

Exploration the future of the metaverse and smart cities

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ABSTRACT

The year 2021 is being called the first year of the metaverse which has been in the spotlight for more than a year. According to a report published on the website of the Spanish newspaper "The Economist", the metaverse is one of the most important technology trends in 2022. From the listing of Roblox on NASDAQ in the United States as the "first Metaverse stock", to the creation of a "Metaverse city" in Seoul, and then to the "inter-temporal interviews of Metaverse" conducted at the two sessions of the National Assembly in China. The discussion on metaverse has gradually expanded from the interpretation of the concept to the possibilities of related applications, and has shown a trend of diversification in terms of topics and subjects. Although metaverse research has become a popular research field in academic circles at home and abroad for less than a year, with the joint efforts of many scholars in many disciplinary fields at home and abroad, academic research on metaverse has made considerable progress with some innovative research findings. Metaverse is moving from conceptual construction and theoretical exploration to the rapid development stage of practical exploration and industrial application in parallel. From the perspective of the current situation of metaverse research, this paper systematically compares the hot spots of metaverse research at home and abroad, and on this basis, prospectively thinks about and explores the future trend of the integration and development of metaverse and smart cities, in order to provide some theoretical reference and inspiration for the current research of metaverse and smart cities.

Keywords: Metaverse, smart cities, development, virtual world, technology.

INTRODUCTION

Recently, the metaverse has exploded on the Internet field and is rapidly spreading to other fields. Many domestic and foreign technology companies are setting up in metaverse-related fields. For example, as early as March 2021, the "Sandbox" game platform "Roblox" included the metaverse concept in its prospectus for the first time, listed on the New York Stock Exchange in the United States, the closing price rose 54% on the first day and the market value exceeded 40 billion US dollars, becoming a "dark horse" in the international stock market, which has led to the strong rise of related metaverse technology concept stocks at home and abroad. In July 2021, Satya Nadella, Chairman and CEO of Microsoft, expressed his commitment to "build the enterprise metaverse". In October 2021, Facebook CEO Mark Zuckerberg announced the creation of "metaverse" product team, and later updated the name of the parent company to "Meta". In December 2021, Baidu released the first metaverse product "XiRang" in China; in addition, ByteDance relied on its huge product matrix to invest in the metaverse field; Tencent taken advantage of its design + content to layout the metaverse field; NVIDIA launched the Omniverse real-time simulation and collaboration platform for enterprises to build a shared virtual three-dimensional world, and game companies such as NetEase, MiHoYo and ZQGame are also laying out the metaverse field. Leading international consulting firms, represented by Bloomberg and PricewaterhouseCoopers, are bullish on the development and future of the metaverse. According to Bloomberg, the metaverse market will reach \$800 billion by 2024, while PwC estimates that the metaverse market will reach \$1.5 trillion by 2030. The metaverse-related topics are rapidly breaking the circle, and the market and social attention are extremely high. This shows that metaverse has become one of the hot topics in the society due to the attention of the society as soon as it appears. The era of "metaverse" is not in the future, but in the present.

THE ORIGIN AND CONCEPT OF THE METAVERSE

Source and Development of the Metaverse

The term "Metaverse" first appeared in the 1992 science fiction novel "Snow Crash" by the famous American science fiction writer Neal Stephenson, which refers to a three-dimensional space that is detached from and parallel to the real world. Users can live and work in the virtual world through "avatar" digital images, realizing online virtual world interaction. Through the publicity of "Snow Crash", a virtual network world parallel to the real world, the "metaverse", was gradually accepted by science fiction writers. The book's vision of a virtual technological society opened the door to the imagination of people. However, neither the author nor the reviewer could have foreseen that thirty years later the concept of the metaverse presented in this book would create a powerful shockwave.



Source: This study.

Figure 1: Development timeline of the Metaverse

The metaverse was gradually established in science fiction films, and another virtual world was described in 1999's "The Matrix". Tron, released in 2010, refined and described the previously mentioned virtual world in more detail. The concept of the metaverse became well known to the public through the science fiction film "Ready Player One" directed by Spielberg, in which the metaverse becomes part of a future human society, and those who are unmotivated in reality use the metaverse to vent and express themselves. The metaverse has also been fully reflected in many games, such as, in 2003, Linden Lab's game "Second Life", which describes a groundbreaking and phenomenal virtual world where players can socialize, shop, build and do business. It is no longer just a game, but has a richer and more developed virtual economic system. For example, "Ninth City", "My World", "Village of Hope", "Second Galaxy" and other metaverse concepts are in full swing. Since the birth of the metaverse, the metaverse scene has been continuously refined and deepened (Figure 1). The ideal metaverse is no longer

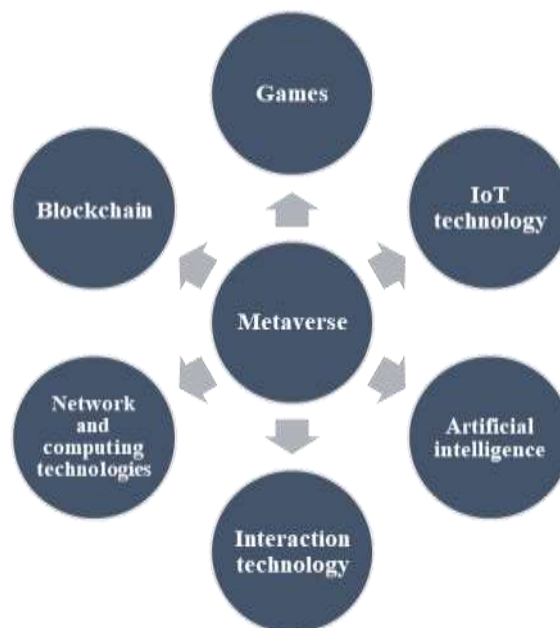
limited to entertainment, commerce, and social, but is more likely to be infinite in scope, and these systems form a relatively complete society with each other.

Concept of the Metaverse

There is no unified concept of what the "metaverse" is, and the Internet giants have different interpretations. Mark Zuckerberg's "metaverse" is a combination of the real and the virtual, making the world less distant. NVIDIA's "metaverse" is to move the real world into the virtual world, to improve the planning and practical efficiency of the industry through complete replication. MiHoYo's vision of the 'metaverse' is the continuation of a living society. Roblox sees the "metaverse" as consisting of eight elements: identity, friends, immersion, low latency, diversity, anywhere and anytime, economic system, and civilization. The "metaverse" is a virtual space parallel to and independent of the real world, an online virtual world that maps the real world, and an increasingly realistic digital virtual world.

The New Media Research Center of School of Journalism and Communication of Tsinghua University published a research report on the development of metaverse from 2020 to 2021, which gave a relatively regular definition of "metaverse": the so-called metaverse refers to a new type of Internet application and social form that integrates virtual space technology, artificial intelligence technology, interaction technology, blockchain technology and other new technologies. It is based on extended reality technology to provide immersive experiences, and digital twin technology to generate a mirror image of the real world, and blockchain technology to build an economic system that closely integrates the virtual world with the real world in the economic system, social system, and identity system, and allows each user to produce and edit content. With the explosive growth of cyberspace and the rapid development of extended reality devices, especially under the influence of COVID-19, virtual space offers the possibility of socialization, making the boundary between physical and virtual space increasingly blurred.

"The metaverse is not a technology per se, but an idea and a concept that requires the integration of different new technologies, and the main core technologies of the 'metaverse' are the following (Figure 2).



Source: This study.

Figure 2: Overview plot of metaverse.

Games: the initial landing scene for the metaverse

The game is widely considered to be the initial gateway to the metaverse, giving players a virtual identity, and players can rely on this identity to socialize within the game, which taking on the beginnings of a metaverse.

Blockchain: the underlying architecture to achieve a decentralized economic system

The metaverse requires the construction of its own independent economic system. Blockchain technology can realize the flow of value within the metaverse through smart contracts, and guarantee the transparent and efficient implementation of system rules.

Network and computing technologies: 5G/6G and edge computing for low latency

The metaverse requires high synchronization and low latency so that users can have a perfect experience in real time and smoothness. The metaverse requires rapid transmission of large amounts of data and relies on a strong communication infrastructure. Limited by the number of base stations, the actual transmission rate of 5G may be difficult to reach its design

level, while according to the Japanese and Korean outlook on 6G network technology, 6G latency is expected to be reduced to one-tenth of 5G and transmission rate is expected to reach 50 times of 5G, which is expected to truly realize the key feature of low latency in the metaverse. In addition, edge computing is often considered a key infrastructure of the metaverse, which helps end users to replenish local computing power, improve processing efficiency, and minimize the risk of network latency and network congestion by adopting an open platform near the source of data and providing the nearest end of the service directly nearby.

Interaction technology: improve user immersion, metaverse must go through

From the early mouse and keyboard to the current VR/AR devices, the operation mode of the game continues to evolve. Through a variety of devices such as body suits and fully automatic haptic chairs, which collect player information and output feedback information to players in real time, players have a more realistic sense of mapping in the virtual space, thus gaining an immersive experience. The ultimate form of development is to realize perceptual experiences such as smell and taste through brain-computer interface technology, while freely interacting with the virtual world, significantly enhancing the realistic experience and immersion.

Artificial intelligence: a supporting technology for building virtual worlds

The development of computer vision, machine learning, natural language processing and intelligent speech have provided the metaverse with a combined virtual and realistic view, making the metaverse with diversity and immersion.

IoT technology: meeting the demand for diversified ways to access the metaverse

IoT technology can meet the requirements of accessing the metaverse in various ways anytime and anywhere, while providing support for the metaverse to sense external sources of information. One of the requirements of the metaverse is easy access, so the way people interact with the Internet will not be limited to mobile phones and computers, but various wearable devices, cars, homes, etc. will be connected to the network. In addition, IoT sensors are an extension of the human senses, which can ensure that the metaverse world captures more information about the outside world.

CURRENT RESEARCH AND APPLICATIONS OF METAVERSE

The Study of Metaverse

Since the first year of the Metaverse in 2021, scholars at home and abroad have conducted extensive research on metaverse, which mainly covers three aspects (Table 1).

Table 1: Research on metaverse.

Research Themes	Research Content	Representative Studies
The study of the metaverse ontology	It mainly refers to research on the concept, mode, technology and other aspects of the metaverse, which is the main topic of interest for scholars in the early years.	Wright et al. propose that metaverse constitutes a new type of augmented reality interaction space through the contact and overlap of numerous nodes in the virtual and the real. Lingzhi Fang et al. argue that metaverse is the inevitable trend of social informatization and virtualization is the ultimate stage of Internet development.
Theoretical study of the metaverse	It mainly refers to study of the specific representation in the metaverse of theoretical models constructed in traditional settings.	(a) Conducting research from two main subjects, users and information, can help improve the understanding of the information behaviour of metaverse users and thus facilitate the promotion of metaverse applications. (b) Comparing the governance structures of four different levels of interconnection based on incomplete contract theory can provide policy recommendations for metaverse governance through the analysis of the optimal order of the metaverse.
Applied research of the metaverse	It primarily refers to the study of the impact of the formation and development of the metaverse in various fields.	The application of metaverse in education, entertainment, business, politics and other scenarios has been widely explored by scholars at home and abroad. However, most of the existing studies have been discussed at the level of theoretical framework, and there is a relative lack of research exploring the path of metaverse realization from the perspective of needs.

Source: This study.

Application of Metaverse

Recently, the "metaverse" has become the new favorite of the industry and capital market. A large number of companies claiming to switch to the "metaverse" and various capitals pouring in. The "metaverse" has instantly become a new hot spot in the Internet industry.

At present, the development of "metaverse" technology is still in its infancy, and it is necessary to take a rational and pragmatic view of the application of "metaverse" technology and the changes that may be brought about by its future development. The application of metaverse is a process that will continue to deepen with the development of technology. In the short term, providing immersive experience services for users in the fields of social entertainment, cultural and tourism activities, education and training will be the main application scenarios of "metaverse" technology. In the medium term, providing technology simulation platform for technology research and development will probably be the main application scenario of "metaverse" technology. In the long term, advanced exploration research in life sciences, material sciences, marine sciences, earth and space sciences, and information sciences will likely be an important use of "metaverse" technology. The "metaverse" can upgrade the existing industry formats. From "Internet+", "Big Data+", "Artificial Intelligence+" to "Metaverse+", the development and application of "metaverse" technology will definitely bring about a revolution in the mode of integration of information technology and economy and society.

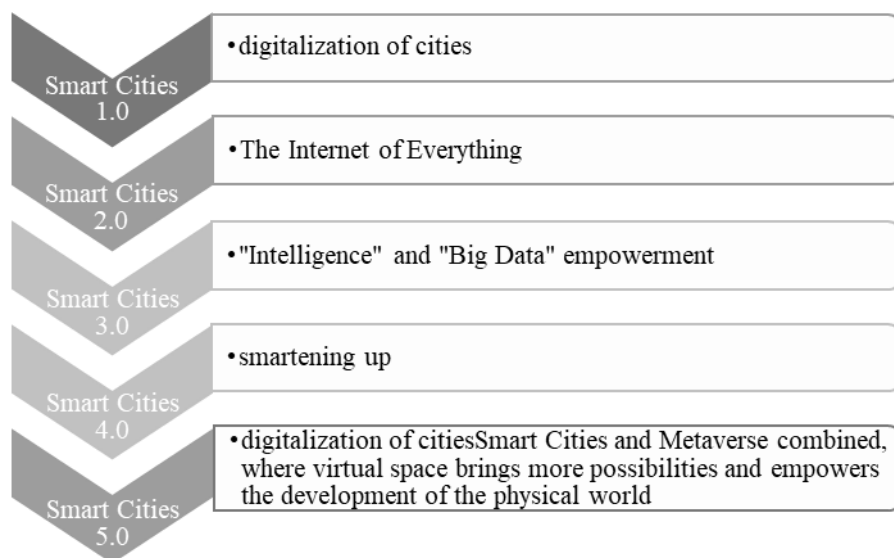
The development and promotion of "metaverse" technology requires consideration of various factors. Firstly, in the process of expanding the "metaverse" scenario, it is necessary to dig deeper into the "metaverse" application scenarios that have the effects of technology application substitution and service comprehensiveness. Do not ignore user experience, social value, economic value and regulatory boundaries without understanding the needs. Secondly, it is important to strengthen technological innovation. The emergence of "metaverse" is the result of information technology development and application innovation, so we should continue to innovate in information perception, data processing, data modeling, software definition, virtual reality simulation, scene rendering, artificial intelligence, information security and other related technological innovation, and promote the in-depth integration and application of related technologies in the metaverse environment. Thirdly, in addition to social value, the development and application of "metaverse" technologies must consider the economic value of the application of practical scenarios, and need to take into account both short-term and long-term input-output ratios.

EXPLORE THE NEW WAYS OF METAVERSE AND SMART CITIES

The root cause of the metaverse explosion is that it brings unlimited imagination to people. The boom of smart cities construction is in the ascendant. The explosion of the metaverse concept will certainly inject new vitality into smart cities, open up more application scenarios for smart cities and push them forward. The metaverse is a completely new concept, and there are still too many unknowns and uncertainties about its development direction after combining with smart cities. However, there is no doubt that the combination of smart cities and metaverse is an inevitable trend. This paper discusses the issues involved in the evolution of metaverse and smart cities, future technologies and future application scenarios.

The Development History of Smart Cities

The current smart cities can be divided into four stages according to its degree of development, and will enter the fifth stage in the future (Figure 3).



Source: This study.

Figure 3: Development stage of smart cities.

Advantages of Metaverse Applied to Smart Cities

From digitalization to intelligence to wisdom, the integration of cutting-edge technologies and smart cities has become inevitable, and technology has become an important means to enhance the effectiveness of smart cities. How to use metaverse technology is a new trend in the construction and development of smart cities (Figure 4).



Source: Baidu pictures.
Figure 4: Metaverse and smart cities.

Since users in the metaverse will interact in the digital space as virtual images, a large number of problems in the real world can be avoided. The advantages of metaverse applied to smart cities include: (1) better accessibility, so that users in different physical locations can enjoy the same information and experience; (2) better diversity, so that different user groups can enjoy a space to get along with each other free from physical resources; (3) better equality, so that users of different races, colors, and languages can enjoy equal opportunities for development; (4) better humanity, so that human culture to be passed on in a more healthy and perpetual way. More importantly, the metaverse may be an important infrastructure for future technological innovation.

Application of Metaverse in Smart Cities
Urban planning and construction

The metaverse can improve scientific planning and smart construction of cities (Figure 5). The metaverse is a natural, dynamic and scientific virtual experiment site that provides an operable path for realistic smart cities construction. Using real city information and social multi-dimensional data to replicate the city in the metaverse, city residents are invited to live virtually in a city with different scenarios to flexibly preview planning effects and to discover planning problems and defects in advance, so that multiple scenarios can be compared, researched, optimized and selected. After determining the suitable planning scheme for the city, the city builder can present the details of the public facilities layout, building structure, greenery planting, etc. of the city construction in the metaverse before the construction starts, and even deduce the possible urban problems that may arise during the construction process for the reference of engineers, builders and managers, and create a precise, dynamic, stakeholder-engaged and sustainable smart cities.



Source: Baidu pictures.
Figure 5: Urban planning and construction in metaverse.

Economic development

Through the coordinated development of the metaverse and the smart city, the virtual goods of the metaverse can, to a certain extent, not only replace the goods in the physical world, but its functionality even exceeds that of the goods in the physical world. The goods in the metaverse thus developed have a huge imagination, so that the total economic volume will no longer be only the quantity of the physical world, but also add the scale of the metaverse economy. Moreover, the pollution and carbon emissions of the physical world would be mitigated to some extent by the partial substitution of the metaverse. Thus the metaverse economy will expand and contribute to the economic development of smart cities (Figure 6).



Source: Baidu pictures.

Figure 6: Economic development in metaverse.

Daily life and education

Life and education in the physical world will be partially transferred to the metaverse and smart cities. With the development of smart cities, people's travel will gradually decrease, and many tasks can be done at home. As a result, transportation will be improved, and the use of water, electricity, gas, etc. will become more predictable. The knowledge and culture of the real world will be reflected in the metaverse, and the new knowledge and culture will be created in the metaverse. The development of the metaverse and smart cities will bring a new way of life and unprecedented experiences to humanity.

Smart City Operations and Emergency Events

The metaverse is a virtual space that runs parallel to the physical world. As a mapping of the physical world, it has the function of simulating the operation of the city. Problems that we cannot perceive or capture in the real world are more easily to be detected in the virtual world, and thus get early warning. In the metaverse, the simulation of urban production, management and other issues, allowing people to anticipate the development of situation and thus make scientific decisions; it simulates real emergency events such as earthquakes, fires, floods and viruses, etc., truly reflecting the tense and critical real scenes in emergency events and the immediate response of personnel, strengthening urban emergency response capabilities and urban resilience. For example, the current global COVID-19 epidemic facing the world, through the metaverse and smart city system, can better deploy epidemic prevention measures to bring the epidemic under control as early as possible.

Future Technology Outlook of Metaverse and Smart Cities

The metaverse and smart cities have unlimited potential for development, but they also depend on the support of future technologies (Figure 7). Current promising future technologies include: 1. Computing platforms, such as quantum computing and biocomputing, etc., provide arithmetic support for the continued development of the metaverse. A metaverse city is an interconnected space, and interconnections in future metaverse city will be more efficient than current networks. However, the network in the metaverse relies on the network of the physical world. At the same time, the communication between the metaverse and the physical world also depends on the network of the physical world. China's 5G network technology and network construction have been in the world's leading position, which has laid a good foundation for the development of metaverse cities, but 5G technology can only support the beginning of the metaverse, and in the subsequent development stages of the metaverse, the requirements for the network will be substantially improved essentially higher. 2. Brain-machine interface, the maturity of brain-machine interface technology means not only the connection between the brain and the machine, but also means that the machine can read, understand and even store the information of the brain, the significance of which is self-evident.



Source: Baidu pictures.

Figure 7: Metaverse technology and smart cities.

The promotion of metaverse to smart city

For the "metaverse", which highly virtualizes the world, social, economic, political, cultural and living systems in human civilization will gradually shift to the virtual world. By extension, the virtualized and digitalized products derived from the diversified applications of various industries will affect the development of the entire "metaverse" world. In a nutshell, the "metaverse" will profoundly change the organization and operation of the existing society by integrating the virtual and the real, forming a new way of life with both virtual and real, and giving rise to a new type of smart city that is integrated online and offline.

- The development of metaverse technology is conducive to the development trend of multi-governance of smart cities. In the metaverse, diversified urban subjects can observe, participate and experience various aspects of urban planning, urban construction, urban management and urban operation from different perspectives, simulating the gaming and cooperation process of each subject in urban operation, presenting an urban operation model that approximates the real world, and discovering the inner connections and laws, implicit order and influence mechanism of cities and people. Even city residents can create their own ideal cities and apply their own urban governance solutions in the metaverse. City policy makers and managers can then bring together the wisdom of the people to take advantage of their strengths, optimize urban construction and innovate urban governance models. The metaverse emphasizes human participation, and people can add new dimensions and domains in the meta-universe to extend the real physical world and create virtual worlds, which helps cities to improve and adaptively optimize, provides accurate and realistic experimental data and governance basis for real-world smart cities, and provides solutions to dilemmas encountered in smart city construction.
- The realistic nature of the metaverse makes it convenient for virtual-real interaction in the realization of smart cities. The metaverse replicates reality in the virtual, and the realization of scenario functions such as ready login, low latency, immersion, strong sociality, free trade, and free creation makes it possible to build a realistic human society in the metaverse. All city issues can be fully mapped in the metaverse, and managers and city residents can live in it. A stable monetary system, a pluralistic cultural system, a free and open social environment, and immersive user participation in the metaverse are the basic operational framework of human society. In this framework, city residents can participate in the virtual-real interaction and interactive feedback of the urban system at multiple levels through the changes in space and time in the virtual city. By observing the dynamics of events in the meta universe, we can discover the changes of situation in advance, simulate the problem disposal process, and provide a feasible pre-treatment scheme for the real world. So as to formulate the overall optimal response strategy for the urban problems in the real world in advance, and realize the overall unified scheduling and collaborative governance of the city.

CONCLUSION

The focus of smart cities is on smart driving, restructuring smart technologies and governance scenarios to alleviate urban problems so as to achieve harmonious coexistence between people and cities. Metaverse technology plays an important role in promoting the development of smart cities. Exploring the intelligent governance of "metaverse + smart city" carries human thinking about urban governance model and the vision of the future shape of the city. The metaverse provides a step-by-step path for human imagination of the future city. It should be pointed out that the metaverse is still in its initial stage. On the one hand, the full realization of the metaverse requires further technological improvement, strengthening the integration and complementation of multiple technologies and smart cities, and reasonably grasping virtual and reality. On the other hand, in a technology-driven smart city, people play a leading role in the application of technology. However, due to differences in human thinking, cognition, and interests, there is often significant uncertainty and ambiguity in the application of technology. How to coordinate the relationship between people, technology and cities in smart cities is a topic worthy of in-depth study. At present, the concrete realization path of metaverse and smart cities is still in the exploration stage, and there is still a long way to go in the future.

At this stage, the "metaverse" is still in the stage of exploration and experimentation. "Metaverse" is more of a concept for various application areas, which needs to be studied and researched, and deeply understood and innovated in the process of practice. A large number of high-tech companies have already invested large amount of money on research and development to prepare for the technology. The development of metaverse and smart cities is to better empower the real economy and make up for the shortcomings of the physical world. The metaverse has unlimited imagination, and its integration with smart cities has a promising future and will shape new production and life styles as well as a new social form [4-5], and the "metaverse" provides a new path for the ultimate realization of smart cities.

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