Metaverse Applications in Libraries: Theoretical Research and Practical Progress

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Abstract

With the technological prosperity of the big data era, supported by the development of AR, VR, artificial intelligence, cloud computing, blockchain, and other technologies, the metaverse is no longer confined to plots in science fiction films and novels, but has entered the real world and found applications in multiple fields such as education, film and television, and social interaction. This paper analyzes the application domains of the metaverse in libraries and prospects its future development trends, aiming to provide references for relevant research and promote the harmonious coexistence and integrated development of the metaverse and libraries. Through literature analysis, content analysis, case analysis, and other methods, it reviews relevant research literature and practical overviews, examining the current state of theoretical research and practical progress in the development of the metaverse and libraries. Current research primarily focuses on the applicability, practicality, and value of the metaverse in libraries, with most studies being forward-looking, starting from the underlying technologies of the metaverse to explore the new opportunities that information technologies bring for metaverse applications in libraries. However, clear and unified conclusions have yet to be formed regarding the conceptual characteristics, service models, and work systems of metaverse libraries, and empirical research on metaverse library application cases is also relatively scarce. Future research should focus on key aspects such as the transformation of smart library scenarios, construction of a foundational theoretical system for the metaverse, risk assessment and mitigation, and eliminating the digital divide.

Full Text

Preamble

The Application of the Metaverse in Libraries: Theoretical Research and Practice
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Abstract:
[**Purpose/significance**] With technological prosperity in the big data era, supported by advances in AR, VR, artificial intelligence, cloud computing, blockchain, and other technologies, the metaverse has transcended science fiction to enter the real world, finding applications in education, film, social networking, and numerous other domains. This paper analyzes the application fields of the metaverse in libraries and prospects for its future development trends, aiming to provide reference for related research and promote the compatible and integrated development of the metaverse and libraries. [**Method/process**] Through literature analysis, content analysis, case analysis, and other methods, we systematically review relevant research literature and practical developments, analyzing the current state of theoretical research and practical progress in metaverse libraries. [**Result/conclusion**] Current research primarily focuses on the applicability, reality, and value of the metaverse for libraries, with most studies being forward-looking investigations that examine new opportunities for metaverse applications in libraries from the perspective of underlying technologies. However, no clear consensus has yet formed regarding the conceptual characteristics, service models, or operational systems of metaverse libraries, and empirical research on metaverse library application cases remains relatively scarce. Future research should focus on library smart scenario transformation, constructing a foundational metaverse theoretical system, risk assessment and mitigation, and bridging the digital divide.

Keywords: Metaverse; Smart Library; Underlying Technology; Virtual Reality
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From traditional libraries to digital libraries and then to smart libraries, each technological transformation has propelled libraries forward, enabling more intelligent organization and utilization of knowledge and information. Compared with other cultural institutions, libraries possess an innate attribute of being "proactive, inclusive, and friendly" toward new concepts, technologies, and methods. With the development and support of AR, VR, artificial intelligence, cloud computing, and blockchain technologies, the metaverse is no longer confined to science fiction but has entered the real world, finding widespread application in film, gaming, finance, social networking, education, and other fields. As cultural institutions with social education functions, libraries are actively applying VR, AR, and virtual simulation technologies in practice, transitioning from digitalization to intelligentization. How libraries can better "settle in the metaverse world" and how the virtual reality characteristics of the metaverse will transform and innovate libraries are topics currently being actively explored in academic circles. With the explosive popularity of the metaverse concept, the academic community has shown widespread concern for library development

in the metaverse era, conducting a series of theoretical studies and practical explorations around metaverse-library applications. Therefore, it is necessary to systematically review and summarize research on metaverse applications in libraries, analyze current theoretical research focuses and trends, examine practical application progress, and prospect future research directions, hoping to broaden ideas for related research and promote the coordinated and integrated development of the metaverse and libraries.

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1 Data Sources and Analysis

The authors used CNKI as the primary source for Chinese literature, constructing the search query "Subject=(metaverse OR virtual world OR digital twin OR blockchain OR virtual reality) AND (library)" with no time limit, supplemented by searches on professional journal websites, yielding 1,078 documents (retrieved on February 24, 2023). After narrowing the scope to "library and digital library," manually removing duplicates, and eliminating conference announcements, news, and other irrelevant or low-relevance documents, 724 articles were obtained. Web of Science served as the primary source for foreign literature, with the search query "TS=((‘metaverse*’ OR ’virtual reality*’* OR twins*) AND ’librar*’)" for the period "January 1, 2000–February 24, 2023," retrieving 1,501 documents. After limiting the language to English and removing conference abstracts, book reviews, and other irrelevant documents, 535 articles remained, which were then analyzed using CiteSpace for visualization.

1.1 Comparison of Domestic and International Publications

As shown in [Figure 1: see original paper], domestic research literature from 2000–2022 shows an overall upward trend, with the earliest related research appearing in 2000 (4 articles). The period from 2016–2022 saw a particularly significant increase. It is evident that current domestic theoretical research on the metaverse and libraries is in a preliminary exploration stage but accelerating, with numerous researchers continuously following up. From the perspective of international publication volume, research started earlier. The launch of "Second Life" in 2003 saw libraries conducting promotion, reference consultation, and other work on the platform, with a noticeable increase in publications. From 2003–2016, publication volume showed a fluctuating upward trend, surging rapidly from 2017 onward. This demonstrates that while early related research was limited both domestically and internationally, the field has become a research hotspot in recent years due to technological development and policy

guidance, showing explosive growth after 2021.

1.2 High-Frequency Word Distribution

Using CiteSpace for word frequency analysis and comparing domestic and international frequencies, [Figure 2: see original paper] shows that high-frequency keywords internationally include virtual reality, augmented reality, performance, rehabilitation, and system. Domestic high-frequency terms include library, blockchain, digital twin, smart service, service innovation, application scenario, and artificial intelligence. This indicates that international research primarily focuses on internal systems such as systems, environments, and models, while domestic research concentrates on exploring metaverse-library issues from the perspective of underlying technologies like virtual reality, digital twins, and blockchain.

1.3 Keyword Clustering Analysis

In terms of research themes and keywords, international research mainly concentrates on virtual reality, blockchain, augmented reality, immersive virtual reality, big data, and management, focusing on the applicability of the metaverse in libraries and its impact. Domestic research emphasizes application scenarios and changes in service models that metaverse technologies will provide for future libraries. For instance, [Figure 4: see original paper] reveals dense clustering of keywords such as "service," "application," and "optimization strategy." Primarily starting from metaverse-related supporting technologies, research examines their functions and roles in libraries, including libraries from a metaverse perspective, metaverse-library integration, and development prospects for libraries in the metaverse. Compared with international research, domestic studies focus more on foundational theories, proposing theoretical concepts through existing technologies to guide practical applications.

2.1 Origin, Concept, and Characteristics of the Metaverse

(1) Origin and Evolution of the Metaverse

The earliest prototype of the metaverse concept was born in literary works, undergoing four distinct stages. The first stage represents the classical form carried by literature, art, and religion, with works such as *The Divine Comedy* and the *Bible*, where people used different carriers to transform fantasies into reality. The second stage is the neoclassical phase carried by science fiction and video games, appearing in sci-fi novels and electronic games, with representative works including *Frankenstein* and *The Lord of the Rings*. The third stage enters the highly intelligent form carried by "decentralized" games, such as *Minecraft* and *Roblox*. The fourth stage is the diversified form that moves beyond gaming to use reality as its carrier, becoming a high-level form of virtual reality, such as virtual concerts, virtual education, and academic virtualization [1]. Current consensus on the metaverse views it as a real-time online world evolved

from the Internet, composed of many interconnected platforms forming a new economic, social, and civilizational system [2]. In 2003, Linden Lab launched "Second Life," the first phenomenonal virtual world and the work considered closest to the metaverse in its early years. The game's launch attracted many university libraries, accelerating metaverse concept application in libraries. Harvard University, Stanford University, and others successively established library branches in "Second Life," where users could visit virtual libraries and participate in surveys [3]. In March 2021, the gaming company Roblox listed on the New York Stock Exchange, with the metaverse concept explicitly written into its prospectus for the first time, attracting widespread social attention. In October of the same year, the company was renamed "Meta," with founder Mark Zuckerberg establishing a dedicated team to develop metaverse products, striving to transform Facebook into a metaverse company.

As the metaverse "fire" burned fiercely abroad, domestic policies were introduced to escort metaverse development. In January 2021, the Ministry of Industry and Information Technology released the *Action Plan for the Development of the Basic Electronic Components Industry*, stating that with continuous innovation in basic electronic components, metaverse infrastructure and industrial applications would usher in leapfrog development. In May, the National Press and Publication Administration issued the *Notice on Launching Demonstration Projects for Science, Technology, and Standard Innovation in the Publishing Industry*, requiring accelerated integration of the metaverse industry with the publishing sector to further improve metaverse layout. In December, the Central Commission for Discipline Inspection published an article clarifying the metaverse definition, birth background, main characteristics, etc., identifying three core technologies and main application directions. Beyond the national level, Shanghai successively issued the *Shanghai Electronic Information Industry Development Plan*, *Metaverse Industry Development Action Plan*, and *Shanghai Cybersecurity Industry Innovation Action Plan*, with other provinces and cities also promulgating metaverse development and industrial layout plans to promote metaverse industrialization. From China's metaverse development planning perspective, the 13th Five-Year Plan identified metaverse-related technologies as breakthrough priorities, such as cloud computing platform construction and digital copyright development. The 14th Five-Year Plan first mentioned the metaverse, gradually advancing it toward industrialization and proposing to further strengthen forward-looking R&D of metaverse underlying core technologies [4].

Following policy releases, numerous domestic Internet enterprises actively invested in metaverse projects. For instance, in 2020, Tencent participated in Roblox's Series G financing, exclusively distributing Roblox products in China; ByteDance invested in Code QianKun to release "Restart World," modeled after Roblox; NetEase launched "Beaver Plan" and invested in the virtual character social platform IMVU to create a virtual scene social model; MiHoYo released the phenomenonal open-world RPG game *Genshin Impact*, popular among young people, and invested $89 million in the private placement of "So-

cial Metaverse" Soul. With metaverse development in full swing and Internet giants joining the fray, the resulting metaverse craze has attracted widespread attention in both academic and industrial circles, making 2021 the "Year of the Metaverse."

(2) Connotation and Extension of the Metaverse

The idea of the metaverse originated from American computer expert Vernor Vinge's 1981 novel *True Names*, which creatively conceived a virtual world accessed through brain-computer interfaces to obtain sensory experiences [5]. However, the term "metaverse" first appeared in Neal Stephenson's sci-fi novel *Snow Crash*, which envisioned a parallel virtual three-dimensional digital space that people could enter through virtual identities [6]. Wikipedia defines the metaverse, also called the metaphysical universe, meta-boundary, hyperspace, or virtual space, as a 3D virtual world network focused on social connections, creating a collective virtual space through the fusion of virtually enhanced physical reality and physically persistent virtual space [7]. However, academia has not yet formed a unified definition of the metaverse, with scholars approaching the definition from different angles and emphases.

From a development stage perspective, Fang Lingzhi considers the metaverse an inevitable trend of social informatization and virtualization, the final form of Internet development [8]. From a virtual-real interaction perspective, Wu Jiang views the metaverse as a ternary world digital society based on digital technology where people participate with digital identities, integrating virtual and real worlds [5]5. Zhao Guodong points out that the metaverse achieves a state where truth and falsehood are indistinguishable and virtual and real merge in user experience [9]. Yang Xinya defines the metaverse as an Internet application combining virtual and real worlds, built by integrating VR/AR, cloud computing, artificial intelligence, and blockchain technologies, with a relatively independent economic system and gradually growing civilizational system, providing users with immersive experiences and encouraging content production in a virtual society [10]. Dionisio J D N et al. propose that the metaverse can help multiple users in remote physical locations achieve real-time interaction, representing a simulation of computer-generated three-dimensional objects or environments [11]. Chen Gang et al. believe the metaverse is a virtual world linked and created through technological means, mapping and interacting with the real world, possessing a new social system as a digital living space [12]. From a technical support perspective, Yu Guoming proposes that the metaverse supports its operation and development through upgrades of multiple characteristics, motivating diverse entities to adopt numerous tools, platforms, and infrastructures [2]55. Huansheng Ning et al. view the metaverse as a new type of Internet application and interaction form, providing immersive experiences based on extended reality technology, creating virtual mirrors of the real world through digital twin technology, constructing an economic system based on blockchain technology, closely integrating virtual and real worlds in economy, society, and identity systems, and allowing each user to produce content and edit worlds [13].

In summary, the conceptual extension of the metaverse is vast, encompassing the entire cyberspace, terminal devices, and real-world conditions [14]. With technological innovation and development, the current metaverse is a high-level form of virtual reality supported by 5G networks, using VR and AR technologies to form visual interactive experiences, employing cloud computing and artificial intelligence for computation and intelligent support, and using blockchain as an authentication foundation.

(3) Characteristics of the Metaverse

The metaverse is envisioned as the next-generation Internet, considered the future of Internet evolution. Analyzing its characteristics can provide clearer and more intuitive understanding of the metaverse concept and explain its relationship with the Internet. Currently, academic opinions on metaverse characteristics vary widely. Renowned analyst Matthew Ball proposes that the metaverse should have six characteristics: persistence, real-time, no admission restrictions, economic functions, connectivity, and creativity [15]. Zuckerberg believes the metaverse must have interoperability and portability. Fang Lingzhi argues that the metaverse needs to have civilization (possessing its own relatively independent civilization) and integration [8]12. Xiang Anling et al. summarize metaverse characteristics as spatiotemporal extensibility, human-machine fusion, and economic value-added [16]. Wu Jiang et al. believe the metaverse differs from traditional environments in three characteristics: everything interaction, virtual-real fusion, and decentralization [5]7. Chen Gang et al. released the START map of metaverse characteristics and attributes, systematically sorting out five major characteristics: social and spatial attributes, technology-enabled transcendence and extension, human-machine-AI co-creation, realism and reality mapping, and transaction and circulation [17].

From the above perspectives, virtual-real interaction and human-machine co-creation are fundamental characteristics the metaverse must possess. With rapid technological development, more advanced technologies will provide more intelligent support for the metaverse. Grasping these characteristics can better enable the metaverse to empower libraries and other fields, reflecting and leveraging its endogenous value of “adhesion, derivativeness, and integration.”

2.2 Value of Metaverse Integration

The *2020-2021 Metaverse Development Research Report* released by Tsinghua University proposes the foundational theory of metaverse value from a scarcity perspective, stating that metaverse real-world twinning can better help real society with interactive socialization, commercial advertising, and political propaganda [18]. It helps compensate for resource scarcity to a certain extent, such as “deriving” tickets for non-public scenes, props, clothing, information, virtual landscapes, and virtual labor through metaverse architecture. Additionally, the metaverse will bring new application scenarios in education, sports, social networking, medical care, employment, shopping, tourism, and many other aspects. Currently, China’s 5G, artificial intelligence, blockchain, VR,

and AR technologies continue to develop and mature, with expanding market scale and increasingly broad metaverse technology application fields. For example, "metaverse" concept films have emerged; Hunan Satellite TV introduced the virtual host Xiaoyang; some enterprises have joined the R&D of virtual digital currency, immersive shopping scenarios, and VR house purchasing; museums actively change their original one-way transmission model to build metaverse museums to enhance user virtual world experiences [19]. The metaverse continuously integrates into various industries and drives their development. Renowned economist Zhu Jiaming proposes that education is the field with the greatest potential for metaverse applications [20], as it provides better infrastructure and scenario expansion for situational immersive teaching. For instance, South Korean company Hodoo Labs launched Hodoo English, grafting 300 characters and over 4,000 dialogue scenarios onto a virtual world to form English conversation practice. Metaverse integration into education will bring more vitality, create new social communication spaces for teachers and students, and enhance learning experience and immersion through virtual worlds [21]. As cultural and educational institutions serving certain social politics and economies [22], libraries should more closely integrate their future development with the metaverse to construct a new development pattern for libraries in the metaverse era. Therefore, the theoretical and practical topic of metaverse application in libraries is increasingly attracting exploration interest from academic and industrial circles.

3 Theoretical Research on Metaverse Application in Libraries

Current explorations of metaverse applications in libraries remain in their infancy, with foundational theories being the basis for advancing research depth. Academic interest in metaverse-library integration research is surging. For example, the 2022 Metaverse and Virtual-Real Interaction Series Forum Organizing Committee and the Global Metaverse Conference jointly held "The Concretization of Paradise: The Ideal of Library Metaverse," while Shanghai International Studies University and Fudan University co-hosted the "Metaverse and Smart Libraries" high-end academic forum, where numerous scholars focused on future development paths for libraries under the metaverse, providing new opportunities for library innovation. Additionally, the Shanghai Library Society will hold the "Wisdom, Inclusion, Transcendence: Toward Library 3.0 in the Metaverse" seminar on March 1-3, where top domestic and international experts will gather to deeply discuss the infinite future of metaverse and smart library development. When metaverse technology development sufficiently supports metaverse construction, the metaverse centered on immersive virtual experiences will undoubtedly bring brand-new development opportunities for libraries. Based on the above bibliometric analysis, theoretical research on metaverse applications in libraries mainly concentrates on three aspects:

3.1 Applicability of Metaverse to Libraries

Currently, metaverse application research in sales, media, entertainment, medical care, manufacturing, and other fields has become a hot topic [23], but has not yet involved the library domain. The metaverse itself possesses certain uncertainties, and although no promotable effective metaverse applications have emerged in libraries, the metaverse and libraries should be closely related. The transformation from traditional libraries to digital libraries and then to smart libraries cannot be separated from intellectual support from new technologies. Facing new demands for intelligent development, the National Library proposed building a "National Smart Library System" to promote library transformation from digitalization to intelligentization [24]. However, some scholars point out that current smart library development remains in a pseudo-smart or partial-smart stage [25], while underlying metaverse technologies can provide new paths to achieve "true" and comprehensive smart libraries and promote smart library service transformation. Scholars have classified and elaborated on these underlying technologies. The *2020-2021 Metaverse Development Research Report* proposes five major metaverse technology foundations, with 5G as the communication foundation ensuring network environment, cloud computing and AI assisting data processing, digital twins ensuring content production for metaverse world blueprints, blockchain providing authentication, and extended reality, robotics, and brain-computer interfaces creating virtual-real interfaces [18]. Yu Guoming proposes six major technology pillars supporting the metaverse, including blockchain, interaction technology, electronic games, artificial intelligence, intelligent networks, and IoT technology [26].

(1) Extended Reality and Artificial Intelligence Technologies
Many scholars start from underlying metaverse technologies to discuss their current application value in libraries and how future technology implementations will promote library development. Extended reality technology is essential for providing immersive interactive environments for metaverse libraries, offering intelligent services through digital avatar-related information [27], helping libraries with scenario construction, designing immersive virtual scenes in the virtual world according to real libraries, and enhancing user immersive reading experiences [28]. Lin, HCS studied differences in situational interest and cognitive load between university library students wearing and not wearing VR devices, finding that VR applications can help students improve traditional learning methods during library orientation and enhance content understanding [29]. Chih-Ming Chen et al. researched the impact of applying an educational AR system based on situated learning theory in libraries on student learning efficiency and performance [30]. Camille Chesley optimized and upgraded library services by designing and testing VR-based library reference consultation services, helping remote learning users improve their experience [31].

As the generation logic of the metaverse, artificial intelligence technology can help improve the precision of smart library services for users [32]. Fu Yunxia proposed technical paths for AI applications in modern libraries from multi-

ple perspectives including collection resources, service models, management systems, network security, and intelligent consultation [33]. Lu Tingting studied future smart library service content optimization and development bottlenecks from an AI perspective [34].

(2) Blockchain Technology

As the authentication mechanism of the metaverse, blockchain technology can help libraries maintain digital resource property rights determination [35]. Lengoatha et al. investigated the willingness to use blockchain technology in collaborative business processes of South African academic libraries, providing a foundation for blockchain applications in library and information industry cooperation through preliminary willingness surveys [36]. Tella, A et al. used sampling surveys to study Nigerian perceptions of blockchain technology relevance in library and archive management, finding that librarians and archivists maintain positive views, as it can help collect, preserve, and share authoritative information in distributed environments [37]. Hoy, Matthew B analyzed blockchain's impact on libraries, concluding that blockchain not only helps librarians collect, preserve, and share authority in scientific publishing but also serves as a digital copyright tool to effectively prevent unauthorized printing and copying of published materials [38]. Liu designed a book sharing service platform based on blockchain technology that can break geographical barriers, achieve cross-regional and cross-platform sharing of paper books, and solve problems of duplicate construction and difficult sharing of library materials [39]. Cai Dandan et al. analyzed future library IT application trends, proposing that blockchain technology will take root in library resource management, ensuring confirmation of rights for library characteristic resources and effectively avoiding duplicate purchases to facilitate co-construction and sharing [40]. Zhou Yao analyzed the driving role of blockchain core values in future library smart development, using technology applications to ensure information storage security and help libraries achieve intelligent upgrading [41]. Fang Yongzhuang et al. connected blockchain technology with library services, which can not only help libraries shift their focus from information disseminators to information organizers and managers but also enhance information storage security to provide guarantees for information services [42].

(3) Digital Twin Technology

Digital twin technology is one of the core metaverse technologies. Digital twins are symmetrical digital "clones" of the real world that can help create virtual mappings of library scenario elements and provide libraries with panoramic new fields [26]57, becoming an engine to help libraries build knowledge services for virtual environments and digital readers [10]42. It further helps future smart libraries with spatial reconstruction, with applications in library facility health management, green libraries, maker space construction, user profiling and evaluation, online learning support services, reproduction of library cultural heritage, and improving user information literacy [43]. Zhang Xingwang et al. used the Xiong'an New Area Library as an example to propose the concept and conceptual model of digital twin libraries, further constructing a technical framework

and future application scenarios [44]. Chu Jiewang et al. discussed the transformation of all-smart library service models and future application prospects from the perspective of underlying metaverse technologies, pointing out that metaverse devices and underlying technologies can help all-smart libraries achieve service transformation in smart book arrangement, shared reader spaces, special user services, unique cultural promotion, personal knowledge spaces, and optimized borrowing experiences, forming an all-smart library ecosystem built in the metaverse [45]. Li Mo designed a six-level metaverse library system architecture from bottom to top based on metaverse foundational concepts and smart library common architecture models, forming a metaverse library technical framework [46]. Wu Jiang et al. outlined the technical system that metaverse implementation relies on from five levels: data processing, rights confirmation and certification, virtual-real interaction, content production, and network linking [47].

3.2 Reality of Metaverse for Libraries

(1) Possibility of Metaverse Library Construction

Currently, metaverse integration applications with numerous industries remain mostly in theoretical conception and preliminary exploration stages, and libraries are no exception. On one hand, metaverse development itself remains uncertain; on the other hand, no effective metaverse applications promotable in libraries have yet emerged. Some scholars have explored whether metaverse-library integration is possible and what impact the metaverse's arrival will have on libraries. For example, Wu Jiang et al. point out that smart libraries are digital-real fusion of digital and traditional libraries, and the digital-real fusion space that the metaverse aims to create is conceptually consistent with what smart libraries seek to achieve, making metaverse and smart library systems closely connected [47]19. Fan Bingsi explains "why librarians must pay attention to the metaverse" from three perspectives: library mission, librarians, and users, noting that future metaverse applications in libraries have infinite possibilities [48]. Xin Haixia demonstrates the compatibility of the metaverse with future libraries from three aspects: library integration into the metaverse, the metaverse's promoting effect on libraries, and the value and construction of metaverse libraries [49]. Yang Xinya discusses the necessity for libraries to implement metaverse strategies from the perspective of "basic library connotation" [10]40, believing that the metaverse's emergence and development opportunities can help libraries solve development challenges, and proposes four specific and feasible entry points for future libraries to build virtual service systems in the metaverse [50]. Ma Feicheng discusses three consensuses existing between library and information science and the metaverse from the development history of the discipline, and proposes four entry points for library and information science to integrate into metaverse research and practice [51]. Liu Wei and Zhu Rui divide the metaverse into four types, exploring applications that different types may derive in libraries and analyzing the possibilities and approaches for future library metaverse construction [52]. Zhou Wenjie conceptualizes the

form and function transformation of libraries in the metaverse era based on the essence of the metaverse and World 3 internal structure representation [53]. These studies demonstrate that scholars hold positive and affirmative attitudes toward the feasibility of metaverse applications in libraries, proposing concepts and frameworks for future "metaverse + library" construction.

(2) Risks and Concerns of Metaverse Libraries

Opportunities and challenges have always been "twin brothers," with each technological revolution bringing major transformations to libraries along with accompanying challenges and risks. Zhao Xing proposes that metaverse development will encounter problems such as detachment from reality, prioritizing games, and unprepared governance [54]. Therefore, while studying the feasibility of metaverse-library integration, we cannot ignore potential negative impacts. Looking forward to metaverse applications in libraries, scholars have respectively proposed, from the core elements of libraries—document information resources, users, personnel, technology, and building equipment—that the metaverse can help libraries solve problems such as insufficient collection space, high technical requirements for staff, and diverse user needs, but metaverse-library integration still hides many risks. For instance, Xu Xin et al. point out seven potential risks in metaverse development: unknowingly empty hype, unhealthy competitive patterns, undialectical technological rejection, unbalanced supply-demand structures, unsustainable radical expansion, unrestrained blind worship, and irrational hedonism [55]. Ji Chao proposes that metaverse libraries may face concerns about cost and technology, library stakeholders, detachment from reality, intellectual property rights, library polarization, and information security and privacy protection [56]. Han Xu discusses issues facing library metaverse construction from four levels: application technology, intellectual property rights, standards and regulations, and privacy protection [57]. Chen Dingquan and Cheng Shiyao et al. believe that while the metaverse brings opportunities to libraries, it also brings challenges, and therefore facing the metaverse craze, the focus should remain on improving foundational capabilities to welcome technological change, or exploring the reference value of metaverse libraries for current library improvement and innovation [58]. Only by facing squarely the potential new hidden dangers that metaverse construction may bring to libraries, maintaining sober cognition and critical thinking, and being prepared for danger in times of safety, can we discuss, research, and apply the metaverse more rationally and scientifically.

3.3 Value of Metaverse for Libraries

As the metaverse injects fresh vitality into the development of gaming, social networking, media, and other industries, scholars have begun to conceptualize the value of metaverse-library integration. Libraries can use their resource advantages to facilitate metaverse construction, while the metaverse can also provide solutions for libraries to break through development bottlenecks.

(1) Libraries' Promoting Effect on the Metaverse

Driven by technological innovation, the emergence of virtual worlds synchronized with the real world means that libraries, museums, and archives, as institutions for preserving and inheriting human cultural heritage, will not change their responsibility to preserve and transmit human knowledge and culture in either the real or virtual world. Therefore, library participation in metaverse construction is essential, as it can help organize, collect, and preserve human cultural heritage within metaverse document information flows. Liu Wei proposed at the "Concretization of Paradise: The Ideal of Library Metaverse" forum that we should not only metaverse-ize libraries but also library-ize the metaverse—not only create libraries in the metaverse and bring library services into the metaverse but also incorporate accumulated and newly generated knowledge into metaverse spaces [59]. Zhang Qinglai and Su Yun believe that as a service institution, libraries can serve as communication pipelines between the metaverse and the real world, use their ability to organize and utilize knowledge to provide resource navigation between different universes, use metaverse evaluation services to promote healthy metaverse development, and provide appropriate native services for various metaverses [60].

(2) Value of the Metaverse for Libraries

The metaverse's emergence also creates new opportunities for library development. Scholars have proposed theoretical frameworks for library development and innovation under metaverse empowerment, believing the metaverse can better empower future libraries to a certain extent. For example, Guo Yajun et al. analyzed how the metaverse can meet virtual library needs in resource retrieval, learning environments, reference consultation, and education, exploring partial application scenarios of metaverse-empowered virtual libraries [61]. Guo Yajun et al. also explored metaverse-empowered public library social education application scenarios from the perspective of public libraries' social education functions, proposing development strategies for public library social education in the future metaverse era [62]. Wen Yingzi proposed that future metaverse applications in libraries can help libraries leverage spatial advantages, optimize service systems, effectively integrate resources, facilitate protection and utilization of precious documents, and enhance library-user interaction capabilities [63]. Wu Jianzhong points out that the metaverse can help libraries better display rare resources, facilitate knowledge discovery and reference consultation innovation to a certain extent, enhance inclusive services, attract more young people to use libraries, and provide research opportunities for deepening digital humanities [64]. The metaverse can also promote the transformation from digital libraries to smart libraries. Zhang Hui et al. focused on characteristics of digital library transformation to smart libraries, noting that the virtual-real complementary metaverse orientation is a major characteristic of library smart transformation, and that virtual-real integrated library service systems are an important part of smart library construction [65]. Tian Limei et al. conceptualized that future metaverse integration in libraries can use technical support to help smart libraries scale scenario application construction, eliminate information gaps, and solve limited physical space problems by creating virtual reading

spaces [32]56. Yang Feng pointed out that metaverse core technologies can be used to reshape smart libraries, applying metaverse technology to library space construction, implementing smart databases, and establishing metaverse virtual librarians to promote metaverse smart library construction [66]. Cai Yingchun et al. sorted out the dialectical relationship between smart libraries and metaverse technology applications, proposing practical paths for smart library construction in the metaverse era [67]. Library-metaverse integration can promote future library development and innovation. Li Hongchen and Ma Jie used immersion theory to propose a future immersive metaverse library architecture, reconstructing attributes and relationships of "people, place, and objects" in metaverse libraries, and proposing development strategies for future metaverse libraries from an immersion perspective [68]. Xu Wenyi explored innovative development angles for metaverse-smart library integration from the perspective of five metaverse characteristics [69]. Xin Haixia constructed seven metaverse library value levels aligned with Jon Radoff's metaverse seven-layer value chain model and depicted their landing scenarios [49]93. Zhang Xingwang constructed a metaverse library cyber-physical fusion model based on current research, dividing its operation mechanism into four levels: physical fusion layer, model fusion layer, data fusion layer, and service fusion layer.

4.1 Early Practice Prototypes

Early metaverse library practice applications occurred in Second Life. Second Life, developed by Linden Lab in 1999, is a 3D virtual reality technology-based virtual world considered the exploration closest to the metaverse in its early years. As different industries rushed to settle in Second Life, the library industry also actively entered the virtual world. In 2006, the Alliance Library System and Online Library Cooperation established the "Cybrary City" information island in SL to provide support and services for libraries joining SL. In the same year, the American Library Association established a small library in SL to associate virtual communities with physical libraries and explore services libraries could provide in virtual worlds [71]. Subsequently, numerous domestic and international university libraries also joined in creating information islands. In 2009, the Hong Kong Polytechnic University Library built the first virtual library in China in SL [72]. Reference consultation service was the earliest service project provided by SL libraries. Using virtual spaces to simulate real library reference consultation services can overcome time and space limitations for barrier-free communication between librarians and readers [73], representing the earliest practical application prototype of metaverse libraries.

4.2 Smart Scenario Transformation

With continuous technological innovation, the connotation of virtual worlds has become increasingly rich, and the metaverse concept has gradually entered public view. However, metaverse development requires collaborative construction of underlying technologies, hardware devices, and content ecology. The current

metaverse in its preliminary exploration stage forms an immersive experience prototype based on underlying technologies [74]. The library industry actively explores metaverse library prototypes by applying different metaverse technologies to digitize library content and assets, enhance library service intelligence, and create immersive experiences for users [75].

Digital twin technology can help libraries digitize content and assets. Meta's internal library attempts to generate twin books and digitally twin infrastructure such as photo albums and office supplies for deployment in metaverse spaces [76]. Through user twins, object twins, and library space system twins, library content and assets are digitized, which can help library users better interact with information in the future, enhance interlibrary loan convenience, and promote library smart scenario transformation. Virtual digital human technology helps enhance library service intelligence. For example, the New Tianjin Eco-City Library and Archives launched a metaverse-driven virtual experience system, placing digital human smart screens in the library that use digital human Xiaobo for intelligent voice interaction to provide services such as book retrieval and online reading [77]. The Binzhou City Library launched a voice-interactive virtual digital human to provide consultation services for users [78]. Virtual digital human technology enables readers to obtain library services equally without time and space constraints, alleviating pressure on human librarians and enhancing library service intelligence [79].

4.3 User Immersive Experience

Virtual reality and augmented reality technologies can create immersive experiences for users, applicable to virtual tours, information retrieval visualization, 3D information resource construction, reference consultation, and other aspects [80]. Virtual tours are relatively common in library VR technology practice, helping users remotely visit libraries across geographical restrictions. For example, Brandeis University Library uses VR technology for virtual tours [81]. Many domestic libraries have also implemented online library roaming on WeChat official accounts. For instance, Hohhot City Library uses VR technology to 100% restore real library scenes for VR roaming and 3D reading [82]; Guangde City Library's VR exhibition hall allows mobile access to library virtual spaces anytime, anywhere [83]; Shanghai University Library's Weichang Book House and Kuangdi Book House launched online 720° VR scene experiences. VR technology can also provide technical guarantees for metaverse library construction and improve service efficiency. For example, the University of Michigan's Waldo Library website provides users with a VR lab where they can create VR to enhance learning efficiency; the Lauringer Library uses VR technology to help students practice dangerous military exercises and simulate complex operations [84]; the National Library of China used holographic projection technology to support the 5G panoramic cultural classics *Yongle Encyclopedia* large-scale series of activities, providing panoramic appreciation of traditional paintings and classics through 270° naked-eye, 360° TV, and 720° glasses [85]. Augmented reality

technology is mostly used in library freshman orientation, self-guided tours, and promotional activities. For example, Jacksonville State University Library uses AR technology for freshman orientation, setting up AR treasure hunt games to help students navigate the library, guide them to solve puzzles, and familiarize them with library spaces and services, making orientation more interactive and immersive [86]; the University of Chicago Library uses AR technology for text projection; Tianjin TEDA Library launched AR interactive encyclopedia services, allowing users to learn knowledge through clicking and dragging on large screens and watch 3D books online to interact with virtual images [87], enhancing library-user interaction functions to better attract readers and enhance reading interest.

4.4 Virtual Reading Space

Beyond integrating underlying technologies to help metaverse library construction, libraries should pay more attention to virtual-real interaction to construct virtual "metaverse" library spaces. For example, the Shanghai Lingang Science and Technology Library, planned to open in 2023, is China's first digital library with metaverse characteristics. The library will strive to build a "meta" library based on human science, history, and cultural systems, using digital immersion as the main interactive experience method. It will comprehensively integrate VR, AR, MR, and 5G technologies to create virtual-real interconnected reading experiences, featuring functional areas such as image reception, professional services, digital reading, electronic virtual reading, and immersive visual reading for readers to choose from. Additionally, it will build a digital experience area with a surround-screen digital VR screening room where readers can establish virtual identities to enter virtual spaces, watch lectures with naked-eye 360-degree holographic images, and provide immersive audio-visual experiences [88].

In May 2022, J.P. Morgan's annual recommended non-fiction books debuted in the virtual world for the first time, providing reading access through an open metaverse library format. The open book list is a summer tradition maintained for over 20 years. The 23rd edition of J.P. Morgan's summer reading list includes 10 books, launched for a limited time in a virtual library exhibition in Decentraland. The difference this year is that the book list will be linked to the metaverse space Onyx for the first time [89]. For a limited time, visitors can explore the virtual library exhibition created in collaboration with metaverse real estate company Everyrealm on the first floor of the lounge. Visitors can create an avatar, enter the virtual library, learn about these books, and watch exclusive interviews with selected authors within the metaverse scene. An academic owl perches nearby, answering readers' book-related questions like a library reference consultation service. Linking the summer book list with the metaverse space Onyx represents preliminary exploration of libraries in metaverse scenes, demonstrating infinite possibilities for future library-metaverse integration. Their fusion can continuously enhance the interactivity, openness, and

mobility of book reading. As underlying metaverse technologies continue to develop and provide strong support, the gradual formation of metaverse libraries will bring newer experiences and perceptions to readers.

5 Research Implications and Prospects

Current research on metaverse libraries in China is in a stage of rapid development from its starting point. Academic and industrial circles are paying close attention and closely tracking this research hotspot, conducting fruitful explorations on the integration and applicability of the metaverse for libraries, reflecting strong confidence in the integrated development of libraries and the metaverse with promising futures. Research results mostly focus on metaverse-library compatibility, opportunities and challenges the metaverse brings to libraries, and service model transformations brought by metaverse technical support, with most being forward-looking studies examining technological changes from underlying metaverse technologies. However, no definitive conclusions have been reached regarding the connotation, characteristics, service models, or operational systems of metaverse libraries, and empirical research cases on metaverse libraries are also scarce. In view of this, the author believes that future metaverse library research should focus on library smart scenario transformation, constructing a metaverse foundational theoretical system, risk assessment and mitigation, and expanding service boundaries to promote more comprehensive, systematic, and in-depth metaverse library research. This will provide decision-making references for exploring scientific metaverse applications in libraries, avoiding "incompatibility," and accelerating the connotation construction and innovative development of smart libraries.

5.1 Using Underlying Technologies to Accelerate Library Smart Scenario Transformation

With information technology development, numerous underlying technologies labeled as "metaverse" have emerged, and smart library construction continuously proposes new demands, urgently requiring specific practices and technical means to support rapid smart transformation. Libraries are committed to providing better services for users. On the basis of ensuring content and resources, they empower content construction through technological progress, promote content-technology integration, and use technology to optimize user experience, reflecting intelligence not only in display forms but also in smart creation, utilization, and sharing [68]7. Currently, some libraries are actively introducing advanced technologies in resources and services. For example, the British Library uses automated three-dimensional stack robots for library storage and sorting, replacing human labor with robots [90]. Sun Yat-sen University Library introduced RFID technology early on, with self-service borrowing machines, security gates, intelligent book carts, and smart bookshelves helping libraries more efficiently locate and circulate books and enhance self-service functions. Each technological transformation drives libraries forward, from automation to intelligence and

from intelligence to smartization. Currently, libraries are at a critical stage of transitioning from intelligence to smartization, requiring new "metaverse" underlying technologies to empower smart library construction and accelerate the building of smart scenarios with virtual-real interaction and immersive experiences. For example, using VR, AR, and 3D naked-eye technology for VR reading allows readers to enter virtual reading spaces and reading scenes within books, enhancing reading immersion and experience. Additionally, underlying metaverse technologies can help build future library virtual service systems. Digital virtual humans such as Tsinghua's digital student "Hua Zhibing," virtual idol "A-SOUL," and Wuhan University Library's "Xiaobu" have attracted widespread attention. Libraries can use AI and digital twin technology to build library virtual digital humans for multi-scenario applications, helping undertake basic business work such as reference consultation and reader services. Furthermore, virtual exhibitions, virtual studios, virtual tours, virtual space services, smart buildings, and digital collections can further optimize library service systems. Especially during public health emergencies, they help libraries provide virtual online services where readers can enter libraries for reading and learning, exhibitions, lectures, and other activities through external devices, not only enhancing library-user interactivity but also promoting library smart scenario transformation.

5.2 Building a Foundational Theoretical System to Promote Metaverse Library Practice

From the current research progress, although theoretical research on the metaverse has achieved a series of results, a mature and complete theoretical system architecture has not yet formed. Particularly, there are no relatively complete and authoritative conclusions regarding the positioning, nature, connotation, and role of libraries from a metaverse perspective. Whether the metaverse can be practically applied to future libraries and what pros and cons exist remain subjects of scholarly debate. How libraries can better integrate new concepts and technologies brought by the metaverse with their own development to become a cure for current development bottlenecks deserves exploration. Libraries undertake the functions of organizing social document information flows, delivering document information, developing intellectual resources, and conducting social education. The emergence of metaverse libraries should not cause libraries to detach from reality and overemphasize virtual facility construction, making entertainment functions greater than cultural education functions. Metaverse library development based on numerous underlying technologies should break through traditional disciplinary boundaries, integrate multiple disciplines, and explore new connotations, natures, and functions of libraries from a metaverse perspective to promote theoretical innovation. Current practical research on metaverse libraries is limited, but theory and practice complement each other, and theoretical research cannot be separated from actual library construction. Metaverse development is in its infancy, and metaverse libraries are being constructed step by step. Although AR, VR, and 5G communication technologies

have been widely applied in library practice, there remains a large gap from the integrated specialized technical requirements needed for metaverse library construction [91]. Theoretical research should pay more attention to integration with practice, building corresponding theoretical systems on a practical basis to guide and promote healthy and scientific metaverse library development. Additionally, as public cultural education institutions, libraries should closely monitor the development and implementation of related new technologies, using theory as foundation and technology as support to avoid missing development opportunities due to closed-mindedness or fear of innovation. Externally, they urgently need to cooperate with computer science schools, social industry institutions, and especially leading information technology enterprises, using practical data and user information needs to leverage technology companies' R&D advantages to accelerate technical breakthroughs, break technical barriers, and develop integrated technologies applicable to metaverse library construction. Internally, they should increase R&D investment, summarize gains and losses of current underlying technologies in practical scenarios, make good use of existing VR, AR, and other technologies, broaden technology applicability and boundaries through software upgrades and development, enhance user experience, and expand application scenarios. Through internal-external linkage, technology R&D, and technology package procurement, they can promote the landing and application of integrated metaverse technologies in libraries, organically combining theory and technology, focusing on practical applications to accelerate the early realization of metaverse libraries.

5.3 Strengthening Institutional Design to Mitigate Metaverse Application Risks

Although the metaverse concept brings great development space for libraries, it still faces numerous issues such as overlapping multiple risks, information cocoons [92], widening wealth gaps and intelligence divides, and personal data information leakage. With new technology expansion and application, library operation models and activity forms will undergo certain transformations, urgently requiring new relevant rules and regulations to adapt to operational model changes brought by the metaverse, and exploring solutions to the "dark side" of metaverse libraries through institutional norms. The metaverse is a virtual world formed by technological development, relying on massive algorithmic data, which leads to continuous compression of individual privacy spaces for application groups. Whether user information security can be effectively guaranteed and whether massive data collection flows to unknown sources for commercial profit purposes remain questions. Therefore, especially when cooperating with social technology companies, libraries should clarify relevant rights and responsibilities, establish relevant institutional norms, and protect user information and property security. At the same time, as technology advances and virtual resources increase, more practical problems will continuously emerge, requiring libraries to break old norms and research management systems and regulations suitable for metaverse library construction needs, guiding development toward

standardization. Simultaneously, staff acceptance and adaptation capabilities for various underlying metaverse technologies in library applications should be enhanced. By constructing and implementing constraint mechanisms for metaverse-empowered libraries, various risks that may arise during metaverse library construction can be minimized, providing institutional guarantees for metaverse library construction. Additionally, metaverse library construction requires massive advanced technologies and equipment, with enormous talent and capital investment costs and high technical thresholds for users. How libraries can avoid neglecting one aspect for another and guarantee every user's right to fairness becomes a major challenge. The *Public Library Manifesto* proposes free service-centered equal public library core values, and Cheng Huanwen also points out that libraries must guarantee the realization of equal library rights for the public—namely personality equality, equal opportunity, and equal service [93]. No matter how metaverse libraries develop, they cannot deviate from libraries' essential attributes and social functions. They should fully consider the relationship between using virtual reality, digital twins, and other technologies and promoting social education fairness, ensuring that special groups' rights are not unequal due to consumption capacity, class, or digital divide. Therefore, more institutional construction is needed to benefit the public, lower technical thresholds, always protect user equal rights, avoid risks and concerns, and maintain metaverse library operational order.

5.4 Bridging the Digital Divide to Expand Library Service Boundaries

The current era is one of rapid development and rise of information networks. Imbalances in information infrastructure construction, information literacy, and information organization and acquisition capabilities have created an ever-widening gap between information-rich and information-poor populations. Reducing information islands, eliminating digital divides, and promoting digital inclusion are missions and responsibilities that libraries should shoulder. The metaverse era brings new opportunities for library smart transformation on one hand, but on the other hand exacerbates the information gap between those with certain information technology and literacy and those without. At the beginning of the Internet's vigorous development, libraries expanded their functions to help the public access information resources and improve information literacy to bridge the digital divide [94]. The new technological impact brought by the metaverse requires libraries to expand service boundaries and undertake the responsibility of bridging public digital divides, making them more compatible with current technological characteristics and development trends. For example, with support from extended reality, blockchain, cloud computing, digital twins, and other technologies, libraries can use VR, AR, 3D, and other technologies to build virtual network spaces, effectively integrating resources, spaces, personnel, and technical resources to form more intelligent information acquisition services. Through user behavior research and knowledge graph creation, they can provide appropriate knowledge information services for different users, creating immersive knowledge

acquisition environments that are superimposed, compatible, interactive, and integrated. Virtual reality technology enables reader reading without time and space constraints, while virtual spaces created through digital twin technology can solve library collection space limitations to a greater extent, further resolving the contradiction between limited library collections and unlimited demands. Additionally, it is worth noting that "gaps formed by differences in software and hardware, user accessibility, ease of use, and convenience in using libraries are also manifestations of the digital divide" [95]. Libraries have always been committed to inclusive services, allowing broad users equal opportunities to obtain services. Effective use of metaverse technologies can help libraries bridge digital and technological divides, continuously expanding library functions and service boundaries to enhance inclusiveness, friendliness, and openness. For example, they can help traditional library functions such as document preservation, user services, and characteristic collection construction break through time, space, and development element constraints. In terms of infrastructure, they should guarantee material conditions for immersive interaction. County and district libraries can provide VR, AR, and other equipment for citizens to share and experience, obtaining the same services as large libraries, using metaverse services to compensate for geographical space barriers and bring convenience in acquisition and sharing to distant populations [96]. This makes user service dimensions broader in length, width, and depth, user experiences more three-dimensional and multi-dimensional, and user "stickiness" to libraries stronger, allowing full enjoyment of various benefits brought by the metaverse era.

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