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Review

Recommendation Systems for the Metaverse

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Abstract: The metaverse, a virtual world closely intertwined with reality, represents the next-generation form of the Internet and encompasses advanced sociability and interaction. With the rapid growth of users and virtual products within this environment, the importance of recommendation systems becomes paramount. This article presents a comprehensive survey that examines the technologies influencing the development of recommendation systems tailored for the metaverse. Firstly, we identify the key trends and fundamental concepts associated with these systems. Secondly, we delve into the core supporting technologies and application scenarios within metaverse recommendation systems. Lastly, we provide insights into future research directions for this rapidly evolving field. Our survey reveals that while progress has been achieved, further investigation is necessary to optimize the technical layout and content of metaverse recommendation systems.

Keywords: metaverse; recommendation systems; virtual world; sociability and interaction; technology development

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1. Introduction

The concept of the metaverse was initially introduced in a work of science fiction literature as a term used to describe immersive virtual environments. The term "metaverse" originates from the notions of "metaverse" and "avatar" introduced in Neal Stephenson's novel *Snow Crash*. The metaverse constitutes a digital realm wherein individuals can embody personalized avatars. By donning a headset and goggles and locating a terminal, one can seamlessly link up with an alternate three-dimensional reality meticulously simulated by a computer. [1]. The metaverse is defined as a virtual realm in which digital avatars, representing individuals and their counterparts, converge to engage in various activities such as work, shopping, education, entertainment, and social interactions [2]. It represents an extensive virtual world where individuals gather and interact via digital platforms, utilizing avatars that they created. The metaverse possesses a structural framework that enables the formation of virtual communities that extend beyond commercial and entertainment purposes. It represents a new generation of the Internet, encompassing a three-dimensional virtual space that facilitates communication and interaction among users through their respective avatars [3]. The concept of the metaverse, a virtual world closely intertwined with reality and representing the next-generation form of the Internet [4], has garnered significant attention following the emergence of platforms such as ROBLOX in 2021 and the involvement of influential companies like Facebook, igniting academic interest and research enthusiasm [5]. This convergence of advanced technologies and the envisioning of a future society has propelled the metaverse into a stage of profound development and application, ushering human society into a new era [6]. The metaverse, with its advanced sociability and interactive environment, is witnessing a rapid influx of users and virtual products at an unforeseen rate [7]. In this context, the role of recommendation systems becomes paramount. Recommendation systems, also referred to as recommendation platforms or engines, are a specific category of information filtering systems that provide tailored suggestions to users, enhancing their interaction experiences within the metaverse [8].

Given the immense potential and value that the metaverse presents for recommendation systems, this article aims to provide a comprehensive overview of metaverse recommendation systems. It outlines the concept and fundamental characteristics of these systems, delves into the underlying technologies shaping their development, and explores the primary application scenarios within the metaverse recommendation ecosystem. Additionally, the article investigates the utilization of blockchains and artificial intelligence technologies in these scenarios. Finally, it offers insights into the future research directions and prospects of the rapidly evolving field of metaverse recommendation systems.

2. Literature Collection and Trend Analysis

In this study, the Web of Science (WOS) databases were utilized to conduct a comprehensive search and retrieval of pertinent articles to establish a literature database. The search process involved employing a predefined combination of keywords and Boolean operators ("AND", "OR") specifically tailored for literature selection. The selection of keywords was based on the subject matter, encompassing concepts such as metaverse and virtual worlds, as well as commonly employed terminology in research articles within the field.

Following the keyword-based search, the selected databases within WOS were further refined to retrieve relevant literature by utilizing the search term [metaverse]. The search criteria focused on specific article types, including articles, reviews, and editorial material. A total of 708 results were obtained from the WOS database through the application of title, abstract, and keyword filters within the timeframe of 1995 to 2023.

A comprehensive literature review was conducted to analyze the trends and developments in metaverse-related research. The analysis involved collecting and examining 708 scholarly papers from the Web of Science (WOS) database. The publication years of these papers spanned from 1995 to 2023, with the search date extending until 30 May 2023. The papers included in the analysis consisted primarily of journal articles and reviews.

Figure 1 illustrates the distribution of publication years for the 708 selected papers, showcasing the growth of research output over time. Notably, the number of papers published on the metaverse in 2022 experienced a remarkable 15-fold increase compared to the previous year. This surge in publications indicates the rising prominence and significance of the metaverse as an emerging field of study.

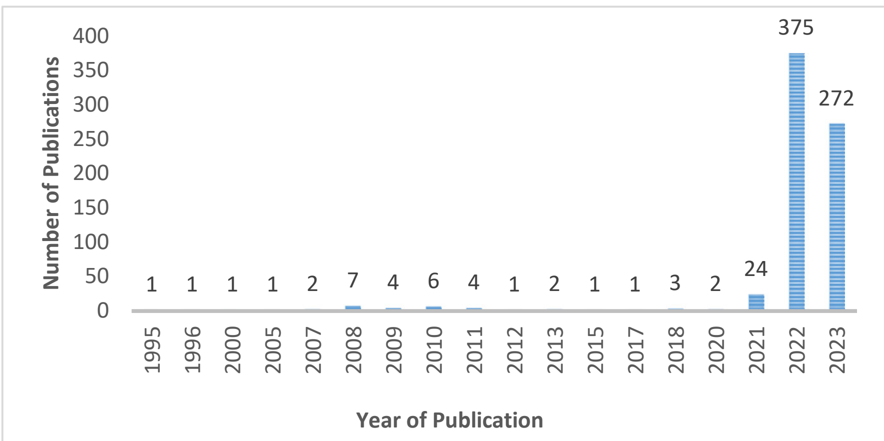

Figure 1. Distribution of publication years of metaverse related papers.

Furthermore, to gain insights into the impact and influence of specific papers, Table 1 presents the 10 most cited articles within the WOS dataset. It is worth noting that all of these highly cited articles belong to the category of journal articles, except for the eighth entry, which is a literature review.

Table 1. Citation times of relevant papers.

Rank	Title	Author, Year	Journal	Citations
1	3D Virtual Worlds and the Metaverse: Current Status and Future Possibilities	Dionisio et al., 2013 [9]	ACM Computing Surveys	157
2	Avatars, People, and Virtual Worlds: Foundations for Research in Metaverses	Davis et al., 2009 [10]	Journal of the Association for Information Systems	151
3	A Metaverse: Taxonomy, Components, Applications, and Open Challenges	Park et al., 2022 [11]	IEEE Access	135
4	Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy	Dwivedi et al., 2022 [12]	International Journal of Information Management	93
5	Making real money in virtual worlds: MMORPGs and emerging business opportunities, challenges and ethical implications in metaverses	Papagiannidis et al., 2008 [13]	Technological Forecasting and Social Change	84
6	Second Life and the new generation of virtual worlds	Kumar et al., 2008 [14]	Computer	71
7	Fusing Blockchain and AI with Metaverse: A Survey	Yang et al., 2022 [6]	IEEE Open Journal of the Computer Society	67
8	A Survey on Metaverse: Fundamentals, Security, and Privacy	Wang et al., 2023 [15]	IEEE Communications Surveys & Tutorials	63
9	Retail spatial evolution: paving the way from traditional to metaverse retailing	Bourlakis, et al., 2009 [16]	Electronic Commerce Research	56
10	What is XR? Towards a Framework for Augmented and Virtual Reality	Rauschnabel et al., 2022 [17]	Computers in Human Behavior	47

3. Metaverse-Oriented Recommendation Systems

The emergence of the metaverse wave has led to a significant trend towards digitization within society, exacerbating the issue of information overload [12]. Consequently, in the context of the metaverse, the research on recommendation systems becomes imperative, as they serve as a crucial conduit between information and users, facilitating effective information retrieval and consumption.

3.1. Overview of Metaverse Recommendation Systems

Given the emergence of the metaverse phenomenon, the digitization trend in society has intensified the challenge of information overload, prompting the need for exploration into recommendation systems within the metaverse environment [12]. Metaverse recommendation systems, as the name suggests, are recommendation systems that leverage metaverse technology. The unique characteristics of the metaverse, including virtuality, real-time interaction, high energy, ansd decentralization, create an innovative setting for recommendation systems, fundamentally altering traditional recommendation approaches. For instance, the product recommendation systems in the metaverse necessitate novel features due to the intrinsic attributes of this virtual environment. Unlike traditional product recommendation systems that solely present product pictures or links as results to users, metaverse product recommendation systems must offer 3D visual effects of the products and even tactile sensations, taking into account the real-time interactivity afforded by the metaverse.

The fundamental distinction between the metaverse and the current Internet lies in the metaverse's real-time support, which establishes a shared data space facilitating continuous updates and development [18]. Consequently, metaverse recommendation systems transcend the traditional mechanistic "input" and "output" interactions between humans and computers, introducing a parallel world alongside real-life experiences for users. Within this new world, individuals and computers engage in real-time, shared, and liberating recommendation models [19]. Thus, metaverse technology provides users with a platform for the integration of virtual and real experiences, offering a real-time interaction space that enables users to feel a sense of detachment from their immediate environment while immersing themselves in another parallel world.

The features of the metaverse establish a fertile ground for recommendation systems, triggering transformative changes to conventional recommendation approaches [20]. Driven by digital technology, metaverse recommendation systems emerge as a vital bridge connecting the virtual and physical realms, serving as a new generation of recommendation media platform poised for the future.

3.2. Ideal Characteristics of Metaverse Recommendation Systems

Illustrated in Figure 2 are the three essential traits of metaverse recommendation systems: dynamic interactivity, streamlined efficiency, and resilient sociability.

(1) Dynamic Interactivity

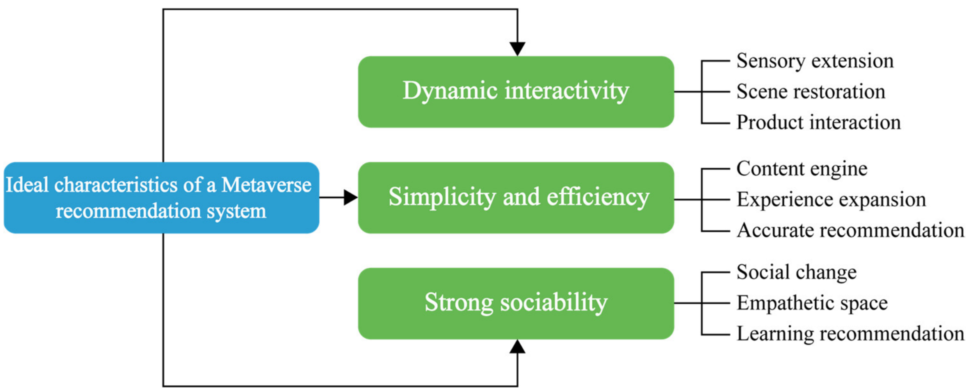

Figure 2. Basic characteristics of metaverse recommendation systems.

The expansion of frontiers and the interactive development wave within the metaverse will foster a new ecosystem for recommendation systems. "Dynamic interactivity" will become a shared characteristic across various recommendation systems, with heightened audience participation. Metaverse technology enables further advancements in human sensory interactions, encompassing the dimensions of sight, sound, smell, taste, touch, and cognition [17]. Ultimately, these senses can be extended, allowing the metaverse to recreate any perspective, scene, or role. For instance, in the realm of fashion-related recommendation systems, future systems can present three-dimensional, realistic fashion products to users, enabling them to experience the visual effects, clothing quality, and even desired wearing scenes (e.g., streets, beaches), thereby providing an authentic recommendation experience.

(2) Simplicity and Efficiency

As recommendation-related content engines and artificial intelligence technologies rapidly evolve within the metaverse, the performance of recommendation systems is further enhanced, streamlining the recommendation process while optimizing efficiency [21]. Unlike the Internet, where recommendation systems are intricately linked, the metaverse allows for the expansion of recommendation systems across all facets of the user experience, simplifying the triggering process and enabling more users to benefit from the recommendation system within the metaverse, thus creating a user-friendly recommendation environment [11]. For instance, during the shopping process, metaverse technology can swiftly analyze users' verbal descriptions, behavioral patterns, shopping habits, and other relevant information to provide quick and accurate recommendations.

(3) Robust Sociability

With the advent of the mobile digital era, social networks have increasingly intertwined with recommendation systems [22]. In the metaverse, the role of social networks within recommendation systems expands, fostering robust sociability within metaverse recommendation systems. With the support of metaverse technology, social interaction methods and platforms undergo revolutionary changes. This transformation facilitates the creation of interest-based social networks that operate independently from users' existing real-life social connections, thereby enabling more unrestricted and expressive interactions. Such networks foster an ideal space characterized by empathy, co-construction, symbiosis, and sharing [23]. All user expressions within this social network serve as nourishment for metaverse recommendation systems, which rely on them for learning and development, thus enabling recommendations based on users' interests and hobbies and achieving psychological resonance.

4. Core Support Technologies of Metaverse Recommendation Systems

As depicted in Figure 3, the metaverse encompasses various underlying technologies such as interaction technology and blockchain technology [24]. These technologies play a pivotal role as the fundamental support for metaverse recommendation systems. Consequently, this paper conducts an in-depth analysis of these techniques, elucidating their distinct features, advantages, and disadvantages.

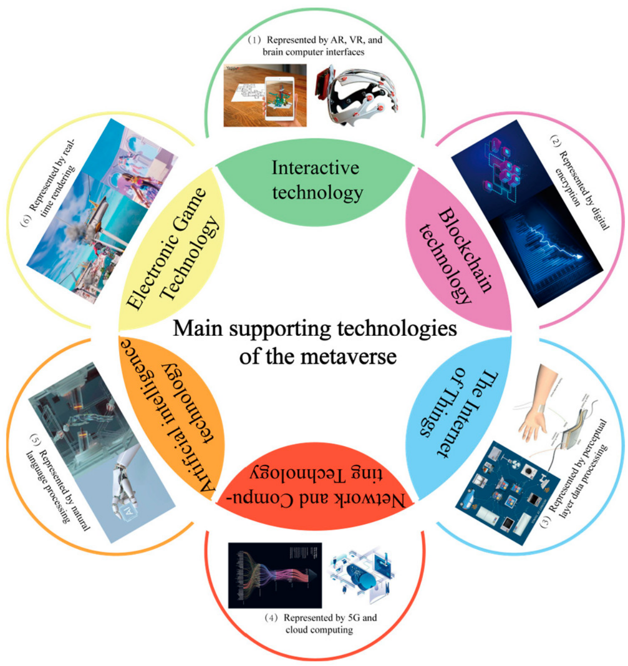

Figure 3. Core Support Technologies for the Metaverse.

4.1. Blockchain Technology

The realization of metaverse recommendation systems as a vital component of metaverse society, in order to establish its independent economic system and economic attributes, necessitates the utilization of blockchain technology [24]. Blockchains, exemplifying decentralized technology, form the foundation for the vision of the metaverse economic system [25]. Through the application of blockchain encryption algorithms, consensus mechanisms, smart contracts, and other related technologies, a new financial system can be provided for the metaverse. This system facilitates financial services, including insurance, trading, securitization, and virtual asset management, enabling a connection between the virtual world and the real-world economic system.

Blockchain technology encompasses five core components: point-to-point transmission, digital encryption technology, distributed storage, consensus mechanisms, and smart contracts. Point-to-point transmission, also referred to as "peer-to-peer" or "P2P," differs fundamentally in the blockchain context from its usage in the internet economy system. In the blockchain context, peer-to-peer payment eliminates the need for third-party payment platforms. Instead, two parties only need to verify their rights to engage in transactions before completing the payment [26]. Digital encryption technology plays a pivotal role in blockchains by ensuring the security of user identity information and transaction data within the metaverse. The distributed storage system stores data across multiple nodes in a distributed manner, ensuring data security and privacy [27]. The consensus mechanism ensures that all nodes in the blockchain can reach consensus within a specified timeframe. It considers factors such as decentralization, security, scalability, resource consumption, transaction confirmation time, throughput, and consistency. Smart contracts, originally defined as digitally encoded commitments that determine which parties are authorized to enforce the terms of the contract, facilitate operations such as transaction control and verification.

Consensus algorithms, network management, and blockchain interoperability have garnered significant attention from researchers, serving as pivotal technical and practical components across various versions of the blockchain. The pursuit of achieving high throughput and low latency has led to the development of numerous consensus mechanisms [28]. In this context, it is necessary to develop and enhance innovative and hybrid consensus algorithms. Furthermore, the operation of a substantial number of participating nodes within the network contributes to elevated energy consumption and greenhouse gas emissions, thereby exerting adverse effects on the climate and the environment.

4.2. Artificial Intelligence Technology

In recent years, the advancement of core technologies, including big data, the internet, cloud computing, and new algorithms, has contributed to the growth and progress of artificial intelligence (AI) technology [29]. AI technology provides technical support for the application scenarios within the metaverse and serves as a crucial infrastructure for its development [30]. By utilizing statistical models, AI technology calculates the probability of data. Big data provides an abundant source of data for continuous model optimization, while cloud computing offers robust computing power, flexible resource allocation, and efficient response mechanisms. The development of new algorithms enhances machine learning capabilities and promotes the advancement of association technology [31]. Furthermore, deep learning facilitates the integration of preprocessing, feature extraction, and algorithm processing, culminating in the formation of reality-to-virtual technology—an essential component of the amalgamation of the virtual and real elements within the metaverse. Through machine learning, the elements and systems within the metaverse can gradually approach human-level learning and surpass it to enhance the intelligence and efficiency of metaverse elements and systems. Speech recognition technology and natural language processing enable effective communication between humans and computers through natural language [32]. This ensures accurate understanding and transmission of information between virtual and real objects and facilitates communication between humans and the metaverse system. It effectively addresses communication challenges posed by regional language systems and pronunciation variations in different environments, facilitating diverse forms of communication within the metaverse world.

Determining ownership of AI-powered content within the metaverse presents a significant challenge. Users are often unable to discern whether they are engaging with a genuine individual or an avatar generated by artificial intelligence (AI). This lack of transparency can result in certain users utilizing AI technology to exploit resources within the metaverse, such as through cheating in games or engaging in unauthorized activities within other users' accounts [33]. Furthermore, it is important to acknowledge that AI systems are not infallible and can potentially make errors or inaccuracies in their operations.

4.3. Interactive Technology

Virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies continuously advance the fusion of virtual and real spaces. Starting with immersive experiences in the virtual world, progressing to the overlay of virtual information onto the real world, and eventually achieving seamless integration and fluid transitions between the virtual and real domains, the interaction between these realms has steadily intensified. This technological evolution has been facilitated by advancements in human-computer interaction technology and sensing technology, which have enhanced convenience, realism, and physical sensations in the interaction modes. Consequently, users can achieve a heightened sense of immersion within the metaverse, yielding a more realistic and engaging interaction experience [34].

However, it is important to recognize that interactive technology also presents potential personal and social challenges. For instance, the collection of sensitive data, including biometric information, by AR/VR devices can enable user identification and the inference of additional information about individuals within the virtual world [35]. Therefore, safeguarding the privacy of such sensitive information becomes crucial for the metaverse to protect its users.

4.4. Internet of Things (IoT) Technology

The Internet of Things (IoT) encompasses various aspects, namely marking, sensing, processing, and information transmission, which rely on key technologies such as RFID, sensor technology, network technology, and communication technology. RFID technology primarily serves as an information acquisition source in the IoT, offering features like long-range capability, fast reading speed, strong penetration, high efficiency, and large storage capacity. These attributes are crucial prerequisites for realistic data acquisition within the metaverse. Sensor technology plays a vital role in collecting information within the IoT, serving as the foundation for IoT applications. Sensors serve as the sensory organs of the metaverse, providing information for its perceptual capabilities. Sensor network technology, through embedded system processing and wireless network transmission, monitors, senses, and collects information, constituting a critical network infrastructure for the metaverse's perception of various entities. Communication technology serves as the data transmission channel for IoT, enabling efficient integration of communication and perception. Proximity communication and optical encounter network communication technologies facilitate seamless information transmission, supporting comprehensive sensory interconnection and the provision of accurate and complete information to the metaverse. The metaverse platform relies on data collected from a range of IoT devices to effectively function across diverse applications such as healthcare, education, and smart cities [36].

However, storage and security issues arise within the IoT due to the vast number of interconnected devices in the metaverse. Ensuring error-free data for analysis is imperative. Centralized storage solutions are not advantageous when data is distributed across virtual worlds, since altering even a single piece of data can impact the entire dataset and compromise findings. Data sharing between virtual worlds relies on the cross-platform capabilities of IoT devices [37].

4.5. Networking and Computing Technology

The metaverse represents a parallel digital realm facilitating human interactions, necessitating ubiquitous connectivity technologies to establish relationships between entities, individuals, and objects. In the digital platform of the metaverse, seamless, uninterrupted, real-time, on-demand high-quality services are enabled through mobile computing networks, deep end-to-end management and cloud collaboration. Networking and communication technologies within the metaverse are responsible for secure and error-free data transmission, analogous to the network layer's role in the IoT architecture. Mobile communication technology, notably 5G networks, plays a significant role in the metaverse by providing high-speed, low-latency, and extensive connectivity services. The fast and low-latency nature of 5G networks effectively bridges the virtual and real worlds. Additionally, emerging communication technologies, such as 6G, have emerged to revolutionize applications across domains, empowering intelligent and autonomous systems and profoundly impacting citizens, consumers, and businesses [38]. Given the metaverse's aims to deliver immersive user experience and heightened demands for data transmission and processing, 6G and future communication technologies possess the potential to offer intelligent capabilities for high-speed data transmission, facilitating deeply immersive user experiences.

The metaverse encompasses complex applications like high-precision VR games, immersive social networking platforms, and intricate economic systems, all of which necessitate substantial computational power to ensure responsiveness. Computational power refers to the ability to process and compute data and is present in a range of smart hardware devices, from laptops and cell phones to supercomputers [39]. Cloud computing, a technology that enables network services capable of processing vast quantities of information within seconds, exhibits performance akin to that of a supercomputer. By providing potent cloud services, lightweight terminal devices, convenient response mechanisms, and cost efficiencies, cloud computing technology empowers the metaverse. The metaverse necessitates increased computing power to deliver prompt responses and immersive user experiences, thereby demanding continuous advancements in computing power-related technologies for its future development [39].

4.6. Electronic Game Technology

Electronic game technology serves as a prominent medium for the presentation of the metaverse, not only providing a platform for its creation but also facilitating interactive content, social scenarios, and traffic aggregation. The collaborative advancement of electronic game technology and interactive technology represent two crucial prerequisites for realizing the exponential growth of the metaverse's user base. The former addresses the challenge of offering exceptionally rich content, while the latter addresses the issue of achieving immersive experiences. Electronic games play a pivotal role in delivering interactive content within the metaverse, serving as a cornerstone for the development of metaverse content and user traffic. This encompasses aspects such as 3D modeling, real-time rendering supported by game engines, as well as 3D engine and simulation technologies linked to the concept of digital twins. Within the metaverse, digital twin models are constructed using information obtained from multiple remote sensors. The accuracy of these twin digital models is inherently influenced by the quality of the data utilized for their creation [40].

5. Application Scenarios of Metaverse Recommendation Systems

Recommendation systems are information filtering systems designed to offer personalized item recommendations to users within service environments that possess diverse data holdings or collection capabilities [41]. The metaverse world, characterized by its complexity and diversity of information, necessitates the utilization of recommendation systems to alleviate the issue of information overload experienced by users. At present, certain recommendation engines, notably Alie, focus on access to the metaverse. Additionally, numerous established recommendation engines, like Medium, are already tapping into the capabilities of the metaverse. As the metaverse is yet to be fully realized, and the life in it encompasses various facets of the real world, the exploration of recommendation systems within the metaverse must be conducted with a consideration of the advancements and prospects of real-world recommendation systems. Given the extensive range of application domains for recommendation systems, such as social networks, e-commerce, travel, healthcare, and streaming media, our focus in this discussion is limited to metaverse recommendation systems in the context of social networks, e-commerce, and travel scenarios. It is important to note that while recommendation systems have not yet been directly implemented in the metaverse, our exploration of metaverse recommendation systems is conducted within the framework of real-world recommendation systems.

5.1. Recommendation Models

The general models of recommendation systems encompass content-based filtering, collaborative filtering, and hybrid filtering. Content-based filtering involves recommending items with similar attributes to those preferred by users [42]. This approach finds applications in various domains such as music and movie recommendations. According to Salter et al. [43], the content-based filtering model recommends items closely related to those previously evaluated by the user. However, it encounters a cold-start problem when dealing with new items. The collaborative filtering model utilizes user evaluation data to construct a database of user preferences, enabling the prediction of items that align with the user's tastes. It can be further categorized as content-based collaborative filtering and model-based collaborative filtering [44]. Collaborative filtering plays a significant role in recommendation systems across numerous applications, making it the most commonly employed approach for developing recommendation systems.

Hybrid filtering combines content-based and collaborative filtering approaches to provide suggestions or recommendations to active users, addressing the limitations of these individual models and enhancing recommendation performance [45]. Hybrid recommendation models primarily aim to alleviate sparsity issues by integrating information from content-based filtering and collaborative filtering models. Moreover, there exist various techniques for combining recommendation models with other methodologies such as data mining [46], KNN (k-nearest neighbors) [47], clustering [48], neural networks [49], and others. The integration of novel algorithms into recommendation systems contributes to their performance enhancement and broadens their development prospects.

5.2. Metaverse Recommendation Systems for Product Transaction Scenarios

Two decades ago, the retail industry encountered a profound and influential challenge that reshaped its landscape: the emergence of e-commerce. E-commerce recommendation systems gather diverse user-related data and employ predictive analytics to anticipate user preferences and deliver item recommendations [50]. Prominent e-commerce platforms like Amazon and Taobao have implemented their own recommendation systems, facilitating business expansion and revenue growth by providing accurate and preferred recommendations to users. Presently, a new challenge is arising with the advent of retailing in virtual environments, known as metaverse retailing. In metaverse retailing, consumers utilize avatars to engage with other avatars within an immersive virtual space to make purchases, presenting fresh hurdles to retailers. Successful establishment of a metaverse business enables retailers to secure a larger market share. For instance, Uniqlo, an apparel retailer, collaborated with Mojang Studios, the developer of the video game Minecraft, to create a line of Minecraft-themed T-shirts, available in both digital Minecraft and physical Uniqlo stores [51]. Despite the numerous opportunities metaverse retailing offers, significant challenges persist. Retailers who have yet to target early adopters of the metaverse, primarily individuals who frequent video games, must navigate uncharted territory and adapt to unfamiliar audiences. Furthermore, retailers must cultivate new capabilities to effectively compete in the dynamically evolving virtual environment. Considering these issues, product recommendations within the metaverse may confront similar predicaments as real-world recommendation systems, encompassing issues like cold-start challenges for new users, uncertainties in consumer behavior, and the formulation of effective recommendations to enhance user interest. These aspects represent potential directions for future research in this domain. The proliferation of product content within the metaverse necessitates the implementation of a robust recommendation system to enable users to efficiently select the most suitable products [52]. In the metaverse, all products are treated as digital assets, and blockchain technology facilitates peer-to-peer transactions without the need for centralized intermediaries. During the transaction process, the consensus mechanism ensures the verification of various transaction aspects, including the identity of the transaction originator and the validity of the assets. Once a transaction is verified by a sufficient number of nodes, it is added to the transaction pool and subsequently packaged into a block [53]. Distributed storage mechanisms ensure the storage of the block across nodes with packaging rights. Digital encryption technology guarantees the uniqueness of recommended products and preserves the value of these products by securely storing the encrypted transaction history on the blockchain.

5.3. Metaverse Recommendation Systems for Social Scenarios

In the physical realm, online social networking services (SNS) such as Facebook, Instagram, Twitter, and LinkedIn have emerged as expansive digital platforms for social interaction. These platforms not only allow users to document their daily lives, hobbies, and interests but also provide spaces for engaging with other users [54]. Social recommendation, in general, entails the recommendation of users to other users. This may involve suggesting social platform content or social accounts to users who may know or be interested in certain individuals. Unlike the SNS, the metaverse introduces life scenarios and avatars, enhancing socialization within the metaverse with greater interactivity, authenticity, and real-time experiences. Through the integration of virtual reality (VR) and other devices, metaverse socialization enables users to engage in activities such as shopping, dating, playing together, and chatting, closely replicating real-world interactions. The expanded range of interactive content within the metaverse facilitates more comprehensive data collection for metaverse social recommendations, enabling more accurate predictions of user preferences. Metaverse recommendation systems in social scenarios focus on recommending subjective content such as social groups, user profiles, and emotional networks [55]. The recommendation process begins with the creation of metaverse characters, where users customize their avatars by selecting various attributes such as body features, facial characteristics, hairstyle, and clothing [56]. The recommendation system can suggest avatars that align with individual preferences and requirements. Once the character creation is complete, users engage in social interactions within the metaverse. They can explore different spaces with friends, participate in parties, immersive activities, and share their social experiences within the metaverse [57]. Artificial intelligence algorithms play a vital role in recommending ideal travel destinations and relevant social content to enhance user engagement. Additionally, user creativity is fostered in the metaverse social scene, allowing them to create virtual objects, spaces, and experiences, such as avant-punk-style glasses, retro-fashionable trench jackets, art galleries, or game rooms. These creations are accessible to all users within the social space, promoting an environment of open consumption and collaboration.

5.4. Metaverse Recommendation Systems for Tourism Services

Travel service recommendations in the real world typically involve suggesting travel destinations, routes, and transportation modes. Previous research has utilized contextual data obtained from social networking services (SNS), such as review data, location data, and weather data, to enhance recommendation accuracy [58]. Although there are already projects like 3D panoramic museums for metaverse tourism, these initiatives often only provide visual satisfaction and are limited by equipment, lacking true immersion. However, the integration of virtual reality (VR), augmented reality (AR), and mixed reality (MR) with tourism has the potential to revolutionize the travel experience. VR allows users to immerse themselves in artificially constructed environments, while AR enhances physical spaces by providing information on portable screen devices. MR typically requires specialized hardware like smart glasses to deliver its services. When combined with gamification, these technologies offer unprecedented creative marketing opportunities and assist destinations and tourism organizations in directing visitors to new areas and facilitating exploration of novel experiences [59]. Research on metaverse tourism should focus on understanding how the metaverse can satisfy users' needs, desires, and requirements, particularly in challenging markets. Metaverse travel recommendations differ from those in the real world, as transportation modes can be disregarded initially. Instead, the emphasis should be on accurate destination recommendations that align with user preferences and historical data. Similarly, the recommendation of travel routes and itinerary plans represents a significant area for future development.

6. Future Prospects of Metaverse Recommendation Systems

6.1. Reducing User Interaction Burden

The development of sensors and devices determines the range of user operations in recommendation systems. Different devices capture various types of action inputs to facilitate immersive interactions within the metaverse. Users can utilize body language, such as gazes, gestures, head movements, and audible and tactile cues, to interact within the virtual environment [60]. Some users may even employ brain signals, such as electroencephalograms, although there are limitations to this approach. However, due to differences in design mechanisms among developers, the types of user actions are still limited and differ from natural interactions in the real world. Users are required to familiarize themselves with specific actions associated with different developers, applications, and platform designs.

6.2. Establish Multisensory Channel Feedback Mechanism

Efforts are being made to explore various types of user feedback, ranging from visual and auditory channels to tactile, olfactory, and gustatory sensations. Numerous devices aim to enhance the realism of virtual environments across different dimensions, thereby improving the immersive nature of recommendations [61]. For instance, researchers are investigating methods, such as electronics, heat, and magnetism, to simulate taste instead of relying on chemical-based approaches, which can present logistical challenges such as refilling. The future is expected to witness the emergence of more integrated devices that effectively combine multiple sensory channels, offering users a heightened level of immersion within the recommendation system.

Haptic interfaces, for instance, enable users to directly interact with real and virtual objects. Through mechanical and thermal stimuli, users can experience the sensation of touching virtual objects and project their hand movements from the physical space into the virtual environment through motion and thermal sensing. Thermal stimulation and sensing play a critical role in tactile interfaces as they aid in object recognition, emotional stimulation, and the transformation of real objects into touch interfaces, thereby significantly enhancing the level of simulated reality.

6.3. Integrating Visualization with User Requirements

Effectively linking visualization to user needs presents a significant challenge in providing user-centered conscious experiences, particularly in terms of when, where, and how information should be presented. Behavioral data of users, such as tracks, clicks, and eye movements, may be utilized to develop information-assisted strategies or automated recommendations using machine learning algorithms [62]. Additionally, empirical analysis of interaction design is required to determine the appropriate arrangement of visualizations and to ensure that their presence does not interfere with the observation of other elements. Furthermore, the interaction with visualizations can be user-controlled or facilitated through non-player characters (NPCs). For instance, intelligent robots can assist users in perceiving the metaverse environment, provide prompts, and engage in interactive visualization-based communication with the user.

7. Conclusions

This study has examined the fundamental characteristics, core supporting technologies, practical applications, and future prospects of metaverse recommendation systems. The analysis reveals that the metaverse imbues recommendation systems with dynamic interaction, simplicity, efficiency, and robust engagement. However, the successful implementation of metaverse recommendation systems necessitates a mature environment that integrates blockchain technology and artificial intelligence technology. Prospective metaverse recommendation systems hold the potential for compelling applications in areas such as product trading and social contexts. Nevertheless, due to the complexity of user interactions and the absence of a comprehensive feedback mechanism, the user experience may suffer from reduced fluency and comfort. Therefore, further research in the field of metaverse recommendation systems is required to gain deeper insights into these challenges and capitalize on the opportunities presented by the future metaverse. It is anticipated that in the future, a comprehensive metaverse technology system will be established, enabling a holistic understanding of metaverse recommendation systems. As technological advancements continue to unfold, the development of graphical technologies in metaverse worlds will enhance realism and enable users to freely input and create within these immersive environments. Consequently, users will serve as a significant source of inspiration for numerous products within the metaverse. User feedback, gathered from various multisensory channels, will contribute to enriching the visualization of the metaverse and aligning it with user needs. This process will further augment the immersive experience for users. In light of evolving user needs and technological advancements, the recommendation system in the metaverse will encounter novel challenges. To address these challenges, integrating multiple technologies and prioritizing the improvement of user experiences will remain constant and effective solutions.

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