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Research on Library 3D Digital Resource Service System in the Metaverse Context

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Abstract

[Purpose/Significance] With the rise of the metaverse, an increasing number of digital resources are entering this domain, including 3D digital resources. 3D digital resources hold a significant position in the metaverse, as they can provide users with more vivid and intuitive experiences and perceptions. Libraries, as important institutions for the storage and dissemination of digital resources, also need to integrate their 3D digital resource services into the metaverse to meet user demands. [Method/Process] Through an investigation of the characteristics of 3D digital resources in the metaverse and the current state of library 3D digital resource services, this paper proposes the construction of a library 3D digital resource service system from a metaverse perspective. [Results/Conclusion] This should be realized through the establishment of full lifecycle management standards for 3D digital resources, the adoption of open-source distributed storage strategies, the construction of a scenario-based resource utilization system, and the utilization of blockchain-based version control technology.

Full Text

Research on Library 3D Digital Resource Service Systems from the Metaverse Perspective

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Abstract:

[Purpose/Significance] With the rise of the metaverse, an increasing number of digital resources are entering this space, including 3D digital resources. 3D digital resources hold an important position in the metaverse, as they can provide users with more vivid and intuitive experiences and perceptions. As a crucial institution for storing and disseminating digital resources, libraries also need to integrate their 3D digital resource services into the metaverse to meet user

demands. [Method/Process] This paper proposes the construction of a library 3D digital resource service system from the metaverse perspective, based on research into the characteristics of 3D digital resources in the metaverse and the current state of library 3D digital resource services. [Result/Conclusion] This should be achieved by formulating full lifecycle management standards for 3D digital resources, adopting open-source distributed storage strategies, establishing scenario-based resource utilization systems, and employing blockchain-based version control technology.

Keywords: metaverse; library; 3D digital resources; service system

Classification Number: G258.6

In recent years, the metaverse has become a hot topic of discussion. As an upgraded version of virtual and augmented reality, the metaverse represents an important vehicle for future digital social interaction, learning, and entertainment. Within the metaverse, users can interact with digital objects, environments, and other users to achieve immersive virtual experiences. Due to its high degree of interactivity and realism, the metaverse is attracting an increasing number of users. Simultaneously, it presents new development opportunities for library 3D digital resource services. In the past, libraries primarily relied on print books as their main information carriers. With the development of digital technology, libraries have gradually expanded their service domains, and digital resources have become a crucial component of library services [1]. As an important subset of digital resources, 3D digital resources, with their visualization and interactive features, have emerged as a new highlight of library digital resource services [2]. Therefore, exploring the construction of a library 3D digital resource service system from the metaverse perspective holds significant research importance.

2.1 Overview of the Metaverse

The metaverse refers to a virtual, three-dimensional, multi-universe space possessing self-awareness and self-generating capabilities. Within the metaverse, users can experience spatial and temporal dimensions distinct from reality through virtual reality technology, engaging in virtual social interaction, entertainment, work, and learning activities, while also creating digital achievements and owning digital assets [3].

As an emerging technological domain, the metaverse is currently in a stage of rapid development. According to Gartner's predictions, the metaverse market will exceed \$2 trillion by 2025 [4]. Concurrently, major global technology companies such as Facebook, Google, and Amazon have entered the metaverse arena, accelerating its development pace. The deep integration of metaverse technologies with virtual reality, augmented reality, artificial intelligence, and blockchain provides new technological support for the development of library 3D digital resource services.

2.2 Characteristics of 3D Digital Resources in the Metaverse

3D digital resources constitute one of the most fundamental resources in the metaverse, encompassing various types of objects, buildings, scenes, and props. These resources are created using digital tools such as CAD software, 3D scanners, and cameras. The characteristics of 3D digital resources in the metaverse are as follows:

2.2.1 Visualization and Immersion

One of the most prominent characteristics of 3D digital resources in the metaverse is their visualization and immersive quality. Through 3D models, users can more intuitively understand and explore objects and environments in virtual space, which also sets higher standards for the metaverse's interactivity and playability. In the gaming industry, for example, nearly all modern games support 3D model rendering. As game graphics have improved and the concept of open worlds has emerged, players can explore game worlds with greater freedom, while the incorporation of 3D models enhances world realism and interactivity, providing more immersive gaming experiences. Additionally, 3D models are widely applied in architecture and design fields. Designers can use 3D models to more accurately present the appearance and functionality of buildings, products, or other items, enabling clients to better understand design details and features and thereby appreciate design value more fully. In the medical field, doctors can use 3D models to simulate and study human organs and pathological changes, leading to better understanding and treatment of related diseases. Similarly, automotive manufacturers can employ 3D models to design and test vehicle appearance and performance, thereby improving product quality and competitiveness.

2.2.2 High Quality and High Capacity

3D digital resources in the metaverse feature rich detail and high quality. Using 3D modeling software, designers can precisely capture and present every detail of an object, making it appear more realistic and vivid. Simultaneously, the digital nature of 3D models endows them with higher precision and quality, providing a reliable foundation for metaverse development. High-quality 3D digital resources in the metaverse are typically generated through the following methods: (1) Photogrammetry: Extracting three-dimensional measurements from two-dimensional data (i.e., images). GPU-based processing technology rapidly reconstructs 3D surface meshes from multiple sets of conventional photographs of physical objects or environments, reassembling 3D digital models through color information or texture maps from the relevant 2D images. (2) Laser scanning: Recording precise three-dimensional information of real-world objects or environments by rapidly sampling or scanning object surfaces with lasers, ultimately reassembling 3D digital models by representing surface colors through color information at vertices. (3) Structured light: Calculating

surface shape based on the deformation of projected light, which can be used for geometric reconstruction of surface shapes to generate 3D digital models. (4) Reference-based modeling: A model creation method based on documents, reference photographs, or other information sources about real-world objects or places. Models are typically created within CAD (Computer-Aided Design) software systems. (5) CT scanning: Also known as computed tomography, this technique uses computer-processed combinations of many X-ray measurements taken from different angles to generate tomographic images and volumetric data of scanned objects for 3D digital model generation. Additionally, with technological advancement, a multimodal modeling approach that integrates multiple information resources has recently emerged [5].

In summary, 3D digital resources are typically composed of large numbers of points, surfaces, and lines, resulting in substantial data volumes. Moreover, 3D digital resources may contain multiple objects, materials, colors, and other information with complex interrelationships, leading to massive data quantities. For example, the 3D digital resource assets used in the well-known film *Avatar 2* totaled approximately 18.5 petabytes [6].

2.2.3 Operability and Ownership

Through 3D digital resources, users can engage in more direct, free, and flexible interactions with information resources such as digital cultural heritage, scientific research, and engineering design. Users can freely select viewpoints, zoom, rotate, and perform other operations to experience the authenticity and appeal of information resources. They can use clipping tools to crop 3D models to specific sizes and shapes, and employ deformation tools such as twisting and bulging to modify 3D model shapes, thereby enabling more diverse designs.

In the metaverse, the ownability of 3D digital resources means that individuals can become legal owners of these resources, possessing usage rights and control authority. This characteristic of ownability makes them one of the most important digital assets in the metaverse.

Currently, many 3D digital resources can already be traded as NFT digital collectibles on various markets and platforms, such as decentralized marketplaces like Nifty Gateway, SuperRare, and KnownOrigin, which allow transactions to be facilitated using cryptocurrencies and smart contracts [7].

3.1 Current Status

Currently, many libraries have collected substantial quantities of 3D digital resources through both purchase and in-house creation, primarily including building models, cultural artifact models, life science models, and geological models. These 3D digital resources provide users with intuitive perception and experience, serving fields such as cultural heritage preservation, scientific research, and education. When creating 3D digital resources in-house, libraries have begun emphasizing quality management of digital resources and have started formulating

full lifecycle management standards covering resource generation, organization, and preservation. Projects such as CARARE [8] and Europeana Data Model [9], for example, have detailed technical procedures for data acquisition and post-processing using methods like photogrammetry and laser scanning, while establishing metadata models with four major categories of information and over 200 elements to identify heritage assets, 3D digital resources (information on resource type, format, and location), activities (historical events occurring at heritage sites), and collection information. These metadata can be mapped to Dublin Core metadata, facilitating both long-term preservation of resource information and resource sharing. Simultaneously, libraries continue to explore different forms of resource services.

- (1) In cultural heritage preservation, representative projects include 3D-COFORM, Europeana, and MayaArch3D. These projects digitize scattered ancient artifacts and ruins with high fidelity to create 3D digital resources uploaded to the internet for user viewing and research. They provide users with opportunities to view cultural artifacts from multiple angles at close range without geographical limitations, while also benefiting cultural heritage preservation and research.
- (2) In research services, the NYC3Dcars project [10] serves as a representative example. Developed by Cornell University Library for autonomous driving research, this project has created a geographically contextualized 3D vehicle database containing detailed vehicle descriptions, including complete six-degree-of-freedom vehicle poses, vehicle types, and 3D vehicle bounding boxes. NYC3Dcars also integrates supporting databases from OpenStreetMap and NYCOpenData to facilitate access to geographic features such as roads, sidewalks, and median polygons, as well as road network connections. Researchers can freely utilize data from multiple databases within NYC3Dcars to build three-dimensional simulation experimental environments for scientific experiments and data acquisition. Additionally, NYC3Dcars provides open-source detection and analysis software to assist in experimental result verification and analysis.
- (3) In education, the MorphoSource project [11] represents a notable initiative. Jointly developed by Duke University Library and museums, this open database aims to promote shared discovery and advance human knowledge and scientific inquiry, containing over 60,000 3D digital models of biological specimens. It not only allows users to browse online for more intuitive understanding of objects but also permits downloading complete 3D digital resources as materials for incorporation into their own research content or achievement presentations. The advantage of 3D digital resources lies in their easy comprehension by people from different disciplinary backgrounds, making them increasingly important in education.

In summary, libraries have accumulated certain experience in managing and serving 3D digital resources. At the resource management level, they ensure resource fidelity, shareability, and operability by establishing full lifecycle man-

agement standards. At the resource service level, libraries primarily support cultural heritage preservation and educational research by constructing 3D digital model repositories and 3D simulation experimental environments.

3.2 Challenges

Currently, library 3D digital resource services face numerous challenges in meeting metaverse requirements.

- (1) The complexity of 3D digital resources demands higher professional expertise from library staff. 3D digital resources feature large data volumes, diverse formats, and complex data relationships. According to incomplete statistics, over ten 3D digital formats are in relatively widespread use, including X3D, STL, OBJ, PLY, VRML, 3D PDF, 3DS, SURF, RAW, MESH, VGL, WRAP, MSH, OFF, HXSurface, SMB, GLTF, and GLB. Digital resources in different formats may require different software for editing, processing, and display, and may even necessitate different hardware devices to support their use.
- (2) 3D digital resources lack unified metadata standards. Metadata is descriptive information about data, including sources, formats, attributes, and constitutes an important component of 3D data resource management. However, the current absence of unified 3D data metadata standards makes description and retrieval of 3D data resources difficult. Currently, the metadata standards used in the industry for cataloging 3D digital resources include Carare, VRA Core, and Dublin Core. Carare and VRA Core are primarily metadata standards established for describing visual resources of artistic artifacts such as objects and buildings in network environments, while Dublin Core tends to be more oriented toward describing 2D digital resources.
- (3) Storage and security of 3D digital resources. On one hand, libraries face higher storage cost issues. For instance, Indiana University-Purdue University Indianapolis, an institution that has just begun collecting 3D digital resources, already has nearly 2TB of data from only a few hundred digitized 3D objects [12]. On the other hand, storage security and copyright security of 3D digital resources also require solutions through technological and management innovation.

4.1 Development Trends of Library 3D Digital Resource Services from the Metaverse Perspective

From the perspective of metaverse development trends, 3D digital resources face certain challenges but also present numerous opportunities in future applications and development. Specifically, the development trends of library 3D digital resource services mainly include the following aspects:

- (1) **Diversification:** As the metaverse evolves, user demands for 3D digital resources are becoming increasingly diverse. In the future, libraries need to provide richer and more diversified 3D digital resource services tailored to user needs across different disciplinary fields. This includes both the visual representation of 3D digital models and the internal knowledge associations within 3D digital models, all of which should be provided from disciplinary perspectives. For example, cultural heritage preservation requires consideration of historical, cultural, and artistic factors to provide 3D digital resource services that offer the most authentic digital replicas from a historical restoration perspective, while scientific research and engineering design require consideration of mathematical, physical, and computer science factors to provide multi-perspective, operable 3D digital resource services.
- (2) **Open sharing:** Open sharing represents an important trend in the future development of library 3D digital resource services. Libraries need to strengthen cooperation with resource storage and service institutions such as museums and archives to promote sharing and exchange of 3D digital resources, while adopting open data standards and sharing platforms to improve the accessibility and reusability of 3D digital resources.
- (3) **Technological innovation:** Technological innovation serves as an important driving force for advancing library 3D digital resource services. In the future, libraries need to monitor the latest developments in 3D digital technology, actively explore new 3D digital resource acquisition, processing, and display technologies, and improve the quality and effectiveness of 3D digital resources.
- (4) **User experience:** User experience constitutes an important direction for future library 3D digital resource service development. Libraries need to enhance user experience and satisfaction by providing higher-quality, more convenient services, thereby strengthening user confidence and loyalty.

4.2 Constructing a Library 3D Digital Resource Service System from the Metaverse Perspective

Given the application and development of library 3D digital resources from the metaverse perspective, establishing a comprehensive 3D digital resource service system is particularly crucial.

4.2.1 Resource Acquisition and Preservation

Libraries primarily acquire 3D digital resources through two channels: in-house digitization projects and procurement. In-house digitization projects involve libraries independently or collaborating with cultural resource institutions such as museums and archives to digitize their collections; procurement involves direct purchase from 3D digital resource vendors such as CGTrader, MyMiniFactory,

and TurboSquid [13]. For in-house digitization projects, equipment such as 3D scanners, cameras, laser scanners, and surveying instruments should be selected based on the specific needs and objects of digital acquisition. The acquisition process should include detailed documentation of the acquisition object, method, time, location, and precision, while ensuring stable acquisition environments to guarantee that the final 3D digital resources meet metaverse requirements for quality and accuracy. Additionally, since digitization acquisition objects are typically precious cultural artifacts from heritage sites and museums, protecting the integrity of cultural heritage is essential. The digitization process should follow relevant laws, regulations, and ethical guidelines to avoid infringing upon artifact rights and personal privacy.

High quality and high capacity are prominent characteristics of 3D digital resources in the metaverse. Traditional localized digital resource storage methods previously adopted by libraries can no longer meet these requirements; open-source distributed storage architecture represents the development direction. The CollectiveAccess [14] 3D digital resource storage system, built on a LAMP stack (Linux/Apache/MySQL/PHP) foundation, employs precisely this architecture and has been adopted by multiple cultural memory institutions, including Duke University Library. Regarding storage formats, X3D [15] and glTF [16] are currently widely used and relatively mature standards. Both can achieve 3D digital resource conversion and display through APIs, support cross-platform applications and high-speed network transmission, and can basically meet metaverse application requirements.

4.2.2 Resource Retrieval

The key to enabling 3D digital resource retrieval lies in establishing metadata models that support multi-disciplinary deep indexing and 3D digital model matching methods. At the metadata level, 3D digital resources in the metaverse are generally digital replicas of physical entities in virtual space. Therefore, metadata should include the following content: first, physical object information, including entity type, era, dimensions, materials, and other attributes; second, digital object information, including digital object creation technology, creation date, resource generator, and resource storage format; third, rights information, including owners of physical resources and digital resources. Additionally, since 3D digital resources are merely spatial geometric graphics lacking textual description, accurate and rich element semantics are needed for clarification.

By harvesting Dublin Core-based digital resources from libraries to achieve knowledge association between the two, interoperability between 2D and 3D digital resources can be facilitated while reducing development costs for 3D digital resource metadata. At the 3D digital model matching method level, exploration should focus on utilizing 3D digital model matching methods to retrieve resources within metaverse virtual environments, that is, using geometric, skeletal, and other image feature information from digital models for image

matching to locate 3D digital resources [17].

4.2.3 Scenario-Based Resource Utilization

In the metaverse, libraries can utilize 3D digital resources to construct virtual service scenarios [18], providing readers with entirely new immersive service experiences. First, libraries can build virtual libraries that differ from physical libraries, not only breaking through physical space limitations to achieve comprehensive display of collection resources but also reconstructing library layouts by adding discipline-themed venues and game interaction experience zones to enhance spatial attractiveness. Second, libraries can develop virtual reading resources that leverage the advantages of 3D digital resources for intuitive display and easy comprehension, providing scenario-based illustrations for abstract textual descriptions that allow readers to transcend temporal and spatial boundaries, thereby reducing the difficulty of knowledge understanding. Third, libraries can use 3D digital resources to develop virtual digital humans, creating either native virtual digital humans as virtual librarians to conduct online reference consultation services or real-person virtual digital humans to interact with readers, enhancing the sense of immersion during knowledge presentations.

4.2.4 Copyright Protection

In the metaverse, 3D digital resources can exist as a form of digital asset, thus imposing higher requirements for copyright protection of 3D digital resources. Currently available copyright protection technologies for 3D digital resources include the following: First, digital watermarking technology, which transforms copyright-related information into highly uncertain image backgrounds or neural network models embedded within 3D digital resources, causing the digital resources to become undisplayable when image backgrounds are truncated or undergo planar geometric transformations. Second, remote rendering technology, where after users manipulate low-resolution 3D digital resources, the remote server randomly transmits high-resolution 3D digital resources matching the post-manipulation state [19]. Third, blockchain technology, which leverages its characteristics of decentralization, reliability, and immutability to create distributed version control mechanisms that enable comprehensive recording and supervision of the entire 3D digital resource lifecycle from creation through modification to transfer, providing technical support for copyright certification and transaction of 3D digital resources. Blockchain technology can be considered the most feasible solution for digital resource copyright protection and transaction in the metaverse [20].

This paper proposes a framework for constructing a library 3D digital resource service system from the metaverse perspective by analyzing metaverse development trends, the current state of library 3D digital resource services, and the challenges they face. It is evident that the metaverse provides libraries with an entirely new service platform that can enrich library 3D digital resource services and meet diverse user needs [21]. However, the development of 3D digital

resource services in the metaverse also faces several problems and challenges. First, the creation and processing of 3D digital resources require specialized technology and equipment, necessitating substantial human and material resource investment. Second, the development of metaverse services requires appropriate legal and policy environments to protect intellectual property rights and data security. Finally, metaverse development also requires public acceptance and awareness of new technologies, necessitating continuous promotion and popularization.

To fully leverage the role of libraries in metaverse resource services, further research and exploration are needed. Future research can develop in the following directions: First, conducting research on standardization and normalization of 3D digital resources to improve data usability and sustainability; second, exploring diversified service models for 3D digital resources to meet different user needs; third, strengthening research and practice on intellectual property rights and data security protection in metaverse services to ensure service legitimacy and credibility. In conclusion, as an emerging service model, the metaverse brings new opportunities and challenges for the development of library 3D digital resource services. Libraries should keep pace with the times, actively explore new service models, strengthen technology development and talent cultivation, and better serve users to advance the development of library undertakings.

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