Metaverse Concepts and Application Scenarios: Research and Market Postprint

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Abstract

This paper reviews academic literature and technical reports from both domestic and international sources, outlines the evolution of the "metaverse" concept, and surveys the application status of key metaverse technologies from the past and present. This paper contends that a salient characteristic of the conceptual evolution of the "metaverse" is its continuously strengthening comprehensiveness since inception, while newly emerging technologies continuously feed back into and expand the blueprint of the "metaverse" . Regarding technological innovation, while maintaining an optimistic outlook, attention should also be paid to the tensions that arise when they are integrated with existing social architectures.

Full Text

The Concept and Application Scenarios of the Metaverse: Research and Market

The Metaverse has garnered widespread attention in recent years, particularly in mid-2021 when Facebook, the world' s largest social media platform, rebranded as Meta. This event captured the interest not only of technologists and academics but also of the general public. This paper aims to clarify the current meaning of this concept, examine how it is being presented to consumers, and explore what forms of Metaverse scenarios its proponents are envisioning.

1.1.1 Networking, Platforms, Virtuality, and Collaboration

After considering the comprehensive meaning and purpose of the literature, this paper categorizes existing Metaverse research into three types: technical, effects-based, and popular science. Among these, articles indexed in SSCI or SCI journals found on Google Scholar are largely limited to the first two categories

—technical and effects-based—while other literature primarily consists of popular science articles aimed at technology enthusiasts and the general public. Technical articles tend to focus on defining the Metaverse itself or establishing definitions for academic rigor, often proposing new technical architectures based on existing feasible technologies. Effects-based research, by contrast, examines whether participants' emotions, understanding, interactions, and behaviors such as learning differ in the Metaverse compared to reality.

Although engineers from different industries frequently describe the Metaverse as a "network" or "collection" in technical literature, their interpretations vary. For instance, engineers and scientists developing immersive training systems for U.S. military pilots are more inclined to view the Metaverse as a collection of virtual spaces or "immersive environments," with the primary goal of enhancing participants' ability to communicate and collaborate across different virtual spaces. Scientists focused on human-computer interaction design, however, emphasize the interoperability and adaptability between networked "virtual spaces" in the Metaverse—the ability for items users create and produce to be replicated or transferred regardless of which virtual world they belong to. From this perspective, the Metaverse represents the continuous strengthening of networking and collaboration capabilities for both virtual spaces and their internal assets (such as virtual artworks, virtual pets, artificial intelligence, and cryptocurrencies).

Examining the Metaverse concept chronologically risks deconstructing it. Google Scholar shows only six results using the term "Metaverse" between 1980 and 1990, with only one article on virtual environment development relevant by today' s standards. Between 1990 and 1995, there were 45 results, most of which considered the emerging internet as the "Metaverse," primarily from magazines rather than academic journals—similar in nature to today' s "36Kr" or overseas publications like *Wired*. From 1995 to 2000, academic (or more precisely, technical) discussions about Metaverse design began appearing in academic conference proceedings, coinciding with U.S. military-sponsored discussions on immersive systems. While this study does not specifically investigate the temporal relationship or causality between these two literature streams, this observation invites consideration of the view that "the use and proposal of the Metaverse concept represent humanity' s desire to conquer time and space." Both the emergence of the internet and the development of immersive systems reflect, in some sense, humanity' s desire to traverse, search, and control any time and place.

This study does not aim to address broad questions such as "What developments have occurred in humanity' s creation of virtual reality environments that transcend temporal and spatial limitations and enable collaboration?" Instead, its primary purpose is to review the evolution of the Metaverse concept and its associated application technologies and scenarios. The following sections will address a series of concepts that have rapidly developed and may not be widely known to the public—yet this is precisely the clever and valuable aspect of the

Metaverse: its blueprint-like concept has exceptional inclusivity, encompassing ideas and technologies such as VR, AR, MR, virtual creation, interactive systems, system accessories, system standards, virtual currencies, cryptocurrencies, NFTs, and digital twins. This paper aims to collect, organize, analyze, and present various perspectives on these developments.

1.1.2 Conceptual Enumerations in Chinese Literature and Reports

Currently, Chinese academia has not yet formed a unified, clear definition of the Metaverse. Related research primarily approaches the concept from technological and industrial perspectives, providing general explanations of its core connotations. Scholar Shen Yang defines the Metaverse as an internet application and social form that integrates virtual and real worlds in economic, social, and identity systems based on extended reality, digital twins, and blockchain technology, allowing users to produce content. Chen Gang and Dong Haoyu define it as a virtual world that maps and interacts with the real world using technology, featuring a completely new social operating system. Additionally, the "2020-2021 Metaverse Development Research Report" released by Tsinghua University' s New Media Research Center summarizes five key characteristics of the Metaverse: integration of virtual and real, UGC (user-generated content) as the main body, embodied interaction, unified identity, and economic system. Huatai Securities' "Metaverse Deep Report" also identifies four core attributes: synchronization and high fidelity with the real world, open-source openness and creative innovation, sustainable development, and a closed-loop economic system.

Evidently, both academia and industry have engaged in extensive discussions about the Metaverse concept. As a new concept integrating virtual and real worlds, the Metaverse—despite some bubble-like hype—holds promise to bring a new round of information technology revolution to human society.

2.1.1 Digital Twins

Since the Metaverse became a hot topic, its applications in gaming and social networking have been widely discussed. Users can create their virtual avatars in the Metaverse, with digital twins serving as the underlying technical logic. First proposed by scholar Grieves in a product lifecycle management course at the University of Michigan, digital twins are also known as the "mirrored space model." Scholar Shen Yang argues that digital twin technology can mirror the real world into virtual worlds, making it the core technology for constructing the Metaverse as a "pseudo-environment" and a product of the fusion between virtual and real worlds. Building on McLuhan' s view that "media are extensions of human senses," scholar Zhang Hongzhong points out that with digital twin technology support, users' digital avatars can engage in socializing, entertainment, shopping, sports, and other activities, while bodily organs become extensions of multiple media in the Metaverse. In the future, digital twin technology will further promote the development of bioengineering, not only replicating bod-

ies in virtual worlds but eventually importing human consciousness into virtual spaces. Thus, digital twins are gradually becoming the technical foundation for humanity' s digital existence.

However, current digital twin technology remains immature, with high technical barriers and expensive computing, storage, and bandwidth costs that deter most enterprises. With the continuous development of 5G, AI, VR/AR/MR, and brain-computer interface technologies, digital twin technology will gradually improve, significantly reducing the cost of building the Metaverse and further enhancing the fidelity of digital worlds to reality.

2.1.2 The "Embodiment" of AI

In the Metaverse, virtual avatars possess dual attributes of "objects" and "people," which will compete and gradually merge as the Metaverse develops. These avatars accelerate the process of human-machine symbiosis and represent a key step in the embodied development of artificial intelligence. Due to the decentralized nature of Metaverse social systems, virtual humans lack regulation and constraints in digital worlds. Digital spaces overturn existing moral and legal frameworks of the real world, amplifying individual freedom and making users increasingly "willful," leading to moral anomie and distortion.

Moreover, virtual items in the Metaverse—such as virtual property, currency, and real estate—often deviate from their intrinsic value after commercial hype. Without support from real value, prices of virtual items in the Metaverse are easily manipulated, with speculative activities carrying risks such as false assets and investment hype. Virtual currency transactions also generate credit risks, technical risks, illegal transaction risks, and devaluation risks. These issues create opportunities for unscrupulous businesses and represent gray areas that the Metaverse industry must combat.

2.1.3 Concretization of Online Social Networking

In the Metaverse, users can create digital identities for social activities. For example, the social application Soul has built a "social Metaverse" that relies on virtual avatar design to provide users with immersive social experiences. Digital identity gives users stronger immersion during social interactions and reduces social barriers caused by physical distance and social status. Therefore, Metaverse social networking based on digital identity enriches online social experiences to some extent.

Unlike the real world, where users can have multiple different digital identities in the Metaverse, raising issues of user credibility. Blockchain technology, with its decentralized, tamper-proof, and traceable characteristics, can ensure that user-generated digital identities are not tampered with and remain unique, thereby guaranteeing digital identity authentication in the Metaverse—including the integrity and trustworthiness of user identity information—and forming a unique virtual avatar corresponding to the real user. Some scholars argue that after

ensuring identity and credibility, the most important aspect of Metaverse social networking is rich sensory experiences. Due to the immersive nature of virtual reality, users can have relatively rich sensory experiences when socializing in the Metaverse. Specifically, in Metaverse scenarios, users can transform "conscious thoughts" into "sensory accessibility," creating diverse social settings such as cafes, restaurants, and bars to enrich their social experiences.

In summary, the Metaverse makes online social networking more concrete and three-dimensional through identity, credibility, and sensory experience. Nevertheless, credit and security issues in Metaverse social networking still require attention, particularly the immersive experiences that blur the line between real and virtual, providing opportunities for social fraud.

2.2.1 Office Work

The COVID-19 pandemic has dramatically transformed people's production and lifestyles, shifting workplaces from offline to online. Metaverse offices are more interactive, allowing users to observe each other' s expressions, body language, and movements through virtual avatars beyond flat text and profile pictures. For example, Meta' s Horizon Workrooms enables users wearing Oculus Quest 2 headsets to create their own avatars and customize appearances through facial recognition and "face-pinching" features.

If we examine virtual avatars in the Metaverse through their "human" attributes, their ethical standards differ from those in the real world. Microsoft' s Mesh for Teams allows users to customize digital avatars and enables enterprises to establish their own Metaverse offices. Baidu' s Xi Rang VR platform allows employees to collaborate and communicate in the Metaverse and hosted China' s first Metaverse conference. Additionally, NVIDIA launched Omniverse to provide users with high-quality remote collaborative office solutions.

Compared to text and image-based platforms like Tencent Meeting and DingTalk, Metaverse meetings using virtual avatars more closely approximate natural human communication. On the other hand, Metaverse offices can save work costs, allowing employees to collaborate without leaving home.

Although Metaverse applications in the office sector are relatively mature, companies must still consider how to maintain employee interaction in virtual offices, how to organize and coordinate in virtual spaces, and how to establish employee relationships and evaluation mechanisms before entering the Metaverse. Additionally, using Metaverse technology for business meetings requires high bandwidth and data flow, making poor meeting fluidity a significant challenge. Future Metaverse office implementation will depend on communication technology development for support.

2.2.2 Metaverse Empowering Education Toward Contextualization

During the COVID-19 pandemic, online teaching became normalized, indicating the integration of the objective knowledge world with the subjective virtual world. The application of "Metaverse + Education" further facilitates this trend. Metaverse classrooms enable teachers and students to interact in virtual scenarios, providing new development opportunities for online education and advancing it toward experiential learning and immersive interaction, where visual immersion and artificial intelligence merge. Metaverse technology promotes immersive educational experiences, contextualizing knowledge from the objective world into situated knowledge.

Due to its immersive nature, the Metaverse is suitable for guiding students in immersive learning, constructing authentic teaching scenarios that allow students to truly focus on class. For example, when offering humanities and social science courses, Metaverse teaching can enable students to transcend time and space, engaging in dialogue with historical figures and deeply experiencing the charm of humanities disciplines.

Simultaneously, the Metaverse empowers scientific research and innovation training. Teachers and students can conduct teaching and experiments in virtual environments, reducing research costs and experimental risks. Professor Shi Yuanchun of Tsinghua University stated, "Metaverse technology helps save education costs and can reduce experimental losses to some extent." Currently, Metaverse teaching still relies on specialized platforms. For instance, the National Virtual Simulation Experimental Teaching Project Sharing Service Platform (http://www.ilab-x.com), funded by the Ministry of Education, represents a typical case of "Metaverse + Education."

However, Metaverse education remains in the trial stage, with several issues requiring resolution. For example, whether students can achieve teaching-level experience quality in Metaverse education and how specialized platforms can be popularized across schools require collaborative efforts from all parties. Therefore, the transformation of existing education models by Metaverse technology remains at the imagination and experimentation stage.

2.2.3 Healthcare

Metaverse applications in healthcare primarily leverage XR technology characteristics, using virtual-real interaction to manage actual medical processes, train medical personnel, and experiment with and evaluate medical decisions and behaviors, providing possibilities for further digitization, parallelization, and intelligentization of healthcare systems. As is well known, surgery, a critical component of healthcare, requires doctors to undergo repeated clinical training to master. In the real world, minimizing surgical risks has long troubled the medical community. Metaverse technology significantly reduces surgical risks, allowing doctors to conduct repeated simulation experiments in virtual environments while also providing targeted guidance for ongoing surgeries.

Currently, in the "Metaverse + Healthcare" industry, Surgical Theater uses XR technology to provide doctors and patients with immersive, multi-perspective anatomical structure views, addressing surgeons' visual blind spots in real operations. Meanwhile, Microsoft has applied virtual reality technology to healthcare. The HoloLens 2, a head-mounted device developed by Microsoft, can be used by doctors before, during, and after surgery. The device can display holographic projections of organs in front of doctors during operations and real-time monitoring and analysis of patients' physical indicators and data, effectively reducing time costs and avoiding surgical complications to some extent.

In summary, the "Metaverse + Healthcare" model can improve doctors' efficiency and precision while minimizing risks caused by operational errors, potentially revolutionizing the healthcare industry. Currently, due to cost and technical limitations, the Metaverse has not been deployed on a large scale in healthcare, but its potential benefits are considerable.

2.3 Content Rating in the Metaverse

In the all-encompassing Metaverse, regulating harmful content is a primary concern. Currently, most platforms still hope to attract user traffic through stimulating and novel content. Since the rise of virtual reality technology, the pornography industry has applied it, seeking to leverage the rich sensory experiences that the Metaverse and XR technology provide to attract users. Additionally, due to reduced constraints in the Metaverse, the pornography industry aims to capture market share under the banner of hedonism. Some scholars argue that gray industries in the Metaverse often induce users with sexual content, causing them to lose mechanisms for personality development and moral correction in desire-amplified virtual worlds.

Because the Metaverse possesses a certain degree of realism, users sometimes cannot distinguish between real and virtual, particularly regarding violent games in virtual reality. Virtual violence may potentially influence users' real-world behavior, raising the risk of increased crime rates. Research by scholars indicates that immersion amplifies the impact of violent games, making players angrier. Therefore, violent scenarios in virtual reality face moral and ethical considerations, and deeper immersion will likely make the aggression-inducing effects of violent games more pronounced.

Financial security and bubbles in the Metaverse industry also require vigilance from enterprises and businesses. Following Facebook' s rebranding to Meta and Roblox' s listing as the first Metaverse concept stock—its share price rising 54.4% on its first trading day—2021 has been called the "first year of the Metaverse," igniting fervor in this track and attracting massive capital inflow. Despite the enthusiasm for this trending concept, hype remains a concern. With rapid integration of talent resources, small, medium, and large enterprises must guard against financial speculation in the Metaverse and view this new concept rationally.

Therefore, enterprises and businesses need to examine and identify risky content, and relevant institutions must promptly establish and improve content rating systems to safeguard the Metaverse industry.

2.4.1 Changes in Real Economy Composition

The advent of the Metaverse economy has increased the integration of digital economy into the real economy. The difference between Metaverse economy and real economy lies in the replacement of traditional production factors like land and population with digital resources. In contrast, the Metaverse economy relies on data, human capital, technology, and financial capital. Fundamentally, however, the Metaverse economy remains a simulation of real economic and social scenarios. Therefore, real economy and Metaverse economy development are not contradictory; the Metaverse economy can empower the real economy, enabling it to enter new spaces and expand into new markets. For example, Republic Realm spent approximately $4.3 million to purchase virtual land in the Sandbox game, making Metaverse real estate popular and sought after by many businesses. This demonstrates how the Metaverse promotes further digital transformation of the real economy.

However, compared to the real economy, the Metaverse economy still faces risks and challenges, including capital manipulation, opinion bubbles, privacy leakage risks, moral and ethical risks, and legislative and regulatory gaps. To address these issues, relevant departments must urgently establish relevant laws and regulations to safeguard the Metaverse economy.

In summary, the Metaverse economy has facilitated changes in real economy composition, with production factors gradually shifting to the digital world. Fundamentally, however, the Metaverse economy is not disconnected from the real economy; they integrate and develop together.

2.4.2 Forms of Online Commodity Markets

Currency and Virtual Property. As mentioned above, the Metaverse concept attempts to encompass numerous types of human activity domains, and modern human activities are inseparable from economic and financial frameworks. This means these Metaverse domains also need to imitate existing economic models and concepts in their early stages, with currency being a crucial component. To date, most Metaverse visionaries imagine a completely decentralized currency system based on blockchain technology. Some scholars believe that blockchain' s "decentralized" characteristics enable the Metaverse to have an independent currency transaction system, forming a closed-loop economic system.

Stepping back, some currently popular Metaverse systems still operate on traditional centralized token models. In such Metaverses, the value of users' productive activities is rights-confirmed in the form of platform-unified currency, which

users can spend within the Metaverse platform or "exchange" for real-world legal tender. Establishing and improving incentive mechanisms for user-generated content is crucial in the Metaverse, representing a key application of blockchain technology. Decentralized value returns are important means to enhance enthusiasm for constructing and engaging with new scenarios. In this sense, the Metaverse will be an important new territory for individuals and institutions to realize value increments.

However, it is worth noting that platform-based centralized currency systems —used by many Metaverse platforms at the time of writing—have fundamental flaws. Although blockchain technology has spawned numerous virtual currencies like Bitcoin and Dogecoin, and its technical security has received some academic recognition, virtual currencies in real life still possess greater financial product attributes than currency attributes. While the possibility of decentralized virtual currencies further developing to replace physical currencies remains, current evidence shows few cases of non-government-operated currency systems maintaining healthy operation. Examples can be seen in the inflation, labor class solidification, and skill discrimination issues encountered by the currency in the Western-developed game World of Warcraft, as well as in economic systems of games developed in China' s context, such as Fantasy Westward Journey. How to effectively integrate decentralized currency systems with the Metaverse still faces many challenges.

Closely related to currency are payment methods. For economic relationships generated in the Metaverse virtual world, digital payments remain the foundation of the digital economy and important infrastructure. However, existing network digital payments represented by WeChat Pay and Alipay cannot spontaneously generate digital currency and do not conform to the underlying logic of blockchain technology support in the Metaverse, necessitating new digital payment derivatives. Some scholars propose that digital fiat currency will become the engine of the new digital economy.

NFT-Based Virtual Item Markets. Currently, decentralized virtual item markets align with the wave of economic globalization. In the Metaverse, user-generated content becomes the primary form, and virtual items created by users can be transformed into digital assets through consumption and purchase by others. Today, transactions of various digital assets on blockchain platforms often use non-fungible tokens (NFTs). NFTs refer to currencies that can be attached to virtual items, representing blockchain-based digital asset ownership that is indivisible, non-substitutable, non-interchangeable, unique, verifiable, tradable, and transferable. The meaning of "non-fungible" is that NFTs cannot be exchanged with each other. Once a product is converted into an NFT, it becomes a unique digital asset on the blockchain, with information about its origin, price, resale, and other details permanently recorded.

Currently, NFTs are regarded as the core underlying technology of the Metaverse, providing technical support for the generation, rights confirmation, pricing, circulation, and traceability of digital assets within it. NFTs are seen as

digital assets that users will hold in the Metaverse and will effectively promote the solidification of the Metaverse economy. Under the boost of the Metaverse and blockchain technology, relevant NFT platforms are developing rapidly. For example, OpenSea is a Metaverse trading platform for virtual artworks and collectibles, where users can conduct virtual transactions by purchasing Ethereum. Additionally, Decentraland is a rapidly developing cryptocurrency-based virtual world where users can purchase virtual land, representing the embryonic form of the Metaverse real estate industry. NFTs also hold important significance in virtual worlds by effectively preventing the easy piracy and copying of virtual items. No matter how much others copy and paste, it does not change the fact that the work belongs to you as the original creator. Currently, NFT applications mainly focus on art sales. Because they are decentralized, virtual items on NFT trading platforms do not require authentication from centralized authoritative institutions.

NFT auctions are gradually replacing traditional auction forms. For example, with NFT support, the 300-year-old auction house Sotheby' s achieved a record total auction volume of $7.3 billion in 2021, including $100 million in NFT collectibles. A notable example is the NFT artwork collection *Everydays: The First 5000 Days*, which sold for a staggering $69 million in March 2021.

The current decentralized virtual market in the Metaverse is primarily NFT-based. NFTs can function like cryptocurrencies such as Bitcoin or serve as unique virtual items. Their future development prospects remain to be observed. Whether they ultimately become a capital carnival or can truly form a complete economic system requires time to tell.

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Note: Figure translations are in progress. See original paper for figures.