All-Smart Library: The Metaverse as a Post-Print Realization Path

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Abstract

[Purpose/Significance] To accelerate the transformation and optimization of library services, this study analyzes the metaverse and its related technologies to explore their application prospects in libraries. [Method/Process] By investigating the metaverse and its underlying technologies, as well as the theoretical logic underlying their application in libraries, this paper proposes future prospects for metaverse applications in libraries. [Results/Conclusion] The application of metaverse and related technologies is crucial for advancing libraries toward fully smart libraries. The metaverse concept also creates significant advantages for library collection resource management, reading spaces, cultural promotion, reading experiences, special user services, and more, thereby achieving a transformative shift in the form of smart libraries.

Full Text

Full Intelligent Library: The Metaverse as a Path to Realization

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Abstract:
[Purpose/Significance] To accelerate the transformation and optimization of library services, this paper analyzes the metaverse and its related technologies to explore their application prospects in libraries. [Method/Process] By examining the metaverse and its underlying technologies, as well as the theoretical logic of metaverse application in libraries, this study proposes future prospects for metaverse implementation in library settings. [Result/Conclusion] The application of metaverse and its related technologies is key to advancing library development toward full intelligent libraries. The metaverse concept also creates

advantages for collection resource management, reading spaces, cultural promotion, reading experiences, and special user services, enabling the morphological transformation of intelligent libraries.

Keywords: Full Intelligent Library; Metaverse; Virtual Reality; Library; Service Model
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In today's world, a new round of technological revolution and industrial transformation is flourishing. Virtual reality represents the signature technology of this revolution and will become a key driver of digital economic development and industrial upgrading. On October 20, 2021, the World VR Industry Conference Cloud Summit opened, where Chinese representative Wang Yong noted that the virtual reality industry has vast development space and enormous potential. He emphasized the need to deepen the "VR+" initiative, enrich terminal products and content services, and promote the industrialization and scaling of virtual reality technology [1]. The transformation and development of virtual and real industries have changed the service methods of traditional cultural venues, and the emergence of the metaverse has brought new opportunities to libraries. Every evolution of the technological revolution has brought disruptive changes to library service models, from traditional services to digital libraries and then to smart libraries. Today, the metaverse represents another 冲击 on library service models.

2. Concepts of the Metaverse and Full Intelligent Library

2.1 Metaverse

The metaverse typically describes a future iteration of the internet, consisting of a persistent shared three-dimensional virtual space linked to perceivable virtual worlds [5]. The term originates from Neal Stephenson's science fiction novel *Snow Crash*, in which the plot takes place in a virtual space where humans live alongside virtual beings through VR devices [6]. From its inception to the present, there has been no unified definition of the metaverse, with different companies and scholars interpreting it in their own ways. The sudden popularity of the metaverse is closely related to Facebook founder Mark Zuckerberg's interview with *The Verge*, in which he expressed his hope to transform Facebook into a metaverse company within about five years [7]. He also believes the metaverse represents the future of the internet. Since then, numerous scholars and entrepreneurs have begun exploring the metaverse concept. Matthew Ball [8] argues that the metaverse must have high realism, where all aspects of real life can be mapped into metaverse space. Zhu Jiaming [9] views the metaverse as a virtual space that is both parallel to and independent of the real world—an increasingly realistic digital virtual world. Jon Radoff [10], founder of Beamable, divides the metaverse into different layers. Following the proposal of the metaverse concept, many companies have attempted to realize it. The US-listed

gaming company Roblox [11] was the first to build a metaverse ecosystem, after which major manufacturers have invested in metaverse construction.

The metaverse aims to build a persistent virtual shared space while maintaining perception and experience of the real world. This requires adhering to the values of co-creation, co-construction, sharing, and co-governance, and comprehensively integrating new technologies such as big data, artificial intelligence, virtual reality, 5G, blockchain, and 3D engines [12]. The technological core of the metaverse lies in integration and application, with its underlying technologies shown in Table 1 . While different fields have different perspectives on the metaverse, in the library domain, merely discussing virtualization and digitization is not the development prospect for intelligent libraries. The concept of full intelligent libraries needs to be realized step by step. Only through continuous introduction of metaverse underlying technologies and continuous upgrading of library intelligent services can the deep integration of metaverse and libraries be ultimately achieved.

2.2 Full Intelligent Library

In 2003, M. Aittola from the University of Oulu Library in Finland proposed the term "smart library" [13], defining it as a spatiotemporally unrestricted, perceivable mobile library service that helps users locate books and other materials through wireless internet connectivity. Smart libraries represent the three-dimensional integration of physical space, digital space, and human society, with core technology groups such as virtual and intelligent technologies forming their foundation [14]. During smart library development, they have experienced pseudo-smart and partial-smart stages, with full intelligent libraries representing the final form [2]. Although full intelligent libraries are based on intelligent technologies, their core is the metaverse underlying technology that provides readers with a shared reading space. This shared space involves dual modeling of readers and libraries, where multiple readers enter the twin digital library in the form of digital avatars. This is not mere speculation—the concept of VR social interaction has existed for many years [19].

The goal of full intelligent libraries is the realization of fully intelligent services and twin digital libraries, which also represent two stages of metaverse application in smart libraries. The first stage utilizes metaverse underlying technologies such as extended reality and blockchain to achieve fully intelligent services, namely unmanned libraries [4]. Since the key to the metaverse lies in technological breakthroughs and integration, this stage of full intelligent library development also focuses on the introduction and integration of metaverse underlying technologies. Many libraries at home and abroad have attempted this, such as Harbin Engineering University Library's WEB collection location system [15] and the University of Miami Library's use of augmented reality technology to identify books [16]. However, these attempts only partially meet consultation and service requirements without librarians and have not yet achieved truly fully intelligent unmanned services.

The second stage is the establishment of a digital twin library (Digital Twin Library) and the realization of full intelligence in real libraries. At this stage, full intelligent library services will break through temporal and spatial limitations. In the metaverse, full intelligent libraries provide digital identity verification, allowing users to freely enter unrestricted library virtual spaces using digital identities, while real libraries achieve fully intelligent services. After the morphological transformation of full intelligent libraries, their service models will change in several aspects: (1) Traditional smart libraries mostly provide intelligent services for individual readers, lacking interaction between readers. While individual readers can use virtual reality technology to enjoy collection navigation and introduction services [17-18], different readers cannot use these devices for knowledge interaction, as the devices are isolated from each other. Full intelligent libraries emphasize reader interconnectivity, using metaverse devices and technologies to enable multiple readers to enter the twin digital library simultaneously as digital avatars. (2) The emergence of full intelligent libraries means a closer relationship between digital and real libraries. When users enter digital libraries, they no longer browse web pages but rather enter virtual libraries similar to those in Second Life [20], with the difference being the addition of somatosensory interaction and real-time rendering lacking in Second Life. Digital library modeling uses real libraries as prototypes for three-dimensional reconstruction, while the digital transformation of collection resources in real libraries accelerates. Supported by metaverse underlying technologies, the continuous interaction between digital and real libraries catalyzes the emergence of full intelligent libraries, enabling the integration of more diversified services such as health information islands, medical libraries, audio-visual entertainment, art galleries and museums, and engineering libraries [21] within a single twin digital library. (3) Full intelligent libraries achieve unmanned services. From the metaverse perspective, achieving full intelligent libraries is not about abandoning reality for virtuality but using metaverse technology to achieve dual upgrading of digital and real libraries. Although some libraries have attempted unmanned services [22], true fully intelligent services have not been realized. For the intelligent development of full intelligent libraries, metaverse underlying technologies need continuous introduction and improvement, including using 3D scanning technology, spatial distance perception, and other technologies to provide library navigation, image-text retrieval, and real-time voice broadcasting [23], and using facial recognition technology, RFID technology, etc., to achieve intelligent monitoring [24].

3. Theoretical Logic of Metaverse Empowering Full Intelligent Libraries

In the traditional reading era, libraries were archival institutions that stored knowledge, preserved paper documents, and provided reading and learning spaces for those in need [25]. However, since the mid-20th century, human society has entered an informatization process—the "ubiquitous information society" [26]. People's demands for collection resources have become increasingly

personalized and diversified. Functionally, modern libraries have transformed into comprehensive activity spaces for knowledge acquisition, relaxation, teaching, and entertainment. Although traditional libraries continuously innovate their services, these optimizations mostly involve physical spaces. With the continuous development of mobile libraries and digital libraries, traditional libraries have begun evolving toward smart libraries. However, for a long time, the development of digital libraries lagged far behind real libraries [27]. The arrival of the metaverse will enable libraries to move faster toward fully intelligent and diversified libraries.

In terms of the theoretical application of metaverse underlying technologies, Li Feifei [28] proposed that blockchain technology can assist in rights management for digital libraries, Liu Wei [29] proposed the integration of 5G and smart libraries, and Fu Ping [30] reviewed and prospected the application of artificial intelligence in libraries. From this perspective, metaverse construction for smart libraries is not mere fantasy; the citation of its underlying technologies has been discussed by many scholars. Regarding the establishment of digital twin libraries, full intelligent libraries pursue authenticity, real-time capabilities, and interaction between readers. Shen Yang [31] proposed the theory of three-dimensional space and virtual spatiotemporal tunnels in 2007, suggesting that connecting several separate closed virtual spaces could form larger virtual community spaces. This spatial interconnection theory provides imagination for the interconnection between digital identities and digital libraries. The virtual library in Second Life [32] also attempted spatial interconnection. Although it lacked real-time reader interaction and somatosensory simulation, its three-dimensional modeling technology and digital transformation of collection resources undoubtedly provided considerable experience and ideas for metaverse application in libraries.

4. Application Prospects of Metaverse Underlying Technologies in Full Intelligent Libraries

4.1 Virtual Reality in Full Intelligent Libraries

The metaverse is inseparable from virtual reality; indeed, virtual reality is the most fundamental technology of the metaverse. Virtual reality typically refers to VR (Virtual Reality), AR (Augmented Reality), and MR (Mediated Reality) technologies. All three have seen numerous applications in smart library construction. For example, the University of Oklahoma Library Management Department once launched a "VR" project that displayed text as three-dimensional images [33]. The University of North Carolina Library enabled readers to see book introductions and history when browsing bookshelves through AR technology [34]. Technologically, VR, AR, MR, and the metaverse each have their characteristics but exhibit generational succession.

The application prospects of virtual reality technology in full intelligent libraries are divided into two phases. The first phase involves the application of virtual

reality technology in unmanned libraries, including using mixed reality technology to combine collection resources with holographic projection. Readers can enjoy visual and auditory integration through head-mounted displays while reading, use AR technology for real-time navigation, and employ MR technology and AR programs to help readers accurately locate books and obtain borrowing status and popularity information [35]. The second phase is the establishment of digital twin libraries. At this stage, digital twin library establishment must be based on real collection resources. By creating digital avatar identities for readers and leveraging the somatosensory equipment of virtual reality to enhance immersion, the system can push relevant information and provide truly comprehensive, diversified intelligent services in the digital twin library based on readers' borrowing habits in the real world.

4.2 Blockchain Technology in Full Intelligent Libraries

Blockchain technology is a distributed ledger method that allows users to track the source and ownership of digital tokens [36]. Whether in the first or second development stage of full intelligent libraries, blockchain technology plays a crucial role. It can determine the initial upload time of virtual digital resources in digital twin libraries through timestamps and prove the authenticity of digital resource owners through full-node authentication and immutability, effectively protecting property rights identification for digital resources in digital twin libraries. Blockchain can also build consortium chains for digital twin libraries to achieve inter-library communication and direct cooperation between libraries and authors, promoting digital resource circulation and enabling the blockchainization of library resources [37].

If blockchain serves as the core technology of the metaverse, then NFT (Non-Fungible Tokens) is the core of blockchain. Non-fungible tokens are protected and non-substitutable tokens on the blockchain. Because non-fungible tokens can map the value of real-world items, their uniqueness and non-substitutability provide a reliable basis for mapping real-world objects to the metaverse [38], enabling users to obtain corresponding economic rights and interests in both virtual and real worlds. In full intelligent libraries, non-fungible tokens can provide non-fungible identification for collection resources, encompassing borrowing records, value, and literature sources. The circulation, reading, and promotion of books are all recorded in the blockchain through non-fungible tokens, making book management more convenient and efficient. Book information can be synchronously displayed through quick scanning of non-fungible tokens. Non-fungible tokens also provide new intellectual property realization forms for digital twin libraries, recording collection resource owners through unique identification and implementing patent rights through unique non-fungible tokens. In fact, the first novel written using non-fungible tokens is already circulating on the blockchain [39], and in the future, digital resources in the form of non-fungible tokens may similarly become part of full intelligent library collections.

4.3 Digital Twin Technology in Full Intelligent Libraries

Digital twin technology refers to using digital means and physical models to build an identical entity in virtual space that reflects its entire lifecycle process. Digital twin technology itself is the core technology of digital twin libraries. Therefore, this paper focuses on the introduction of digital twin technology in full intelligent libraries, particularly how it can achieve unmanned library services. The goal of unmanned libraries is to provide readers with fully intelligent self-services. Through digital twin technology for digital modeling, a panoramic model of the library can be constructed. Readers use three-dimensional models instead of traditional floor plans for navigation, browsing resource catalogs in different library areas through programs in the panoramic model to improve borrowing efficiency. During the borrowing process, a dynamic collection resource reading data display platform built with digital twin technology provides real-time resource recommendations for readers and constructs twin portraits based on readers' reading habits and interests [40], enabling precise recommendations for future borrowing experiences. Digital twin technology can provide readers with more book information during the borrowing process, displaying entities such as cultural relics and ruins from books in visual form to optimize reading experiences. Unmanned libraries do not mean no management personnel are needed. Twin librarians can provide consultation services and reading guidance, while management personnel can monitor and manage the library interior in real-time through the twin library, including facility maintenance and safety detection. They can also dynamically predict future resource needs based on borrowing conditions in the twin library, enhancing situational awareness for service optimization. Overall, the application of digital twin technology in full intelligent libraries is shown in Figure 1 [Figure 1: see original paper].

5. Service Transformation of Smart Libraries from the Metaverse Perspective

The metaverse is not the singular development of blockchain, virtual reality, or artificial intelligence but a comprehensive technological innovation. Therefore, the development of the metaverse in smart libraries must always be considered holistically. This paper prospects the application of the metaverse in smart libraries from multiple aspects: collection resource management, shared reading spaces, special user services, simplified borrowing methods, optimized reading experiences, and cultural promotion, discussing the service transformation of full intelligent libraries built in the metaverse. See Figure 2 [Figure 2: see original paper].

5.1 Collection Resource Management: Achieving Intelligent Book Arrangement

In the metaverse, full intelligent libraries enable the clustering, fusion, and reorganization of multimodal information resources and build three-dimensional

library models using digital twin technology. For the arrangement and classification of multimodal collection resources, full intelligent libraries in the metaverse are not organized by discipline but by reader needs. Based on reader needs, cloud-based full intelligent libraries retrieve books across all fields and rearrange all-domain books according to the strength of association between books and reader needs. Strongly associated books are placed at the top of the discipline field, while weakly associated books are placed at the bottom. During subsequent reading, the full intelligent library has already formed a book arrangement that meets reader requirements. If reader needs change, the library conducts secondary retrieval and rearrangement. Different reader needs result in different book arrangements, giving each reader their own full intelligent library in the metaverse.

5.2 Optimizing Reading Experience: Enjoying Dynamic Real-Scene Reading

The evolution of social forms and the iteration of document carriers have led to the transformation of library missions and service methods [41]. Physical documents will always be the foundation of libraries, but the emergence of the metaverse promotes the integration of virtual and real, enabling implicit information and knowledge in physical documents to be displayed visually to readers. The essence of traditional virtual reality technology applications is partial virtuality combined with partial reality, with issues such as insufficient immersion and low frame rates. The metaverse enables readers to achieve comprehensive immersion during reading through human-computer interaction technologies such as digital twinning, spatial perception, motion capture, gesture recognition, and digital avatars, allowing readers to interact with characters in books and presenting book knowledge in audio-visual form. High immersion and interactivity not only satisfy readers' desire for novelty in reading but also provide new paths for library cultural dissemination.

5.3 Cultural Exhibition and Promotion: Novel Operational Models

The influence of traditional library promotion models is gradually diminishing in the internet age. Only by finding more novel and unique promotion methods can libraries attract mass participation. In the metaverse, library managers can conduct cultural dissemination by uniquely modeling virtual libraries, regularly setting library themes, and holding virtual book exhibitions. They can also bind non-fungible tokens on the blockchain with collection resources to achieve cultural promotion effects. In fact, this promotion model has already emerged in the art, souvenir [42], and fashion industries. Libraries have both the possibility and necessity to create unique cultural and creative products and souvenirs associated with non-fungible tokens to achieve cultural transmission. By continuously updating library themes in the metaverse, strengthening thematic associations with other fields, and introducing blockchain technology into the art domain, libraries can increase reader attention.

5.4 Special User Services: Providing Universal Cultural Services

According to the State Council's "14th Five-Year Plan for the Protection and Development of Persons with Disabilities" issued in 2021, China has tens of millions of disabled persons, mostly with visual and hearing impairments. As public cultural service venues, libraries are not convenient for disabled readers. In most cases, disabled persons face numerous restrictions and are in an information-disadvantaged position. To promote the equalized development of public cultural services, public libraries must explore new intelligent public cultural service models for disabled persons [43].

For disabled persons, the metaverse can provide libraries with multiple service models. For visually impaired readers, libraries can use intelligent robots to provide voice assistance services, ensuring visually impaired readers have full voice guidance throughout their time in the library. Simultaneously, intelligent robots can introduce book classifications and content for each bookshelf and avoid crowded routes by calculating real-time pedestrian flow [44]. For hearing-impaired readers, metaverse technology can provide visual enhancement services, using augmented reality technology to provide visual information prompts and retrieval, overlaying text and images on real objects in the library through AR devices. Another service model is establishing smart libraries in the metaverse to enable home book borrowing for disabled persons. Through equipment such as holographic projection for visual simulation, smell sensors for scent simulation, somatosensory devices for physical simulation, and brain-computer interfaces for psychological simulation, disabled readers can "physically" visit libraries in the metaverse by creating virtual reader images, borrowing and returning books, experiencing virtual reading communities, and recording virtual reading notes.

5.5 Personal Knowledge Space: Readers as Knowledge Creation Subjects

The metaverse itself is a persistently open space. Openness and sharing enable the metaverse to support user-generated content. This means that libraries built on the metaverse ecosystem also generate new knowledge innovation methods. Readers can use AI creation in the metaverse space using library collection resources, forming personal knowledge spaces within metaverse libraries. These spaces are virtual spaces built within metaverse libraries where readers create and publish native digital knowledge. This knowledge creation is entirely based on virtual objects, such as novels and film works describing virtual worlds. Different readers' personal knowledge spaces will become important components of libraries in the metaverse, creating high-intensity associations between readers' digital creations and library collection resources. This both strengthens readers' sense of participation in metaverse libraries and provides new momentum for library transformation [45].

5.6 Shared Reading Space: A Universally Connected Online Library

The Second Life social platform brought us the prototype of the metaverse, but Second Life's core is the combination of three-dimensional modeling and the internet. Readers can only enter virtual libraries using keyboard and mouse devices, lacking somatosensory interaction, making the reading experience not significantly different from traditional digital libraries. The full intelligent library in the metaverse, however, highly integrates rules and algorithm operations, blockchain and digital currency, UGC and virtual reality, and other technologies. Based on the digital twin concept, it builds a fully simulated digital twin library where readers can enjoy library services at home through somatosensory devices and virtual reality technology. The library in Second Life [46] provides ideas for metaverse library construction, such as the digital transformation of collection resources and integration of open access resources. For establishing libraries in the metaverse, we can use the Second Life library as a framework, improving its shortcomings in real-time rendering, somatosensory interaction, and low latency through more sophisticated underlying algorithm technologies combined with physical modeling, making the metaverse library an online open universal library. In this universal online library, a decentralized, multi-level shared space can be established, enriching the service boundaries of this shared space with more diverse virtual scenarios for learning, office work, socializing, and entertainment, making the service model of libraries in the metaverse more comprehensive.

Borges believed that if there is a paradise, it must be like a library [47]. The emergence of the metaverse brings new ideas for the morphological transformation of future libraries. Although the metaverse has not yet been realized, its underlying technologies are gradually permeating our daily lives. Applying a new technology to a new field inevitably involves many problems. Although the emergence of the metaverse may change human beings and even entire social rules, it undoubtedly brings new opportunities to libraries. Libraries must pay close attention to the birth of emerging technologies, carefully consider the rules, processes, methods, procedures, and underlying logic of metaverse application in libraries, and actively embrace new technologies by continuously introducing their underlying technologies into smart library construction. If the metaverse becomes reality, full intelligent libraries will consequently achieve transformation.

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Full Intelligent Library—Metaverse will be the Way to Achieve

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By exploring the metaverse and its underlying technologies, and the theoretical logic of metaverse application in libraries, this study proposed the future prospects of metaverse application in libraries. [Result/Conclusion] The application of metaverse and its related technologies is the key to advancing the development of libraries to full intelligent libraries. Metaverse enables libraries to optimize collection resource management, reading space, cultural promotion, reading experience, and special user services, and realize the morphological change of intelligent libraries.

Keywords: full intelligent library; metaverse; virtual reality; library; service model

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