# Research on the Innovation of Augmented Reality Technology in Museum User Experience Design

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**Abstract:** *Background:* Museums are key institutions for preserving relics and conveying cultural values. However, traditional display methods fail to meet the public's growing demand for engaging cultural experiences, especially in the digital era, where technologies like augmented reality (AR) and virtual reality ( VR) are advancing rapidly. This has prompted museums to innovate with online exhibitions, transforming into interactive, multi-functional cultural spaces. *Purpose:* This study aims to explore how AR technology enhances museum user experiences, enabling immersive cultural engagement, promoting widespread cultural resource sharing, supporting cultural and creative industries, and driving dual progress in social culture and economy. *Methods:* The research examines AR applications in museum user experience design through literature review and case analysis, focusing on innovative practices. *Results:* AR technology shows significant impact in multiple museum scenarios, it enriches tour services by enabling dynamic navigation and historical scene reconstruction, as seen in the Zhang Qian Memorial Hall and Sichuan Museum. This leads to enhanced immersion and extended visitor stay time. Additionally, AR transforms exhibit presentation via 3D modeling and contextualized learning environments, addressing space constraints; strengthens interactive experiences through intuitive interfaces and multi-sensory engagement, boosting participation and memory retention. Furthermore, AR revolutionizes educational communication with tools like the "Met AR" app, improving information retention and making content more accessible. *Conclusion:* The study summarizes innovative methods with social, industrial, and cultural value, providing systematic theoretical support and practical references for the digital development of museum user experience design.

**Keywords:** Augmented Reality (AR), Museums, User experience design, Interaction design, Innovation

## 1. Introduction

### 1.1 Research Background

With the progress of various new technologies and smart devices, augmented reality (AR) technology has gradually penetrated into our daily lives, especially in the fields of education and entertainment, which provides users with a new interactive experience. As a bridge connecting historical relics and cultural deposits, museums serve as an important link for cultural display and heritage. They play an important role in promoting the national spirit. According to statistics released by the International Council of Museums (ICOM) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2020, the number of museums worldwide has reached 95,000 (UNESCO, 2020). However, in light of the growing public demand for public cultural experiences and the new interactive modes brought about by the advancing digital technology, traditional museum display methods are gradually failing to attract audiences seeking interaction and entertainment. They cannot meet the needs

of modern audiences for interaction and immersion, and are facing the challenge of how to use new technologies to improve visitors' experience.

The application of AR technology offers unique opportunities for enhancing the user experience in museums. Research into innovative uses of AR technology not only improves user experience and visitor interaction but also brings new vitality and educational significance to the museum. This integration can create a multidimensional interactive environment, encouraging immersive emotional exchanges between users and cultural relics. It is particularly effective at attracting more visitors, especially the younger generation, who are more receptive to new technologies and have more urgent needs for an interactive experience. Overall, this approach can greatly promote the user experience design in the museum and further enhance its cultural impact.

### 1.2 Research Purpose

The main goal of this research is to thoroughly explore the innovative application of AR technology in enhancing the user experience design of museums and educational impact for visitors. With the continuous development and advancement of technology, AR technology has emerged as a very important new tool in the field of museum display and education. For example, the British Museum successfully used AR technology to present more vivid and realistic historical scenes and improved the audience's sense of participation and satisfaction.

This study will focus on an in-depth analysis of how AR technology is transforming museums from traditional static displays to dynamic interactive experiences, and how innovative design concepts can be used to meet the specific needs of different user groups. Through these studies, we hope to provide a new perspective and method for the educational communication and cultural promotion of museums, so as to further enrich and expand the educational function and cultural influence of museums.

### 1.3 Research Content

Since Ivan Sutherland first developed the augmented reality system in 1968, AR display technology has developed rapidly. It is expected to revolutionize how people perceive and process digital information (Shi et al., 2021). Unlike traditional museums, which rely on voice, text, and artificial user interaction that is often tedious, AR technology superimposes and integrates digitally generated virtual information with the real environment. This enhancement significantly enriches visitors' experiences in museums and becomes an innovative force in museum user experience design. According to the QYResearch report, the global AR/VR market is expected to reach $37.01 billion in 2029, with a compound growth rate (CAGR) of 46.3% from 2023 to 2029. This significant growth trend shows that AR technology has a promising future in cultural institutions such as museums, where it is becoming an important tool to attract visitors and enhance the educational experience.

This paper will discuss the application status and innovation of AR technology in museum user experience design, combined with case studies. It will analyze how to deeply consider user demand analysis when designing the museum AR experience to ensure the technology's ease of use and accessibility. In addition, attention should also be paid to avoiding information overload and designing optimization strategies to ensure that users can focus on the core educational content. Through these innovative applications, museums can attract more young audiences and, at the same time, provide a more lively and interactive learning environment for all visitors. This approach promotes the dissemination of culture and the popularization of education.
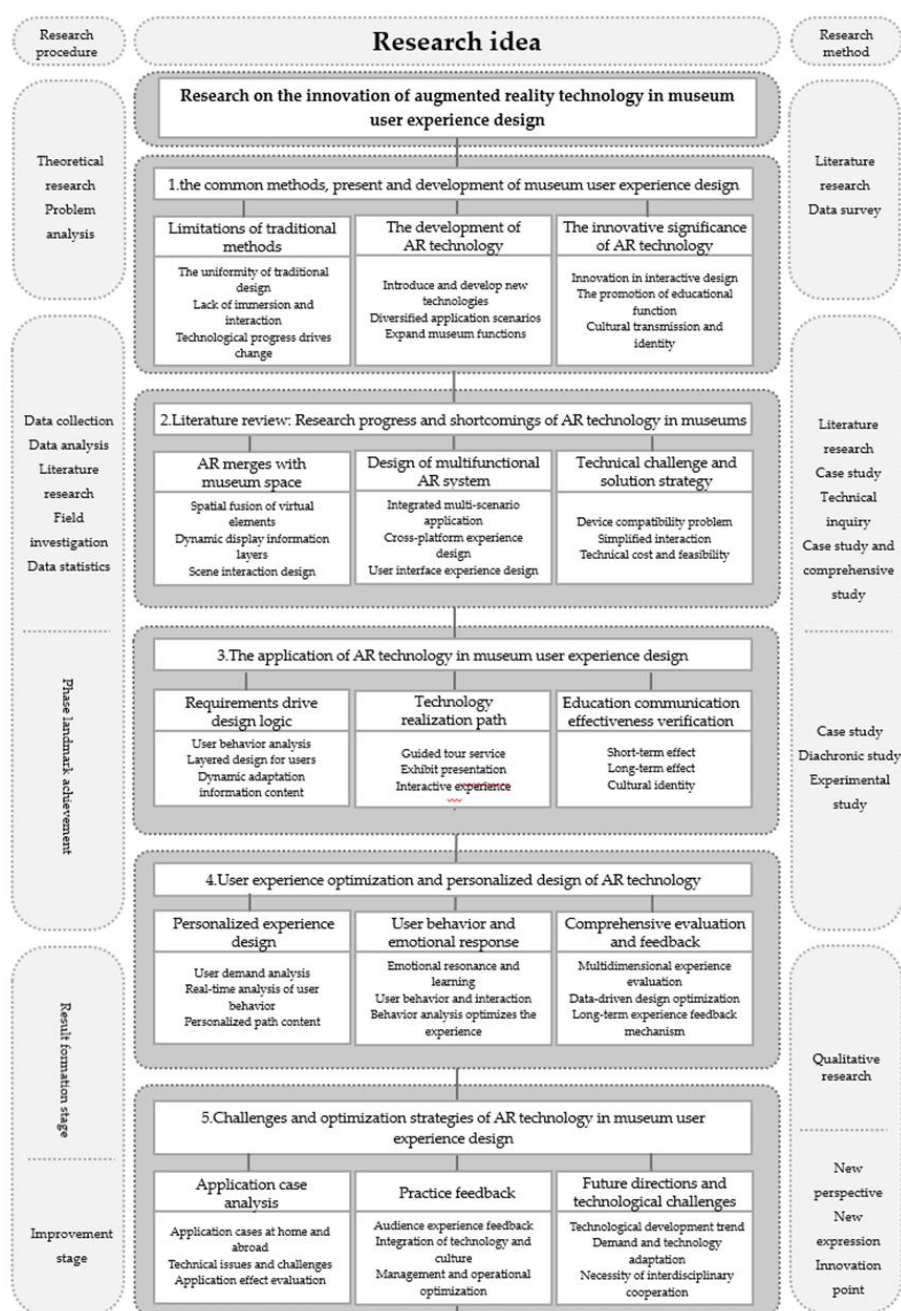
Figure 1: Frame diagram

## 1.4 Research Methods

We used a case study approach to provide insights and deepen our understanding of how specific museums have successfully applied AR technology. Additionally, we have applied a design thinking model to optimize the design of AR applications through a continuous iterative process, ensuring that these designs not only keep up with the latest trends in technological developments but also meet the actual needs and expectations of museum users.

## 2. Literature Review

With the rapid advancement of digital technology and the ongoing museum digital transformation, the innovative application of AR technology in user experience design has become a research hotspot in recent years. Scholars generally believe that AR

technology, through virtual-real integration and interactive design, can reconstruct the audience's visiting experience and promote the transformation of museums from "information transmission" to "immersion and participation" (Zhang et al., 2024; Li & Chen, 2024; Chen & Cheng, 2024). This concept has evolved from technical functions verification to enhancing the user experience. Early research primarily concentrated on hardware adaptation and the scene implementation of multi-focus AR (Li, 2023; Ren et al., 2025), while more recent studies emphasize how technology can enhance cultural transmission and foster emotional resonance (Hou, 2024; Zhen & Huang, 2024).

The existing literature promotes the integration of AR technology and museum user experience design, both theoretically and practically. First, practical verification has been conducted on guided tours, interpretation, and cultural and creative scenes. This has led to the study and refinement of standardized design strategies, such as the hierarchical model of user experience (Li, 2023) and the principle of virtual-real integration (Xu, 2025; Yang, 2022; Zhang, 2024). These strategies provided methodological support for implementing technology effectively. Second, expanding the theoretical framework across disciplines moves beyond traditional functional perspectives. The theories of Immersion design (Zhang et al., 2024), the multi-modal interaction model (Yang, 2024), and the humanities and art communication perspective (Hou, 2024) jointly build a multidimensional analysis system for user experience. Third, research on technology integration highlights the driving forces behind data-driven approaches (Liu, 2024a), AI collaboration (Chen & Cheng, 2024), the intelligent generation of virtual scenes and interactive content (Wang & Liu, 2025) and digital narrative (Zhen & Huang, 2024) in the innovation of museum services. This lays a solid foundation for developing intelligence and globalization in this sector.

This paper holds that the core value of AR technology in museums lies in technology-content-user three-dimensional collaboration, which requires both functional innovation and cultural depth.

Existing studies can be divided into the following three categories according to the differences in topics:

The first type of research focuses on the scenario-based application path of AR technology, and its core debate lies in the balance between technical adaptation and functional innovation. One viewpoint is that AR should give priority to the upgrading of basic functions of museums, such as improving the efficiency of information transmission through dynamic navigation systems (Li, 2023; Xu, 2025). On the other hand, another viewpoint promotes user demand-driven technology design, such as incorporating personalized interactive mechanisms into digital cultural creation (Yin & Wang, 2024; Hu & Xu, 2024). It is clear from these studies that the main consensus is that the scene landing of AR technology must consider functional practicality and experience attractiveness. What is worth wondering is why, in the midst of fast technological transformation, some museums continue to face the design issue of "emphasizing function and light experience"? And this is the dilemma at the heart of the second kind of research.

The second type of research focuses on expanding the dimension of user experience, with its core issue being the theoretical construction of immersion, cultural identity, and multi-sensory interaction. From a technological perspective, one viewpoint emphasizes the supporting role of virtual-real integration in enhancing immersive experiences (Zhang et al., 2024). The other viewpoint, taking a humanistic approach, believes that AR should convey cultural connotations through 3D restoration and dynamic narration (Hou, 2024; Wu, 2024). In addition, Yang (2024) further proposed the theory of "multi-modal intelligent interaction", which advocates for integrating vision, hearing, and touch to drive emotional resonance. This type of research forms a progressive relationship with the first type: the former addresses "whether the technology works", while the latter answers "how good the experience is". However, most existing theories are based on short-term effect assessments, and they fail to deeply explore the long-term

effectiveness of cultural communication, which is precisely the focus of the third type of research.

The third type of research explores the innovation paradigm driven by technological convergence, and its primary contribution is to show the synergistic potential of AR with artificial intelligence and data technology. For example, Liu (2024b) proposed a data-driven optimization model to improve the dynamic adaptability of AR content through user behavior analysis; Chen and Cheng (2024) demonstrate how AI-enabled virtual scene generation technology expands the boundaries of AR narrative. This kind of research not only highlights the dependence of the first two types on a single technology but also indicates a trend toward the intelligence and globalization of museum services in the future (Zhen & Huang, 2024; Li & Chen, 2024). However, its limitation lies in an overemphasis on technological innovation, which can lead to a neglect of the balance between cultural universality and localized expression. This balance is the key field that this study aims to address.

Table 1: Summary of Literature Features

| Research Direction | Reference | Trait |
|---|---|---|
| Specific application scenarios of AR technology in museum user experience | Research on User Experience Design of Museum Tour System Based on AR Technology; Innovative Application of Augmented Reality Technology in Museum Exhibition Interpretation; Research on Product Interactive Display Design Based on Mobile Augmented Reality Technology | AR technology promotes the functional innovation of museum exhibits, displays, and tours through system design, scene verification, and optimization. |
| Deepening the user experience dimension and multi-sensory interaction | The Application of Augmented Reality Interactive Technology in History Museums; Review of Research on Museum Immersive Experience Design; From User Experience to Experience Design: Intelligent Multimodal Interactions in Digital Aesthetics; Digital Display Design Drives Cultural and Artistic Spirit Communication of Museum Relics; Research on Interactive Design of Cultural and Creative Products from the Perspective of User Experience | AR uses emotion-driven and multi-sensory interaction to upgrade viewing to cultural participation and strengthen the emotional connection of cultural heritage. |
| Children's movie characters AR application development driven by technology convergence and innovation | Research on the Application of Augmented Reality Technology in Museums from the Perspective of Digital Public History; Reflections on the Digital Narrative Paradigm of Contemporary Art Museum Exhibitions; Application of Augmented Reality Technology in Intangible Cultural Heritage Display and Education; Research on Interactive Design of Museum Display Space Based on User Experience | The collaborative innovation of technology, culture, and user needs provides systematic solutions for museum digitalization. |

Although many studies have made remarkable progress, their limitations still focus on three points: the contradiction between cultural universality and localization, the imbalance between technology dominance and content depth, and the lack of evidence of long-term cultural impact.

First, most studies are based on a single cultural background (such as Chinese intangible cultural heritage or local museums), which limits their cross-cultural adaptability (Wu, 2024; Ren et al., 2025), which may lead to the risk of cultural misinterpretation of AR narratives.

Second, the tendency to give priority to technology often overshadows the importance of content quality. For example, the relationship between information overload and cognitive load during exhibit interpretation has not been adequately

evaluated (Xu, 2025). Additionally, there is a lack of specific strategies for conveying humanistic values (Hou, 2024).

Finally, short-term, results-oriented studies overlook the long-term impact of AR on user behavior and cultural identity. For example, the immersive experience offered by cultural and creative products is only evaluated through initial research (Yin & Wang, 2024), while deeper learning outcomes and cultural memory retention among users are rarely tracked (Zhang et al., 2024).

## 3. The Application of AR Technology in Museum User Experience Design

### 3.1 User Demand Analysis

In today's world, museums play an important role in cultural inheritance, but they face the challenge of leveraging technologies to enhance visitor experience. Especially in exploring AR technology for museum user experience design, analyzing visitor demands has become an essential step. Our analysis reveals that visitor expectations for museum experiences are changing significantly. They are no longer satisfied with the traditional static viewing methods; instead, they seek richer and more profound experiences through more interactive and participatory approaches. Therefore, the museum community must actively embrace technological innovation, particularly by incorporating AR technology to meet these visitor demands. By creating highly interactive displays, museums can significantly increase user engagement and satisfaction, resulting in a more vivid and memorable experience for visitors.

In addition, user needs analysis highlights the importance of a personalized experience. Museums can use AR technology to provide users with personalized tour services, such as customized exhibition content and interactive experiences according to users' interests, historical knowledge level, and personal preferences. This approach not only enhances the personalized experience of users but also effectively promotes cultural awareness and educational outreach. By integrating science and technology, visitors can enjoy greater convenience while gaining a deeper understanding and appreciation of human history and culture.

### 3.2 The Application of Augmented Reality Technology in Tour Service

With the continuous advancement of AR technology, museum tour services are undergoing a revolutionary transformation. By superimposing virtual information on the visual and auditory experiences of the real world, AR technology presents complex concepts and stories in a more understandable and engaging manner. This makes museum displays more vivid and intuitive.

The application of AR technology not only allows visitors to observe and understand the exhibits from a new perspective but also stimulates their interest in art and history. For example, the Zhang Qian Memorial Hall utilizes VR technology to recreate historical scenes, enabling the audience to experience the life course of Zhang Qian firsthand (Dai et al., 2024).

User experience design is critical when designing AR navigation apps. To ensure these apps are easy to use and effective, designers often adopt a "user-centered design" (UCD) approach. This approach focuses on creating intuitive and engaging interfaces based on the needs and behaviors of users. For example, by analyzing a user's behavior patterns in a museum, a designer can create an AR navigation app that adapts the way information is presented and the depth of content based on the user's actual behavior and preferences. The personalized design not only avoids information overload but also significantly enhances user satisfaction and engagement.

The application of AR technology in museum tour services has also promoted innovation in educational communication. With AR technology, museums can transform traditional static exhibitions into dynamic, interactive educational platforms. For example, the British Museum uses AR technology to allow visitors to see lifelike

three-dimensional restoration images of ancient Egyptian pharaohs through mobile devices. This technology enables visitors to interact with these images and learn about ancient Egyptian culture.

Through AR dynamic scene restoration in the exhibition hall of "Ancient Sichuan", Sichuan Museum significantly improved the audience's sense of immersion and emotional resonance (Li, 2023). In addition, the AR photo punch card system of the Beijing-Hangzhou Grand Canal Museum increased the visitors' stay time by 30% through its engaging "blind box badge AR navigation." This verified the practical value of technology for optimizing user experience (Liu et al., 2024). This innovative approach not only attracts a younger generation of visitors but also dramatically expands the museum's educational function.



Figure 2: Shows the AR camera system and AR dynamic scene restoration exhibition hall in the museum

### 3.3 The Application of Augmented Reality Technology in Exhibit Presentation

In the way museum exhibits are presented today, the application of AR technology is gradually becoming an innovative means of display, which provides a new interactive experience for the audience by layering virtual information over real-world visuals. AR technology transforms static exhibits into dynamic and interactive three-dimensional models. This innovation significantly enriches the audience's perceptual experience (Li et al., 2014).

The application of AR technology in the presentation of exhibits aligns with the "context-aware learning theory", which suggests that learning effectiveness is closely related to the situational aspect of the learning environment. Through AR technology, the museum can create a contextualized learning environment that enables the audience to learn and explore in an immersive experience, achieving better educational communication. Moreover, AR technology addresses the problem of space constraints by enabling virtual displays that showcase large exhibits or cultural artifacts from distant regions that could otherwise be impossible to display in a limited physical space. The flexibility and interactivity of this technology transform museum exhibitions, making them more vivid and engaging. As technology continues to advance, it is clear that AR technology will play a more important role in museum education and cultural communication in the future.



Figure 3: Shows how AR technology can superimpose virtual information in the real world

### 3.4 The Application of Augmented Reality Technology in Interactive Experience

In the interactive experience of museums, the application of AR technology is gradually becoming an innovative means of display, which provides visitors with unprecedented interactive experiences by overlaying virtual information onto the real world. Some museums have successfully incorporated AR technology into exhibitions, enabling visitors to see the stories and history behind the exhibits through mobile

phones or dedicated devices, thus deepening their understanding and interest in the exhibits (Li et al., 2014). This technology not only enhances the user's sense of participation but also strengthens memory retention through interactivity, which greatly expands the educational function of the museum.

When designing interactive experiences that use AR technology, it is important to find a balance between technological advancement and user friendliness. Therefore, designers should create intuitive interaction designs that make the technology easy to operate. This can be achieved by simplifying the operation process, providing clear instructions and feedback, and utilizing natural user interface (NUI) technology. By doing so, we can effectively reduce the cognitive load on users and improve the overall quality of the interactive experience.



Figure 4: Shows the fusion application of AR technology and NUI technology in the museum

### 3.5 The Application of Augmented Reality Technology in Educational Communication

In the field of educational communication within museums, AR is becoming a revolutionary tool. It provides viewers with a new interactive learning experience by layering digital information on top of the visuals of the real world. This technology not only improve the audience's participation and information retention rate but also make the educational content of traditional museums more vivid and easier to understand.

The Metropolitan Museum of Art's "Met AR" app, for example, allows visitors to see a three-dimensional model of the artwork through the camera on their phones or tablets, providing an enhanced visual experience alongside the original piece. In addition, AR technology can also combine educational content with entertainment through interactive games and storytelling to stimulate the interest of learners. AR technology has changed the way we interact with art and history, and it has opened up new possibilities for the future of museum education.



Figure 5: Shows how the Met AR app uses mobile to view 3D models of artwork

### 4. The Innovation of Augmented Reality Technology in Museum User Experience Design

### 4.1 Research on Innovative Ideas

In the field of AR technology and museum user experience design, exploring innovative ideas is the core driving force to promote the integration of technology with culture. Through the clever introduction of AR technology, museums can create a new immersive experience for visitors. For example, recreating the lively scene of an ancient Roman market or the magnificence of a medieval castle in a museum exhibition provides users with a unique perspective and feeling beyond traditional museum visits. This approach greatly enhances the vividness and interactivity of educational communication.

Additionally, through in-depth analyses of user needs, the design team can apply innovative ideas to develop personalized navigation applications for different age groups and interest points. Examples include elaborate interactive scavenger hunts for children and in-depth interpretations of artworks for art enthusiasts. Through these innovative applications, museums can significantly improve the quality of the visitor experience, expand their educational function, and enhance the broader impact of cultural communication, thereby contributing to the progress and development of society and culture.
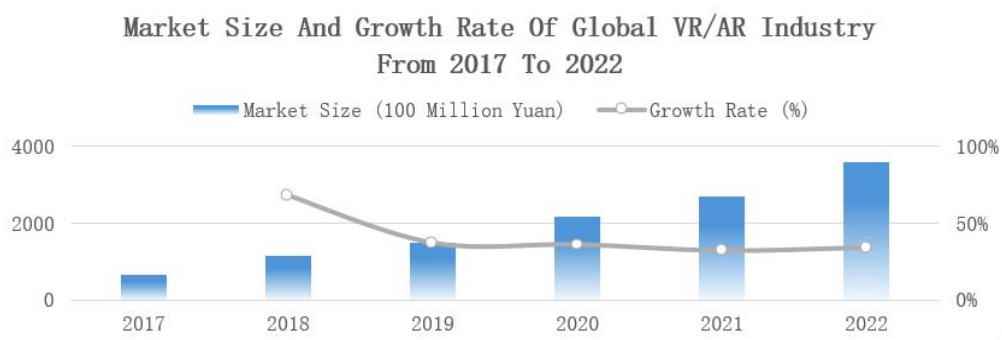


Figure 6: Virtual (augmented) reality industry is used in all areas of life, empowering various industries, the Demand for application scenarios is growing, and the global virtual (augmented) reality industry market scale is rising year by year.
Source: VR gyro, arranged by China Economic Industrial Research Institute

### 4.2 The Integration of Augmented Reality Technology and Cultural Creativity

In exploring the integration of AR technology with cultural creativity, we discovered that the innovative application of AR technology can elevate the user experience design in museums to unprecedented levels. According to the article "Research on the Application of Augmented Reality Technology in Museums" (Li et al., 2014), more than 60% of visitors reported a significant increase in their understanding and interest in exhibits after using AR technology. This technology not only provides a more vivid display but also gives visitors a deeper understanding of cultural backgrounds and historical stories through interactive experiences.

For example, the Palace Museum has developed the "Palace Museum AR" application, which allows visitors to see the original appearances of ancient buildings and even interact with virtual figures from the palace. This experience enhances the communication power of culture and also enhances the educational value of the museum.

AR technology provides a new platform for museums to integrate traditional culture with modern technology, creating unique cultural experiences. For example, it can transform scenes in a painting into a three-dimensional animation. When visitors view them through mobile devices, the people and scenes in the painting seem to come to life. This engaging display not only attracts the younger generation but also helps preserve traditional culture in a more dynamic way. Moreover, AR technology can also be combined with storytelling, allowing for an augmented reality narrative mode. This enhances visitors' experience by providing a richer and more immersive cultural story during their visit, effectively fulfilling the dual purpose of education and entertainment.

Figure 7: In 2023, the total shipment of AR equipment in China increased. 2023 China AR equipment 262,000 units, an increase of 154.4%; China's AR shipments are expected to reach 421,000 units in 2024.
Source: IDC, CIC Industrial Research Institute

In terms of design innovation, the integration of AR technology and cultural creativity requires a seamless connection between technology and cultural content to create meaningful interactive experiences. Designers need not only a strong technical background but also a deep understanding of culture. So designers can design AR experiences using a "context-aware" model, which emphasizes providing customized information and experiences based on the user's environment and context. In this way, museums can provide visitors with a more personalized and immersive experience, leading to increased user satisfaction and engagement.

### 4.3 Diversified Experience Design

The integration of AR technology and museum user experience design has made diversified experience design a central focus of innovative applications. By introducing AR technology, museums overcome the limitations of traditional displays and provide visitors with an immersive, interactive experience. According to a report in Museum and Society magazine, some museums reproduce historical scenes through AR technology, and the audience can see the vivid reproduction of ancient civilizations through mobile devices. This not only enhances the efficiency of information transmission but also enhances the audience's participation and interest.

In addition, diversified experience design should also consider the needs of audiences of different ages and cultural backgrounds. It is essential to create interactive content that aligns with their cognition and interests. For example, children can learn about history through AR games, while adult audiences may be more inclined to a more in-depth historical exploration and cultural topics. In the design process, we can utilize the "five senses model" of user experience design, which includes vision, hearing, touch, smell, and taste. This approach helps create a comprehensive sensory experience that balances function with form, ensuring that the integration of technology naturally supports the goals of education and cultural communication.

Diverse experience design also emphasizes emotional resonance with the audience. AR technology enables museums to create experiences with storytelling and emotional depth that allow viewers to empathize and engage more deeply during their visit. For example, the panoramic roaming design of Kunming Zoological Museum utilizes AR interactive technology to dynamically display specimens (Gong et al., 2024). The audience can activate the virtual animal model through gesture-based interactions, which enhances resonance through multi-sensory engagement. Additionally, AR technology can reproduce the key moments of historical events, allowing the audience to feel as if they are in the historical scene and to feel the atmosphere and emotions at that time. This immersive experience not only enhances the audience's participation but also deepens their understanding and memory of history and culture.

Museums also need to focus on the usability and ease of use of technology when designing diverse experiences. While AR technology can provide a rich interactive experience, a complex operation or an unfriendly interface may confuse and frustrate the audience. Therefore, the design team should pay attention to the details of the user

experience and ensure that the integration of technology provides a smooth and natural visiting experience to the audience.

### 4.4 Cross-border Cooperation and New Display Methods

In the current field of innovative applied research on AR technology and museum user experience design, cross-border collaboration and new forms of display are widely recognized as key factors driving the digital transformation of museums. By working closely with technology companies, educational institutions, artists, and cultural content creators, museums can combine the latest AR technology with rich cultural content to create interactive experiences that were previously unimaginable. For example, Google's Art Project uses AR technology to allow global users to visit the world's major museum exhibits online at home. This cross-border cooperation not only broadens the museum's audience but also makes the museum's display more diversified and interactive.

The exploration of new display methods, especially the introduction of AR technology, has provided a new channel for educational communication in museums. The educational function of museums should not be limited to traditional interpretation boards and guidebooks, but should provide a more vivid and intuitive learning experience through technology. For example, through AR technology, museums can restore historical scenes, allowing visitors to see the activities of historical figures in specific scenes through mobile phones or AR glasses, and this immersive experience greatly enhances the efficiency of information transmission and increases audience engagement. In addition, AR technology can also incorporate gamification elements to design interactive games that combine learning with play, making the educational learning more interesting.

In the context of cross-border cooperation and new exhibition methods, museums find a balance between the advancement of technology and audience acceptance. A study of AR applications in museums shows that users' acceptance of technology is strongly related to their age, familiarity with the technology, and the overall ease of use. Therefore, museums should adopt a user-centered design (UCD) approach when designing AR applications to ensure the ease of use and interactivity of the technology. It is also important to avoid overwhelming users with excessive information, which can lead to cognitive overload. By creating well-designed display content and interactive links, museums can effectively use AR technology to enhance the user experience while promoting cultural awareness and education.

### 5. Design Challenge and Optimization Strategy

### 5.1 Technical Limitations and User Adaptability

When discussing the application of AR technology in museum user experience design, two key factors to consider are technical limitations and user adaptability.

Technical limitations are mainly reflected in the performance of hardware devices, the optimization of software algorithms, and the richness of content creation. For example, the field of view (FOV) and resolution of AR devices directly affect the user's immersion, while latency issues can disrupt the coherence of the experience. According to market research, the FOV of AR glasses currently on the market is usually around 40 degrees, which is far lower than the natural human field of view, which limits the immersion experience of users.

The issue of user adaptability relates to user acceptance of new technologies and the learning curve. Therefore, designers need to continuously optimize interaction design through user research and testing to reduce the cognitive load of users. For example, using intuitive user interfaces and simple interaction processes can effectively improve user adaptability. In the design process, Donald Norman's theory on user experience can be used for reference (Liu, 2024) to ensure the ease of use and pleasure of technology.

In summary, technical limitations and user adaptability are important factors for effectively integrating AR technology into museum user experience design. Only by finding a balance between technology and users can we truly achieve a meaningful convergence of technology and culture.

Designers must consider the adaptability of different age groups when creating AR experiences. Children and the elderly may face more challenges when using AR technology due to vision loss or unfamiliarity with the new technology. Therefore, it is critical to design more user-friendly interfaces and interaction methods tailored to these specific groups.

For children, incorporating colorful and vivid interface elements, along with simple, easy-to-understand instructions, can stimulate their curiosity and encourage exploration. For older users, voice navigation and enlarged interface elements can be provided to ensure they can easily use AR technology.

Furthermore, designers should consider the adaptive needs of people with disabilities through customized design, allowing everyone to enjoy the rich experience brought by AR technology. Through these meticulous design considerations, the popularity and satisfaction of AR experiences in museum settings can be further enhanced.

### 5.2 Information Overload and Cognitive Load

When applying AR technology to the design of museum user experiences, it is crucial to address the issues of information overload and cognitive load. While AR technology can enhance the presentation of exhibit information and backstories in a richer and more dynamic form, it can also overwhelm the audience by delivering too much information in a short period, resulting in cognitive load.

Cognitive load theory (Chen, 2007) points out that humans' working memory has limited capacity. If the information presented exceeds the individual processing capacity, learning efficiency and overall experience quality may suffer. For example, one study showed that when museum visitors receive more information through AR devices than they can process, their comprehension and memory of the exhibits are reduced.

Therefore, when designing an AR experience, it is necessary to carefully plan the strategies and pace of the presentation of information, ensuring it is engaging and manageable to prevent visitors from feeling stressed or confused. In addition, designers should consider using hierarchical information presentation methods, allowing users to selectively access information according to their interests and at their own pace. This approach can help manage cognitive load effectively while enhancing the user experience.

Museums can also help visitors better understand and absorb information by incorporating visual and auditory guidance. For example, the use of clear and concise icons, animations, and sound effects can attract the attention of the audience and make the information easier to understand and remember. Additionally, designers should consider using AI technology to adjust the content presentation and delivery according to the behavior and feedback of the audience. This approach allows for personalized AR experiences,　reducing cognitive load and enhancing audience participation and satisfaction.

### 5.3 Design Optimization Strategy

The application of AR technology in museum user experience design is the key to ensuring effective design optimization strategies. These strategies are crucial for successfully integrating technology with cultural content. For example, by analyzing the user behavior data, museums can identify areas where visitors pay the most attention (hot spots) and areas that receive little attention (cold spots) during AR tours. This

information can then be used to adjust the content layout and interaction designs to enhance user engagement and satisfaction.

According to Nielsen's usability testing principles, design teams should ensure that AR applications are intuitive, efficient, memorable, error-free, and satisfying, thereby reducing the cognitive load on users during interaction with the technology. Moreover, the AR experience design in museums should emphasize a seamless connection between technology and content while maintaining a balance between advanced technology and the depth of cultural education.

A study on Chinese artworks has found that visitors' participation, knowledge learning, meaningful experience, and emotional connection have been significantly improved after using AR technology (Gong et al., 2022). Therefore, an effective design optimization strategy should focus not only on technological innovation but also on deeply understanding user needs. Continuous iteration and optimization are essential for enhancing the overall user experience.

In the specific implementation, the design team can utilize the concept of gamification and integrate AR technology with elements such as storyline and task challenges. This approach allows the visitors to acquire knowledge, enhancing both their enjoyment and engagement. Additionally, the design should also consider visitors of different ages and backgrounds to ensure inclusivity and accessibility. This could include features like multilingual support, barrier-free design, and allowing everyone to have a high-quality AR experience. Furthermore, strengthening the cooperation between museums, universities, and scientific research institutions to develop new technologies and applications is crucial for optimizing design strategies. Through these initiatives, the impact of AR technology on museum user experience can significantly contribute to cultural preservation and educational outreach.
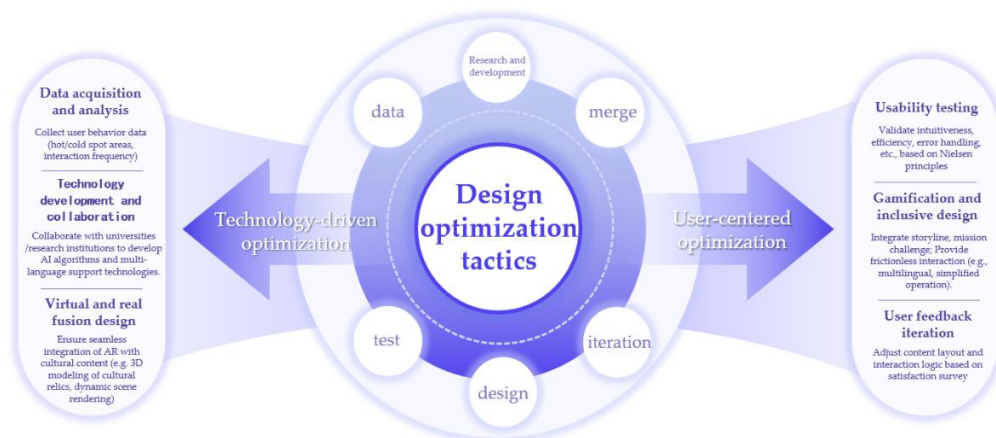


Figure 8: Design optimization strategy thinking.

### 6. Conclusion and Prospect

This study provides an in-depth analysis of how AR technology can enhance the user experience in museums. The findings indicate that AR technology significantly improves the interactive experience and educational impact for visitors. For example, the Smithsonian's National Museum of Natural History launched an AR app called "Skin and Bones" in 2015. The data shows that after using the app, the average visitor's time spent in the Bone Hall increased from 1 minute 34 seconds to 14 minutes, an increase of more than 1000%(Shu, 2022). This result validates the great potential of AR technology in the communication of museum education.

In addition, the study also found that the combination of AR technology and cultural and creative industries can create a new way of display, such as through AR

technology to reproduce historical scenes, so that visitors seem to travel through time and space, and experience historical events. This approach not only engages visitors but also enhances their learning in an entertaining way. In conclusion, the study emphasizes the importance of integrating technology with culture and provides a new perspective for the future development directions of museums.

With the continuous progress of AR technology, the design of user experience in museums will usher in unprecedented changes. It is expected that AR technology will become more widespread in the coming years, allowing museum visitors to enjoy richer and more personalized guided experiences through personal devices or dedicated AR glasses. For example, ABI Research predicted in a 2021 report that the AR market will exceed $140 billion in 2025.（ABI Research, 2024). This will provide museums with a substantial platform for technological application.

Moreover, as the technology matures, museums can use AR technology to provide more in-depth educational content. This could include interactive learning modules that enable visitors to engage with historical and cultural knowledge, thus improving the effectiveness and enjoyment of educational communication. By integrating AR technology with cultural creativity, museums will be able to create more engaging displays and provide more profound cultural experiences for the public.

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