Mixed Reality Technology and Its Application Prospects in Libraries (Postprint)

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Abstract

[Purpose/Significance] Based on the intrinsic characteristics of mixed reality technology, this study envisions its application prospects in libraries to promote the optimization and transformation of library services and management. [Method/Process] Through comparative analysis of mixed reality technology, virtual reality technology, and augmented reality technology, and based on the practical applications of mixed reality technology in related industries, this paper proposes the possibilities and prospects for its application in libraries. [Results/Conclusion] The integration of mixed reality technology with libraries is an inevitable trend of technological development. Mixed reality technology creates greater advantages for library resource allocation, space management, collection management, reading services, and will advance the construction of fully smart libraries.

Full Text

Mixed Reality Technology and Its Application Prospects in Libraries

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Abstract

[Purpose/Significance] Based on the connotation and characteristics of mixed reality technology, this paper explores its application prospects in libraries to promote the optimization and transformation of library services and management. **[Method/Process]** By comparing mixed reality technology with virtual reality and augmented reality technologies, and drawing on the practical applications of mixed reality technology in related industries, this paper proposes the feasibility and prospects of its application in libraries. **[Result/Conclusion]**

The integration of mixed reality technology with libraries represents an inevitable trend in technological development. Mixed reality technology creates significant advantages for library resource allocation, space management, collection management, and reading services, and will drive the construction of fully intelligent libraries.

Keywords: library; mixed reality technology; MR; mixed reality library; VR/AR

2 Mixed Reality Technology (MR) and Its Applications

2.1 Concept and Characteristics of MR

Mixed Reality (MR) is a new generation of information technology that creates a channel between virtual and real worlds for users through computer technology, visual design, and sensor technology. By performing secondary calculations on the real world and virtual objects, it integrates virtual scenarios with reality, using computers to construct a completely new three-dimensional space where users can engage in real-time interaction within the mixed reality environment. The core of MR technology lies in merging the real world with the virtual world through 3D scanning, spatial distance perception, and other techniques. This fusion is not a simple overlay of images, but rather a "real-virtual indistinguishable" objective world where physical entities and virtual digital elements are perfectly connected through recalculation. MR imaging requires more complex algorithms and greater computational power, but its imaging effect is closest to real scenarios, offers the largest viewing angle, and provides superior sensory experiences. MR technology features real-time operation, allowing users to freely switch between virtual and reality according to their needs while simultaneously interacting with virtual objects in the real world.

2.2 Comparison Between MR and VR/AR

The term VR was formally proposed by J. Lanier, founder of VPL Company, in 1989. VR refers to using computers to generate a virtual world completely isolated from the real world—"creating a new world"—providing users with a "fully immersive" experience through VR terminals at 720° omnidirectional viewing angles. The core of VR technology lies in graphics computing power and hardware performance. Since it creates a purely virtual digital world, it has lower algorithm requirements but higher demands on terminal equipment.

AR technology was proposed by T. Caudell and his colleagues at Boeing in the 1990s. AR is a new technology that integrates real-world information with virtual-world information, with its core lying in real-environment recognition and image recognition. AR technology superimposes the virtual world onto the real world, with clear boundaries between virtual images and the real environment in its imaging. AR has lower hardware requirements and can present

naked-eye images on mobile terminals and PC terminals through software.

From a technical advantage perspective, MR technology is more advanced than AR/VR technology and better meets social development needs. The three technologies have significant technical correlations but also distinct characteristics, mainly manifested in three aspects: imaging effect, interaction range, and core technology (see Table 1). In terms of imaging effect, the world that VR technology interacts with users is a purely computer-constructed simulated environment, whereas in MR technology, users can simultaneously communicate and interact with both the real world and the virtual world. During imaging, AR simply superimposes digital information into the user's line of sight, lacking changes in lighting and shadows, making projected images difficult to integrate with the real world. MR images, however, can change based on the user's environment and perspective, with projected virtual images appearing closer to real objects. In terms of interaction range, MR and AR are consistent as both involve the intersection of virtual and real worlds, while VR involves only a single virtual world. The core technologies of VR, AR, and MR involve marker tracking, graphics recognition, and graphics computing, with MR's key technology being spatial perception and fusion—also a challenge for further development of VR and AR.

"More enriched than VR, larger viewing angle than AR" is one of MR technology's slogans. MR encompasses the characteristics of both VR and AR, requiring both computer technology to construct virtual worlds and the integration of virtual worlds with real worlds to simulate their mutual influence [21]. The degrees of virtuality in VR, AR, and MR are shown in Figure 1 [Figure 1: see original paper].

2.3 Applications of MR Technology

In the mature environment of AR, VR, and related technologies, MR technology applications are becoming increasingly widespread, extending to culture, economy, education, and other fields. Western Michigan University Aviation Associate Professor L. Brown introduced MR technology into aviation laboratories after understanding its applications in the medical field, integrating HoloLens into flight simulators and applying the JetXplore interactive program to simulate flight scenarios and display aircraft internal structures, greatly improving teaching effectiveness [22]. In September 2016, the Palace Museum signed a strategic cooperation agreement with Phoenix TV, committing to developing and constructing Palace Museum cultural resources using popular technological means such as MR and AR to create Palace Museum cultural IP and promote cultural heritage development [23]. In September 2020, Xinhua News Agency used 5G and remote co-screen technology to create an MR mixed reality interactive studio, presenting a "real-virtual interwoven" scenario by creating and switching different virtual scenes, providing users with an "immersive" experience [24].

MR technology has already seen numerous application instances in libraries. J. Yasha et al. [25] used Google ARCore SDK and Unity 3D to launch a mobile application enabling users to achieve physical interaction with virtual libraries using markerless AR. Foreign case studies show that MR technology implementation in libraries can be promoted from three aspects: funding support, librarian support, and technology embedding [26]. In August 2017, the MR digital library interactive exhibition area established by Qidi Digital World attracted significant social attention [27]. In the MR digital library, users can achieve real-time interaction with characters or images from books, such as phoenixes, mythical beasts, and Sun Wukong, through Microsoft MR glasses. The introduction of MR technology completely revolutionizes traditional book display methods, enabling users to obtain more intimate and three-dimensional sensory experiences. The emergence of MR and other new technologies has transformed traditional library resource management and service methods. The MR digital library exhibition area created by Qidi Digital World represents a typical practice for implementing the MR library concept. With the collaborative development of artificial intelligence, digital twin, and other technologies, the construction of MR libraries will be gradually realized.

3 Feasibility and Necessity of Applying MR Technology in Libraries

Since its inception, libraries have directly or indirectly undertaken the mission of recording and inheriting human civilization. With the development of human social forms, library functional forms have also evolved due to technological changes and shifts in people's lifestyles. Compared to the past, library visits, book borrowing volumes, overall collection sizes, and building areas have all increased significantly. With the rapid development of social information and increasingly personalized resource demands for libraries, libraries have continuously innovated reading formats, but these innovations have mostly been limited to physical spaces. Modern libraries have become venues for human knowledge acquisition, relaxation, and integrated education and leisure. While currently still relying on physical libraries as the foundation, mobile libraries and digital libraries are continuously developing and gradually transforming toward intelligent, personalized, and humanistic smart libraries. Multiple library forms coexist, and this situation is expected to continue for a considerable future period [28].

3.1 Feasibility of MR Technology Application in Libraries

In an environment of continuous technological updates, libraries are developing toward intelligence, with VR and AR applications in libraries already emerging in large numbers. VR technology applications in libraries focus on constructing virtual libraries. Some large libraries have built digital 3D venues completely consistent with their internal environments based on real scenes using 3D modeling and real-scene scanning [29]. Readers can remotely access libraries without

leaving home through VR devices. Meanwhile, sensor devices can simulate real scenarios such as walking in libraries [30] and flipping through books, exemplified by the "Reading Tunnel"—China's first VR library created by Shanghai Jiao Tong University Press. In 1993, G. Fitzmaurice first proposed the concept of computer-augmented libraries [31], after which many scholars conducted application research on AR technology in library navigation systems, book positioning, AR bookshelves [32], AR books, reference consultation services, commercial AR platform applications, and cultural product development [33]. AR technology has achieved multi-dimensional interaction and value-added services across literature, space, reading, experience, and exhibitions in libraries, integrating with user service systems to enhance library service capabilities [34]. Professor Fu Ping from Central Washington University stated in "New Trends in Library Technology Development" that VR, AR, and robotics are important technological trends for smart libraries with enormous development potential in the future [35].

MR is not an imagined or 凭空出现的技术, but rather developed based on existing VR and AR technologies. Current research on VR and AR applications in libraries is extensive, and MR applications will represent a new trend. Grounded in higher social demands and accumulated technical experience, MR application in libraries possesses certain feasibility.

3.2 Necessity of MR Technology Application in Libraries

The introduction and integration of MR technology is a necessary means to promote the intelligent transformation of libraries. The maturity of the technological environment and user demands are the fundamental driving forces for MR library construction. With the continuous development of MR technology, public calls and expectations for MR applications in libraries are growing increasingly stronger. From a macro perspective, the rapid development and maturation of 5G, artificial intelligence, cloud computing, and other technologies provide the technological prerequisite for MR technology application in libraries. Requirements for information technology cultivation in policies such as the "14th Five-Year Plan" provide policy guidelines for MR technology application. From a meso perspective, the introduction of MR technology in related cultural institutions such as museums provides practical experience for MR application in libraries. The library's own collection of books and other rich digital resources provide the possibility for MR technology integration. Simultaneously, library space and collection resources require optimization management through MR technology. From a micro perspective, the personalization and humanization of user services require MR technology to provide new platforms, while the diversification and differentiation of user demands require MR technology to meet them.

4 Prospects for MR Technology Application in Libraries

This paper prospects MR technology application in libraries from six aspects: resource construction, space management, user management, collection management, reading methods, and morphological transformation, as shown in Figure 2 [Figure 2: see original paper].

4.1 Resource Construction: Promoting Digital Resource Integration and Fusion

How to achieve digital resource integration and optimization has always been a problem that libraries strive to solve. Through digital resource integration, diverse service methods can be provided for readers. MR technology application enhances the flexibility of digital resource integration. When there are errors between the virtual scenarios provided and user needs, or when user needs cannot be met, digital resources can be reintegrated by adjusting existing virtual models. Under the support of MR technology, libraries' digital resource integration level will be greatly improved.

From the perspective of storage methods, facing existing two-dimensional information such as text, images, audio, and video, MR can provide a three-dimensional storage mindset. By establishing purely virtual digital models and creating MR scenarios that combine digital information with real information, libraries can break through the limitations of semantic integration, enabling related digital resources to form resource libraries through three-dimensional network structures. Compared with existing digital resource storage models, MR technology relies more on cloud storage, greatly reducing digital resource management costs.

From the perspective of integration strategies, MR technology integration of digital resources not only breaks through time and space limitations but also enhances inter-resource connectivity. Compared with metadata integration and semantic tag classification, MR technology integrates various scattered digital resources with weak logical associations from a multi-dimensional space perspective, allowing users to better perceive, understand, and apply collection resources [37]. Under MR technology support, libraries' digital resource integration level will be substantially enhanced.

4.2 Space Management: Expanding Virtual Space Resources and Optimizing Physical Space Resources

The primary function of libraries is to acquire and process information resources and provide organized information to users. Today, information generation is growing exponentially, and library collections are gradually increasing. While digital resource growth does not significantly demand physical space expansion, paper resource growth strains physical space. Although expanding library building area can alleviate storage pressure to some extent, space increase always lags behind resource growth. How to achieve efficient storage and optimize resource

layout using limited space has always been a fundamental challenge for libraries. MR technology is expected to alleviate this contradiction.

Libraries can use MR technology to construct virtual reading rooms. Based on circulation system statistics, books with high and low borrowing frequencies can be stored digitally in virtual reading rooms. For frequently borrowed books, a "semi-virtual, semi-physical" storage model can be created to expand the sharing scope of virtual books, achieving a "one book for multiple people" state. For rarely borrowed materials, storing them in virtual stacks allows users to access them when individual needs arise, saving physical shelf space. Real-time feedback on virtual reading room usage can inform librarians to increase or decrease certain resource types. MR-based reading rooms can allocate resources according to different user needs, creating personalized learning spaces to meet individual reader requirements.

4.3 User Management: Providing Dual Navigation for Users

In today's era of exponential information growth, information dispersion and authenticity affect users' effective acquisition and utilization of information. Libraries gather professional knowledge and profound insights from experts across various fields and periods, but this also creates "library anxiety" for many users—how to find needed professional knowledge within massive buildings. Although reference consultation services are continuously improving and providing increasingly precise information resources, problems remain: limited staff cannot timely meet most user needs, and some users rarely use manual services due to psychological barriers.

In paper book borrowing, a persistent problem exists: readers' difficulty finding books and chaotic book placement due to insufficient understanding of call numbers, ultimately leading to disordered shelves. Under AR program guidance, library users can discover needed books faster [38]. MR technology can provide services in both geographic navigation and knowledge navigation. On one hand, MR technology's Simultaneous Location and Mapping (SLAM) can obtain readers' book locations and combine them with geographic navigation's virtual constructed routes to solve book-finding problems. Readers only need to locate twice and follow virtual routes to reach book destinations most conveniently. On the other hand, MR technology integrates library spatial resources and digital resources, enabling real-time recommendations of materials, resource acquisition methods, and routes based on readers' selections of book specialization levels, keywords, classification numbers, and resource types. This will greatly alleviate readers' library anxiety, solve the "book-finding difficulty" problem, and facilitate efficient resource acquisition for more readers.

4.4 Collection Management: Optimizing Collection Book Management

Traditional physical libraries mainly provide services through paper books, documents, and journals. Paper resource services have two major advantages: first, information can be presented directly to users without other display media, with long preservation times; second, reading habits formed over time and special sentiments toward reading paper books have made printed information resources occupy an important position in physical libraries. This has resulted in digital resource procurement funds already accounting for 60-80% of total procurement funds in many large libraries, while costs for paper resource management (including personnel salaries, daily operation and maintenance costs, investment in shelves and other furniture equipment, and opportunity costs of library buildings) far exceed digital resources in overall library budgets.

Another problem caused by increasing library collection sizes is the shortage of reserved shelf space, leading to "shelf expansion" that affects book shelving and normal circulation, requiring staff to frequently perform shelf shifting. In 2013, Miami University Library used "ShelvAR" to solve collection inventory and shelving problems [39], saving related labor costs. By introducing MR technology, libraries can analyze book borrowing frequencies based on reader borrowing data, establish interactive databases, and provide more convenient book search and consultation services. Using AR programs to visualize classification and serial number information of shelved books, libraries can provide interactive guides based on readers' historical borrowing trajectories and real-time borrowing/returning needs. In MR application processes, libraries can reduce shelving burdens and improve book utilization efficiency. As technology matures, MR technology can optimize book management guidance.

4.5 Reading Methods: Providing Dynamic Reading Functions

Dynamic reading refers to making book knowledge visually transform into active characters that can interact in real-time through MR technology. With the maturation and application of 5G+ technology, creating immersive interactive experiences will be an inevitable trend in the digital reading industry. Supported by 5G, artificial intelligence, AR, VR, and MR technologies will further develop, transforming digital reading from "viewable" to "experienceable," greatly enhancing readers' concrete understanding of abstract concepts and vague scenarios and their audio-visual enjoyment of digital reading content [40]. Many domestic paper media, such as *Shenzhen Evening News*, *Luoyang Evening News*, *West China Metropolis Daily*, *Chengdu Business Daily*, and *Wenhui Daily*, have launched dynamic news based on MR technology, striving to infinitely extend readers' cognitive space within limited narrative fields [41]. Faced with limited resource allocation space, high technical capability requirements, and funding constraints, libraries can first understand public needs through analyzing previous book borrowing data and conducting questionnaires, then select to provide dynamic reading services for some materials.

Readers can experience vivid characters and scenery through MR holographic lenses and perceive character dialogues and activities through spatial audio devices while interacting with book characters. This creates a reading experience different from tradition, with stronger authenticity and immersion than VR and AR. Dynamic reading supported by MR technology emphasizes dynamic interaction between readers and book content, more comprehensively and deeply meeting users' sensory needs. Conducting dynamic reading activities based on MR can not only enhance reading interest but also provide new paths for library cultural dissemination and innovation.

4.6 Morphological Transformation: Building Fully Intelligent Libraries

Based on current overall understanding of smart library construction, smart libraries remain in pseudo-intelligent, weakly intelligent [42], and partially intelligent stages. Their next development stage will inevitably be a newer form. This paper proposes a new concept—the fully intelligent library—and provides a preliminary description.

The morphological transformation of fully intelligent libraries includes primary and advanced forms. The primary form is the unmanned library, and the advanced form is the digital twin library. Unmanned libraries mainly refer to libraries that can be used by readers 24 hours a day without librarian attendance [43]. MR technology application can solve problems in unmanned library operation, including book management, consultation services, and emergency events, making MR technology an essential support means for constructing 24-hour unmanned libraries. The emergence of digital twin worlds has innovated knowledge production methods and provided new impetus for library transformation [44].

The digital twin library (Digital Twin Library) is a virtual personal library that combines users' information behaviors in virtual environments with those in physical library environments using MR technology. Based on users' work, learning, and research content, combined with library literature resources, it proactively pushes related information and provides truly comprehensive, three-dimensional, and suitable personalized intelligent services [45]. In 2008, the National Library first launched a "virtual reality system," achieving virtual roaming of libraries by creating virtual spaces [46]. The personal twin digital library established using MR technology can provide precise resource services based on users' preferences, specialties, and research content, while MR technology can simulate experimental operations, solving a series of problems including insufficient physical space and resources.

Promoting the construction of fully intelligent libraries is the goal and direction of MR technology application and an inevitable trend for meeting people's higher needs. Although MR technology has expanded new spaces for libraries' future development, introducing a new technology into a new field will inevitably

lead to various new problems. Due to current shortcomings in technical equipment and other aspects, the integration of MR technology with libraries will inevitably undergo a relatively long 磨合 period, representing a new challenge for both technical personnel and library managers. Particularly noteworthy is that MR technology application 离不开 5G support. Relying on 5G's enhanced mobile broadband services enables readers to obtain immersive, real-time, authentic perceptual experiences with zero distance from the world [47]. Therefore, with the popularization of 5G technology, 5G+MR libraries will enter people's research and learning activities, and the commercialization of 5G will catalyze the arrival of the MR library era.

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