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Analysis of International Research Trends on Metaverse

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Abstract

This study attempted to explore the realization and research direction of a successful metaverse environment in the future by analyzing international research trends of the metaverse using topic modeling. A total of 208 papers among WoS and ScienceDirect papers using metaverse as keywords were selected, and quantitative frequency analysis and topic modeling were performed. As a result, it was confirmed that research has rapidly increased after 2022. The main keywords of the research topics were 'second', 'life', 'learning', 'reality', 'metaverse', 'virtual', 'blockchain', 'nft', 'medical', 'avatar', etc. The topic keywords 'Second life & Education' and 'Virtual Reality & Medical' accounted for a large proportion of 57%, followed by 'Blockchain & Cryptocurrency', 'Avatar & Interaction', and 'Sensing and Device'. As a result of semantic analysis, current metaverse research is focused on application and utilization, and research on underlying technologies and devices is also active. Therefore, it is necessary to identify the commonalities and differences between domestic and foreign studies, and to study the application method considering the domestic environment. In addition, new jurisprudence research is more necessary along with predicting new problems. It is expected that the results of study will provide the right research direction for domestic researchers in the era of digital transformation and contribute to the realization of a digital society.

1. INTRODUCTION

The metaverse, which is rapidly emerging as a keyword of interest around the world, has been regarded as the same concept as the virtual world. However, after the announcement of ASF's 'Metaverse Roadmap', it has been recognized as a phenomenon in which the real world and the virtual world are merging, and it has been re-emerging [1]. According to a policy briefing in 2022, it is analyzed that the metaverse has risen rapidly due to the development of digital technology, expectations for a new platform, and the emergence of a digital native generation. It is said that COVID-19 has accelerated the digital transformation in all areas of the economy and society, bringing the new normal era where non-face-to-face communication has become common [2]. In 2020, PwC forecast also predicted that the metaverse-related VR and AR market will grow more than 15 times from $45.5 billion in 2019 to $1.54 trillion in 2030 [3].

Therefore, this study aims to help domestic researchers to find the right direction by analyzing the trend of overseas metaverse research. By searching the Web of Science and ScienceDirect, papers with the subject

word (title, keyword, abstract) of 'Metaverse' were selected for analysis. We intend to analyze more detailed research trends through meta-analysis and topic modeling techniques. As a result, the quantitative aspect of changes by period of overseas research was examined, and the meaning was analyzed. As a result of topic modeling, we will examine major topics and topic trends in terms of content and understand the trends and meanings of research topics.

2. RELATED RESEARCH

2.1   Concept of Metaverse

Metaverse is a compound word of 'Meta' meaning transcendence and 'Universe' meaning world. It was first used in the sense of 'three-dimensional virtual world' in the American science fiction novel 'Snow Crash'. Although there is no established definition yet, it has a conceptual meaning as a 'virtual shared space' where the Internet space and the physical space coexist [4]. In 2007, ASF defined the metaverse as "the convergence of a virtual enhanced physical reality and a physically permanent virtual space". In a word, it means a space where the virtual world and the real world are fused [5]. Various researchers have defined it as 'a virtual world in which everyone engages in social, economic and cultural activities using avatars' or 'all phenomena in which daily life is moving and expanding to the digital world to satisfy the needs that are lacking in the analog world'. while establishing the concept [6~7].

2.2   Analysis of Research Trends

As a result of examining related studies using big data analysis techniques, it was possible to confirm research in various fields for quantitative and qualitative analysis. Studies using meta-analysis, text mining, and topic modeling are mainly dealt with. Papers generally aim to analyze changes in major topics and themes of metaverse research. In terms of method, there are more studies of topic modeling using LDA-based or BERT rather than meta-analysis. LDA has limitations in explaining correlations between topics. For this reason, the same method as BERT is also used in topic modeling [8]. This is because BERT can identify the relationship between documents according to the word order and time in a sentence [9].

The related papers used the following purposes and methods. The purpose of the first paper is 'quantitative analysis of international research trends/characteristics related to metaverse', and 'descriptive statistics, multidimensional scaling, and keyword network analysis' were used [10]. The second purpose is 'Discovering research topics and provide directions for metaverse platform research', and 'word-cloud analysis, keyword network analysis' was used [11]. The third purpose is 'Exploring the direction of metaverse augmented reality research, encourage active convergence research and provide implications', and 'LDA-based topic modeling' was used [12]. The fourth purpose is 'For the purpose of trend analysis on the performance of the existing virtual environment-based education, to draw educational engineering implications, and to contribute to research on the use of virtual environments', and 'LDA-based topic modeling, time series analysis' was used [13].

3. METHODOLOGY

The procedure of this study is as follows. Quantitative research changes were confirmed by performing frequency analysis, and research topics were confirmed by topic modeling using the BERT model. Based on this, the meaning of two research topics was derived by analyzing the trends and characteristics of overseas metaverse research.

Papers were collected from Web of Science and ScienceDirect. The keyword (title, keyword, abstract) was searched with 'Metaverse', and a total of 230 articles were composed of data. Articles without keywords or irrelevant to the study were removed. If a word contains '-' or there is a typo, preprocessing was performed to unify it as 'Metaverse'. As a result, the final 208 papers were selected for analysis, excluding 22 papers. To identify the research trend, a frequency analysis of the study period was also performed. According to the publication period, the range is from 2004 to 2023, and the number and frequency of papers by research period were analyzed. The core research method of this study is topic modeling. Topic modeling is an algorithm that finds a topic in a large amount of unstructured data. It is a statistical technique that extracts topics based on embedded words and analyzes relationships to identify changes [14~15]. LDA, an algorithm for deriving key words, has been used the most because it is easy to interpret the results and is advantageous for topic deduction from large amounts of unstructured data [16]. However, topic modeling of the BERT model, which is excellent for natural language processing, has recently been in the spotlight. Bidirectional Encoder Representations Form Transformers (BERT) is a pre-trained model released by Google in 2018. Since then, it has been evaluated as a model that marked a milestone in this field, showing the best performance of natural language processing. It is based on a pre-trained model on a large amount of unlabeled data. In another labeled task, we use a model that has undergone a fine-tuning that readjusts the hi-parameters with additional training. This is because it refers to existing cases showing such high performance [17].

This study used Google's BERT model, which is a high-performance model for pre-training language representation. Based on Google Colaboratory, Python code was written, and data was analyzed. BERT uses an input embedding method based on the sum of Token, Segment, and Position. For this, distillbert-base-nli-mean-tokens is used, and the Uniform Manifold Approximation and Projection algorithm is used for embedding dimensionality reduction. In addition, we used the Hierarchical Density-Based Spatial Clustering of Applications with Noise algorithm for clustering embeddings and generating similar document clusters [17]. Finally, for the meaning analysis of the results of this study, two research themes were set and their meanings were analyzed. Research topic 1 is about the characteristics and meaning of overseas metaverse research according to the research period. Research Topic 2 is about the key keywords and themes of overseas metaverse research and what their meanings are.

4. RESULTS

4.1 Result of Frequency Analysis

As shown in Figure 1, the number of papers from 2004 to 2023 increased sharply in 2022. Before 2008, it was 1 or 2, but since 2009, it has been maintained at a certain level within 10. In addition, the number of papers increased rapidly in 2022. 127 papers were published in 2022 alone, which is about 1.7 times higher than the total before 2021 (76), showing a rapid increase in quantity during this time.

4.2 Result of Topic Modeling Analysis

Figure 2 shows 5 research topics (Topics 0 to 4) derived as a result of topic modeling. Also, as shown in Table 1, they appear to be related to the extracted 10 key keywords. Based on the number of related documents and keyword frequency of the 5 research topics, it is possible to understand how important each topic and keyword is being treated in the metaverse trend analysis study. Also, based on the derived topics and keywords, the keywords of the research topics were determined and marked for each topic.
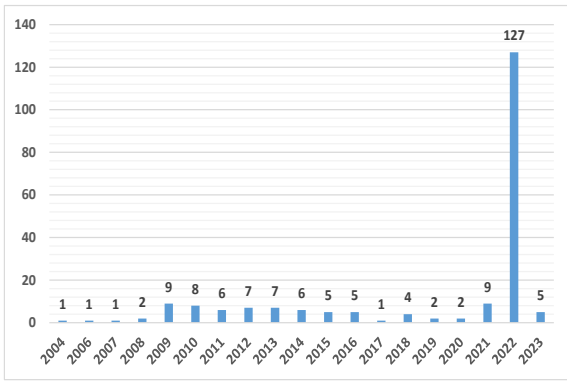
Figure 1. Number of metaverse-related papers by research period

Figure 2. 5 research topics and documents related to the metaverse

Table 1. 10 key keyword and frequency by research topic

No.	[Subject] Topic keyword (Frequency)	Count
0	[Second life & Education] second(18.7), life(18.2), learning(15.2), virtual(11.8), system(9.5), management(6.2), worlds(6.0), education(5.8), environments(5.5), elearning(5.5)	35
1	[Virtual Reality & Medical] reality(17.2), metaverse(15.6), virtual(12.3), augmented(9.7), medical(7.7), health(7.7), experience(7.2), medicine(7.3), design(6.1), nuclear(5.6)	27
2	[Blockchain & Cryptocurrency] blockchain(23.4), nft(14.4), metaverse(13.3), cryptocurrencies(8.4), returns(8.4), cryptocurrency(6.1), decentralization(6.1), abnormal(6.1), defi(6.1), playtoearn(6.1)	20
3	[Avatar & Interaction] avatar(18.8), affordance(13.6), 3d(13.3), audio(13.1), interaction(10.9), metaverse(10.0), duality(8.3), motion(8.3), enactive(8.3), actualization(8.3)	14
4	[Sensing & Device] tactile(15.6), control(11.7), sensors(9.0), additive(9.0), precision(9.0), device(9.0), thermal(9.0), sensing(9.0), displays(8.3), threedimensional(8.3)	12

Topic 0 is mainly research on 'Second life & Education'. The keywords that account for more than 10% are 'second(18.7)', 'life(18.2)', 'learning(15.2)', and 'virtual(11.8)'. Keywords such as 'education(5.8)' and 'elearning(5.5)' seem meaningful. In other words, it shows that the study on the expansion of the virtual world into the second living space occupies an important weight. Keywords related to 'education' or 'learning' totaled 26.5%. It can be shown that studies such as education, learning, and e-learning based on virtual environments occupy the main flow. Topic 1 is mainly research on 'Virtual Reality & Medical'. The keywords that account for about 10% or more are 'reality(17.2)' and 'virtual(12.3)'. Keywords such as 'augmented(9.7)', 'medical(7.7)', 'health(7.7)', and 'medicine(7.3)' seem meaningful. In other words, it shows that, along with general research on virtual reality or augmented reality, research on their application to medical care or health occupies an important part. In particular, keywords related to 'medical' or 'health' accounted for 22.7% of the total. It can be shown that these studies occupy the main trend. Topic 2 is mainly research on the topic of 'Blockchain & Cryptocurrency'. The keywords that account for more than about 10% are 'blockchain(23.4)' and 'nft(14.4)'. Keywords such as 'cryptocurrencies(8.4)', 'cryptocurrency(6.1)', and 'defi(6.1)' seem meaningful. In other words, it shows that research on the blockchain, which is essential for the reliability of

the virtual world called Metaverse, and cryptocurrencies, virtual finance, and nft, which are the core means of the Metaverse economy, occupy an important part. Keywords related to 'cryptocurrency' account for 26.7% of the total. It can be confirmed that these studies are treated as important and occupy the main trend. Topic 3 is mainly research on 'Avatar & Interaction'. The keywords that account for more than 10% are 'avatar(18.8)', 'affordance(13.6)', '3d(13.3)', and 'audio(13.1)'. Keywords such as 'interaction(10.9)' and 'motion(8.3)' seem meaningful. In other words, it shows that the study of avatar, a tool for communication between participants in the virtual world, or the study of their natural movement, etc., is important in implementing it in a 3D environment. Keywords related to 'interaction' accounted for 24.5% of the total, and keywords related to 'actualization' also accounted for 16.6%. It can be shown that research such as interaction and activation of objects in the virtual world is being treated as important, and it can be confirmed that it occupies a major flow. Topic 4 is mainly research on 'Sensing & Device'. The keywords that account for more than about 10% are 'tactile(15.6)' and 'control(11.7)'. Keywords such as 'sensors(9.0)', 'device(9.0)', 'sensing(9.0)', and 'displays(8.3)' seem meaningful. In other words, it shows that research on sensors for recognizing devices and objects such as VR, AR, and XR, which are key tools to feel the virtual world as reality, is important. Keywords related to 'sensor' totaled 18%, and keywords related to 'device' accounted for 17.3%, confirming that related research is being treated as important.

Additionally, a distance map showing the relationship between research topics was identified. As a result, the five research topics do not overlap each other and form an independent group. Nevertheless, they are located close to each other. Therefore, it is considered that there is a relationship between the themes, and it is assumed that there is a relative difference. As shown in Figure 3, it can be roughly divided into three groups. Group 1 consists of Topic 0 and 1 and forms the largest scale. This group is about 'Second Life & Education' and 'Virtual Reality & Medical' and is highly related to each other. As the virtual world expands into the second living space, it can be understood that the applied research on various activities such as education

Figure 3. Distance map of research topics

and medical care based on it is closely connected with each other. Group 3 consists of Topic 3 and 4. This group is related to 'Avatar & Interaction' and 'Sensing & Device'. It can be understood that research on sensing to feel the virtual world like reality and research on devices to interact with other participants such as avatars are closely connected with each other. Group 2 consists of Topic 2 alone. This group is about 'Blockchain & Cryptocurrency'. It can be understood because it is about the underlying technology such as blockchain or cryptography, separate from Group 1 and 3. Therefore, it can be shown that it is located at the center of Groups 1 and 3 and is an important link in these studies.
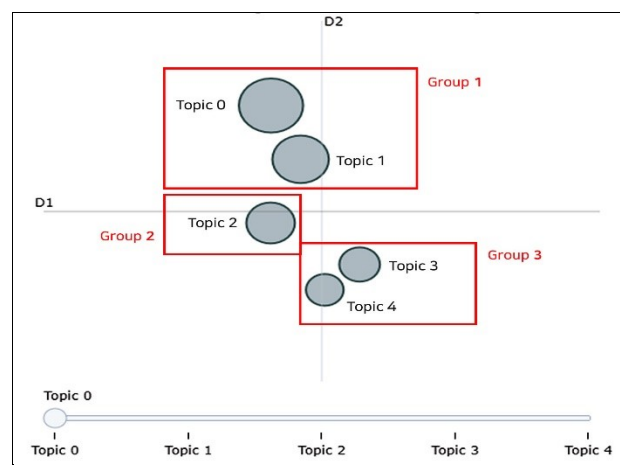
4.3 Result of Meaning Analysis for Research Subjects

Based on the results of 4.1 and 4.2, the meaning of two research topics was analyzed. First, metaverse trend analysis research increased in quantity in 2022. This is because interest in non-face-to-face services has increased rapidly due to the pandemic, and a new phase called Metaverse 2.0 has arrived [18]. According to Google Analytics, the number of searches for metaverse words increased more than ten times from 2020 to 2021 [19]. According to Statista, the market size of the metaverse is currently accelerating, and it is expected

to grow ninefold from $28 billion (about 31 trillion won) in 2021 to about $250 billion (about 280 trillion won) by 2028 [20]. Therefore, the current metaverse is the hottest issue at home and abroad and will be an attractive research topic. Second, in metaverse research, 'Second Life & Education' and 'Virtual Reality & Medical', which are Group 1 in terms of topics, are leading the flow of research quantitatively. It shows that the metaverse is about the connection with reality as a second life space. In addition, it can be understood that first, research to apply metaverse to education and medical fields is being conducted most actively. Education is the most urgent area after 2020 due to the non-face-to-face situation. Therefore, metaverse research will be needed more than any other domain. Medicine is a field with problems that are difficult to practice or experience. Therefore, implementation in an environment such as the metaverse has an important meaning. In addition, health-related experiences on the metaverse are highly marketable. Therefore, it can be understood that this study is necessary. The next largest Group 3 is 'Avatar & Interaction' and 'Sensing and Device'. This is because research on sensing to feel the virtual world like reality and research on devices to interact with other participants are very important for successful influx of participants into the metaverse. Lastly, Group 2 is 'Blockchain & Cryptocurrency'. Although it is the smallest in quantity, it is the most important factor to make the metaverse a reliable virtual world. In the digital environment, trust is a very important factor in common. However, the metaverse is connected to reality, so online behavior directly or indirectly affects offline. Therefore, research such as blockchain and cryptocurrency as a trust base for economic and social transaction behavior in the metaverse is qualitatively very important.

5. CONCLUSION

In this study, the characteristics and meanings were analyzed to find out how the interest in metaverse, which has risen rapidly after Pandemic 19, appears in foreign studies. A total of 331 papers were subjected to quantitative frequency analysis and topic modeling using metaverse as a keyword. As a result of the analysis, the metaverse study is characterized by a quantitative increase in 2022. This is because interest in non-face-to-face services has skyrocketed and the era of metaverse 2.0 has arrived. Second, topics such as 'Second Life & Education' and 'Virtual Reality & Medical' lead the quantitative flow. This is because an important and basic research is how the metaverse, the second living space, is connected to reality. Third, the most urgent areas of application are education and medical care. This is because research begins in areas with great practical difficulties in a pandemic situation.

Based on these results, implications for domestic application can be drawn. First, at this point, metaverse research tends to focus on application and utilization to replace difficulties in the real world. Second, research on the underlying technologies and devices for the success of the metaverse is being actively conducted. Therefore, it is necessary to identify commonalities and differences with international studies through trend analysis of domestic studies. If domestic research on the former is insufficient, it is necessary to consider the application plan considering the domestic environment. If domestic research on the latter is insufficient, it should be accepted and related research should be carried out quickly. New legal principles and discipline studies on the metaverse, which are insufficient studies in overseas studies, as well as research to predict new possible problems should be carried out together. This study analyzed the overseas research trends of Metaverse using topic modeling. It is expected that the research results will provide the right research direction for metaverse researchers in the era of digital transformation and contribute to the realization of a digital society.

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