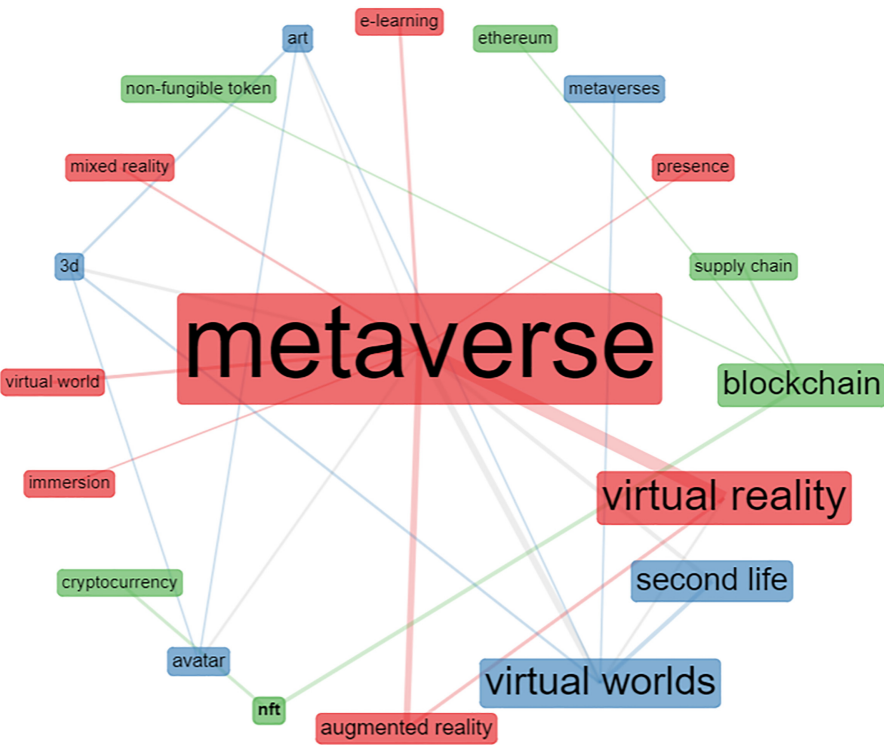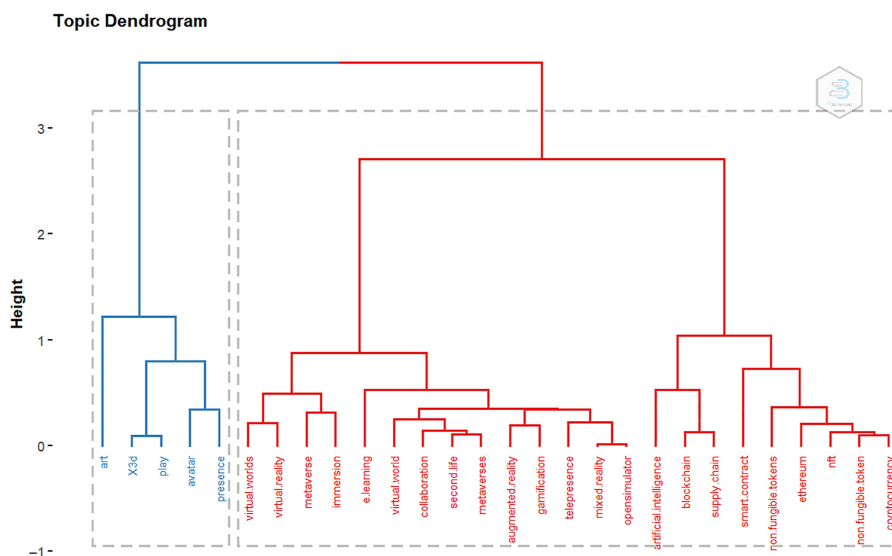
Figure 9.
Core distribution of keywords co-occurrence network

The metaverse has been defined as a game-based learning platform, illustrating that large-scale games provide new ideas for the integration of the metaverse with the education industry (Getchell *et al.*, 2010). Second Life games provide users with a platform for artistic creation and commercial cooperation and also provide valuable experience for the expansion of the application of the metaverse to the art and commercial fields.

4.2.3 Keywords cluster analysis. The hierarchical clustering method can detect data at different granularity levels, and it is easy to realize similarity measurement or distance measurement (Yang *et al.*, 2021). In this paper, 183 metaverse literature are analyzed by bottom-up condensed hierarchical clustering, and the tree diagram of each topic is obtained. The results are shown in Figure 10 below. According to the distance between categories, this paper divides keywords into three clusters. Since the concept of metaverse was proposed, the trend of keywords clustering in its literature is as follows:

(1) Basic element cluster of the metaverse

The cluster contains keywords such as "3D", "Avatar", "Art", "Presence", etc. Metaverse has basic elements such as a virtual avatar, 3D space and interactive accompanying activities (Yang *et al.*, 2021). Its combination with the art field crosses the boundary between the virtual world and the real world, providing an opportunity for users to experience artistic creation. Constructing a printing art ecosystem experienced through virtual avatars in the virtual world, text can be felt as highly participatory art, rather than read as information content (Ayiter, 2014a, b). The exhibition space built with metaverse technology allows users to freely build composition methods and forms according to the concept of the exhibition and provides

Topic Dendrogram

users with a personalized exhibition viewing experience based on existing exhibitions (Chun and Yeo, 2022).

(2) Cluster of main research achievements of the metaverse

This collection is the largest cluster in the current metaverse literature, with "Metaverse", "Virtual world", "Second life" and "E-Learning" as the core keywords. This cluster represents the main research results in the metaverse field. As a platform for the integration of reality and the virtual, the metaverse promotes the application and integration of politics, economy, society, culture and other fields in the virtual world (Oh, 2021). At present, the application of virtual reality is more and more widespread and has penetrated entertainment, education, medical treatment, commerce and other fields. In the field of entertainment, influenced by the second life, many players have jumped in. Some even quit their jobs in real society and focus on creating wealth in the virtual world. In addition, many entertainment companies seek a new path for the innovative development of the cultural and entertainment industry by launching the combination of virtual characters and real characters (Kim and Jinyun, 2021). In the field of education, virtual reality, as a new teaching medium, can fully reflect the situational and interactive nature of the teaching process and improve the teaching effect (Zhao *et al.*, 2009). Especially in medical education, the research on virtual teaching is a current research hotspot that has a wide range of application prospects (Yang, 2016).

(3) Basic cluster of metaverse technology

In recent years, the keywords represented by "Blockchain", "Nonfungible token" and "Artificial intelligence" constitute the basic cluster of metaverse technology. Among them blockchain plays a great role in the circulation and sharing of metaverse data with its characteristics of decentralized trust mechanism, non-tamperability and traceability (Zhu and Xu, 2021); Based on big data, deep learning and arithmetic power, artificial intelligence has been relatively mature in the application of speech recognition, face recognition and other technologies. At present, it is changing to complex tasks such as logical reasoning and domain migration. These breakthroughs in the key technologies of the metaverse have

played a key role in promoting the further integration of the metaverse with mathematics, finance, computer, military and other fields (Crespo *et al.*, 2013).

4.3 Theme evolution analysis

This section will build on the above analysis to provide an answer to RQ3: How have the research hotspots in the field of metaverse changed since 2000, and what are the implications for future research? To ensure the scientific validity of the subject terms, this paper analyzes the evolution of the research themes in the metaverse-related literature from 2000 to 2022 in chronological order. In this procedure, the evolution process of the metaverse topic is divided into three stages: from 2000 to 2010, from 2011 to 2019 and from 2020 to 2022. The research keywords for each stage are analyzed, and the thematic evolution path is visualized. The results are shown in Figure 11 below.

According to the number of connections and the size of nodes, we find that there are great differences in the research topics of the metaverse in each period, and the evolution path is clear. The obvious themes in evolution paths are:

(1) "Second life" → "Metaverse" theme evolution path

The core theme of each stage is used as the main path to construct a relationship network, with the core path nodes at a distance of less than 2, as shown in Figure 12 below. In the first stage, the path takes "second life" as the core theme and the keywords directly connected with it are virtual reality and metaverse. Based on second life, virtual reality can be defined as a computer-based simulation environment where users can live and interact with others (Kumar *et al.*, 2008), which further explains the essence of the virtual world. At the same time, by discussing the business opportunities and challenges of second life, we can further determine the systematic problems that need to be solved for the development of the metaverse (Papagiannidis *et al.*, 2008) and effectively promote the development of the virtual world and the metaverse. The core theme of this path was transformed into virtual world. In the second stage, the path has "virtual worlds" as its core theme, which is directly linked to keywords such as art, 3D, Second Life, etc. and from which many branches have been derived, such as metaverse retail, open simulators, etc (Bourlakis *et al.*, 2009; Crespo *et al.*, 2013). At this stage, the related technologies of virtual world developed rapidly (Wang *et al.*, 2017) and were widely used in architectural education, autism treatment and so on (Pak *et al.*, 2012;
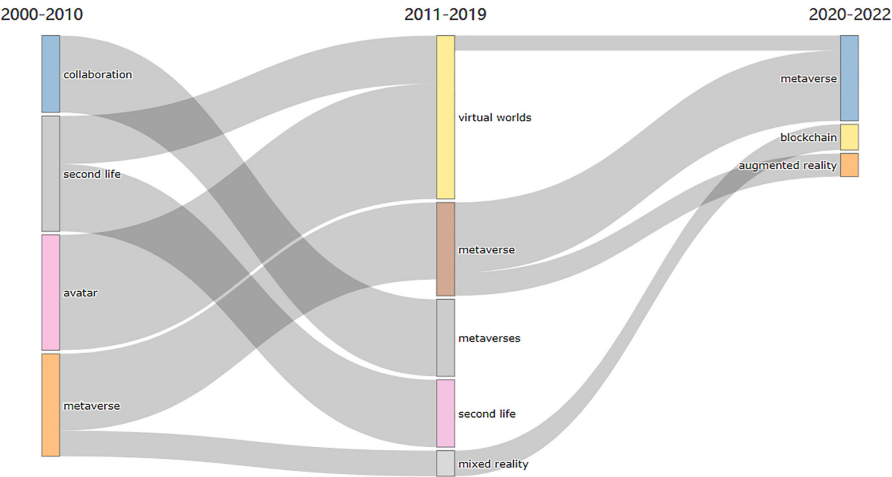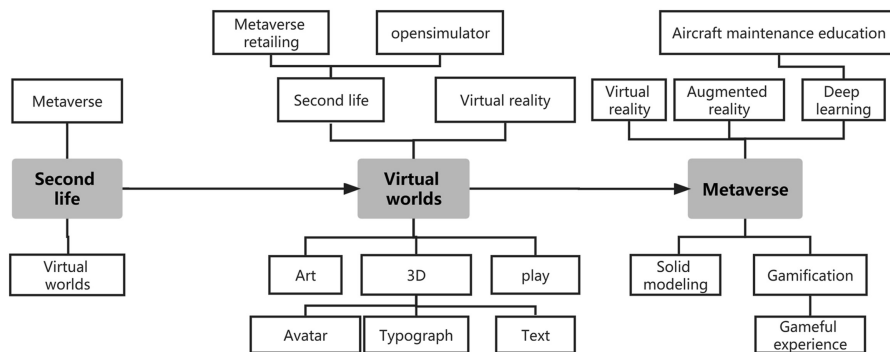
Figure 11.
Theme evolution map

Figure 12.
"Second
life" → "Metaverse"
theme evolution path

Stendal and Balandin, 2015). With the wider range of applications for virtual world, it has become a new challenge for virtual world development to move from a complex but completely separate set of immersive environments to a large integrated network of 3D virtual world or metaverse. The core theme of the path shifted from the virtual world to the metaverse. The third stage is the evolution stage with the metaverse as the core theme. At this stage, the research on the metaverse is more comprehensive. The keywords directly connected with the metaverse include deep learning, extended reality, virtual reality, solid-state mode, game console and have also been extended to gamification experiences, aircraft maintenance education and other experimental branches that span a wide range of fields (Park *et al.*, 2021; Siyaev and Jo, 2021). This evolutionary path, starting from the second life, constantly explores the metaverse, enriching the specific forms of the metaverse. In the future, research into the idea of the metaverse as a whole will continue to receive a lot of attention.

(2) "Metaverse" → "Metaverse" theme evolution path

This evolutionary path differs significantly from the other two. As can be seen from Figure 13, the core theme of all three stages of this path is the metaverse, so this path can reflect the specific development of the metaverse at each stage. In the first stage, there are four keywords directly connected with the metaverse, such as 3D, virtual world, virtual body and second life, and there are no other extended branches, which show that the research related to the metaverse at this stage has the characteristics of small scope and narrow research direction. 3D, virtual worlds and other technologies are the basis for the realization and development of the metaverse. The combination of 3D technology and web-based systems
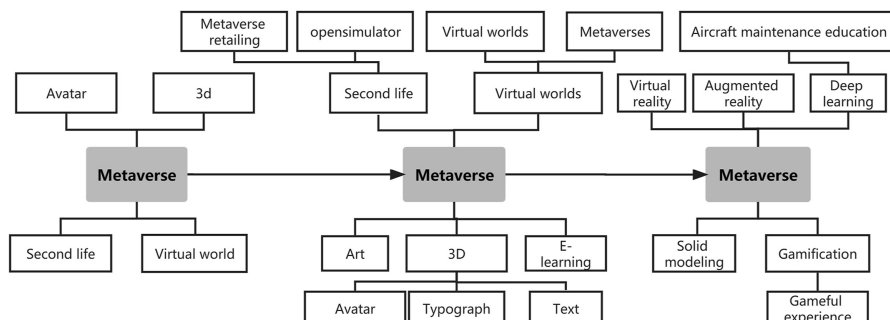

Figure 13.
"Metaverse" →
"Metaverse" theme
evolution path

provides an extensible learning framework for Metaverse (Marmaridis and Griffith, 2009), and its integration with social networks also greatly promotes the anthropomorphic process of Metaverse elements (Arroyo *et al.*, 2009). And virtual world and virtual avatar are the foundation of metaverse research (Davis *et al.*, 2009). In the second stage, the keywords directly linked to the metaverse became five, such as online learning, 3D, art, virtual worlds and Second Life. It can be seen that the research scope of the metaverse, in addition to the original Second Life and virtual worlds, has also produced creative integration of disciplines with the arts and online education by saving resources and other advantages (Estudante and Dietrich, 2020). As can be seen from Figure 11 above, in the third stage, the research focus of this pathway tends to be consistent with the evolutionary pathway that starts with Second Life, with the same core themes, directly connected keywords, evolutionary branches and other features. The research related to the rich metaverse system will continue to receive the attention of many scholars in the future.

(3) "Metaverse" → "Blockchain" theme evolution path

As can be seen from Figure 11 above, this path and the previous "metaverse" → "metaverse" both evolve from the metaverse as the starting point, so its first stage evolutionary state is the same as the previous path. The continuous development of mixed reality at this time provides a new path for the development and application of metaverse. As can be seen in Figure 14, in the second stage the central theme of the path evolved into mixed reality, with telepresence as the only keyword directly linked to it, which shows the evolution of the research theme of the metaverse toward technological exploration. Mixed reality aims to make real objects interact with 3D digital content and increase mutual understanding by mixing the physical world and the virtual world (Zhang *et al.*, 2022). At present, mixed reality has been widely used in medicine (Balci *et al.*, 2022; Ogunseiju *et al.*, 2022), education and other fields. Its application in social media provides a feasible path for the realization of metaverse. By studying the mixed reality interfaces of emerging social platforms, it is possible to summarize a series of metaverse qualitative principles that contribute significantly to the development of the metaverse (Prieto *et al.*, 2022). Meanwhile, with the establishment of "Ethereum", blockchain development has entered the 2.0 era. Its features such as decentralization, transaction accountability and smart contract-based automation provide a new framework for the construction of metaverse applications (Li *et al.*, 2021; Nguyen *et al.*, 2022). In the third stage, the research theme of this path evolved into the blockchain, and the keywords directly linked to it are superconducting fibers, NFT, smart contracts, supply chain and distributed ledger technology. Blockchain has brought a revolution in many fields, such as Finance, Healthcare, Supply chain, Insurance and Internet of Things (Sanka *et al.*, 2021). Its combination with the game industry has given birth to Metaverse (Vidal-Tomás, 2022). At this stage, the technical characteristics of keywords directly related to the core topic are
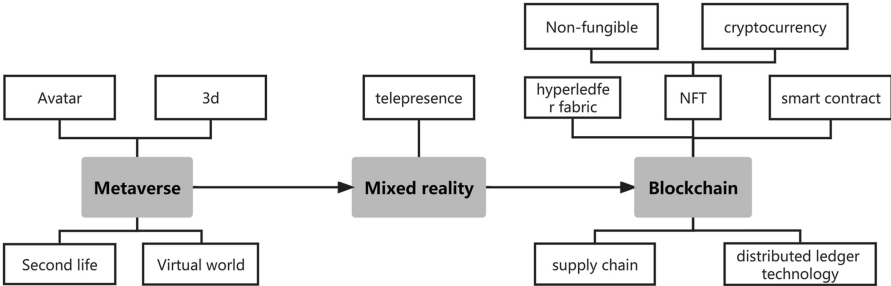

Figure 14.
"Metaverse"
→ "Blockchain" theme
evolution path

obvious. It can be seen that as technology continues to improve and breakthroughs are made in technologies such as blockchain, the technical nature of metaverse-related research continues to increase. With the accelerated integration of the metaverse with various industries, the importance of metaverse-related technologies will further increase and become a key research direction for metaverse research along with metaverse concept research.

As an emerging concept, the research theme has evolved from games such as second life and the metaverse concept itself to the cross-fertilization of blockchain, augmented reality and other technologies with the metaverse and the further enrichment of the metaverse concept. It is thus predicted that in the future, scholars will further enrich the metaverse theory system in three directions, including the realization of the metaverse and related technological development, the cross-fertilization of metaverse concepts with various disciplines and the analysis of the pros and cons of metaverse development.

5. Discussion

With the development of cloud computing, artificial intelligence, blockchain, wireless communication networks and other related technologies (Wang, 2022a), the metaverse has broken the boundary between reality and virtual reality, bringing new possibilities for social networking, entertainment and work. Taking the metaverse literature in the WOS core database since 2000 as the research object, this paper makes a systematic quantitative analysis of the research results in the field of the metaverse, summarizes the output and research hotspots of scientific research in the field of metaverse at each stage from the perspective of time sequence, combs the evolution path of the metaverse. Finally, this paper predicts the future research trend in this field.

The research results show that since the advent of the concept of the metaverse, the annual number of literature issued has shown a fluctuating upward trend. Affected by capital, epidemic and other factors, the research results of metaverse sharply increased in 2021. However, the total amount of metaverse literature is low, and a complete theoretical system has not yet been formed. By analyzing the characteristics of metaverse literature, it is found that the current metaverse-related research has unbalanced characteristics in both spatial and domain dimensions. In the space dimension, the research on metaverse is mainly concentrated in the United States, China, Japan and other countries, while the research on metaverse in Italy, Brazil and other countries is still lacking and has not yet formed a global research scale. In the field dimension, most of the current research is still focused on technical fields such as electronic engineering and computer science. Among them, the creative integration of AR and other related technologies with mobile learning, museum exhibition and other fields has also shown remarkable results such as improving students' learning enthusiasm (Li and Liu, 2022), enhancing teaching quality and increasing the return visit rate of museums (Dalili Saleh *et al.*, 2022). On the whole, however, the integration of metaverse and traditional fields such as manufacturing is still very limited. Therefore, although the number of literature published in the metaverse has increased by leaps and bounds since 2021, relevant research and development are still in their infancy.

At the same time, games such as second life and my world shorten the distance between the real world and the virtual world, providing a window for the public to experience the metaverse. Second life provides a new virtual world for the majority of players, where players can socialize, shop and even do business. The sense of experience derived from life has won the favor of many users. The game provides a practical reference for how to better create a metaverse mechanism. In my world, players can create in a sandbox and build their ideal world online. This mechanism refines the scene of the metaverse and opens the door to people's imaginations of the metaverse. Therefore, the introduction of games such as second life lays a foundation for people to understand and accept the metaverse and also provides a reliable way to visualize the metaverse, which is of great significance to the development of the metaverse.

At present, the research direction of the metaverse is gradually focusing on blockchain, virtual reality, artificial intelligence, augmented reality and other technologies. These technologies have high research potential and are expected to become the main research direction of the metaverse in the next few years. Since the 21st century, the pace of information technology reform has been accelerating. Cloud computing, big data, artificial intelligence, blockchain, virtual reality and other technologies have been emerging. Therefore, mankind has entered the era of big data. However, this series of new information technologies have only solved the problems in a certain field of the information world. No information technology can fully depict the whole information world (Huang and Cao, 2022). The metaverse started with the game platform and is based on digital currency. It integrates all kinds of existing new information technologies to form an information technology whole and uniformly depicts the future new information world, that is, the metaverse integrates many information technologies into a whole. Therefore, these basic technologies are not only supported for the development of the metaverse but also the fundamental driving force for the development of the metaverse at this stage.

6. Conclusion and implication

6.1 Conclusion

On the whole, this paper makes a systematic quantitative analysis of the research results of metaverse It finds that the field of metaverse has not yet formed a complete theoretical system. Therefore, it is still in its infancy. There are unbalanced characteristics in both spatial dimension and domain dimension. In addition, the application of the metaverse is also very limited. It is found that most metaverse studies are related to the application in tertiary industries such as museum services (Hsu and Liang, 2022), education (Li and Liu, 2022) and medical services (Naveh and Bronstein, 2019), while only a few studies have found applications in other related fields such as industrial production and information systems. As an emerging concept, the metaverse formed its own unique evaluation path after more than ten years of development. The visualization results show that the themes of metaverse research in each period are significantly different and have clear evolution paths. Scholars have gradually made the transition from focusing on the concept of metaverse itself to information technology. The current industry and academia are focusing on blockchain, virtual reality, artificial intelligence, augmented reality and other technologies. And they have started to try to integrate the metaverse with other fields to continuously promote the development of metaverse. Therefore, improving the conceptual system of the metaverse, expanding the application environment of the metaverse and constantly optimizing the basic technology of the metaverse are the research priorities in the field of the metaverse in the future.

In addition, this study has some limitations: (1) In this study, the keywords "metaverse" and "Non-Fungible Token" are used to search the sample literature, not considering that the articles on the topics of augmented reality and virtual reality also contain a lot of metaverse ideas. (2) The source of the article sample is WoS, while Google Scholar or Scopus databases are not included. In future work, we will start by adding literature search keywords and expanding literature sources to conduct a more systematic quantitative study of metaverse-related research results.

6.2 Implication

The next stage of development of the metaverse is to reconstruct the social, consumption and other aspects of reality in the digital world, which will bring great changes to various industries and also bring many potential risks to the economic, political, cultural, social, ecological and other fields (Wei and Su, 2022). To avoid the metaverse causing human beings to fall into a long virtualization trap (He, 2022), the builders of the metaverse, the government, the

participants of the metaverse and other parties should use a more objective and rational perspective to look at the explosion of the metaverse and its impact on the future. The builders of the metaverse should abandon blind competition and be blindly radical. Focus on eliminating the digital divide, guaranteeing the information fairness of information human rights and information technology under centralized technology governance and creating a metaverse that truly benefits mankind (Xu *et al.*, 2022). The government should grasp the boundaries of the development of the metaverse from three aspects: legal regulations, scientific and technological regulations and educational regulations (Zhao and Lu, 2022). While avoiding the dominance of a platform or a country in the metaverse field, we should strengthen the self-discipline of the metaverse industry with a more complete legal system and stricter moral standards. In addition, all participants in the metaverse platform should balance the relationship between the virtual world and the real world and embed the metaverse in the real society to avoid being divorced from reality. Delineating the boundaries of development is the basis for the development of many new things. Metaverse is no exception. In the future, with the improvement of various systems and laws, the realization of the metaverse may open the full truth era of the internet.

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